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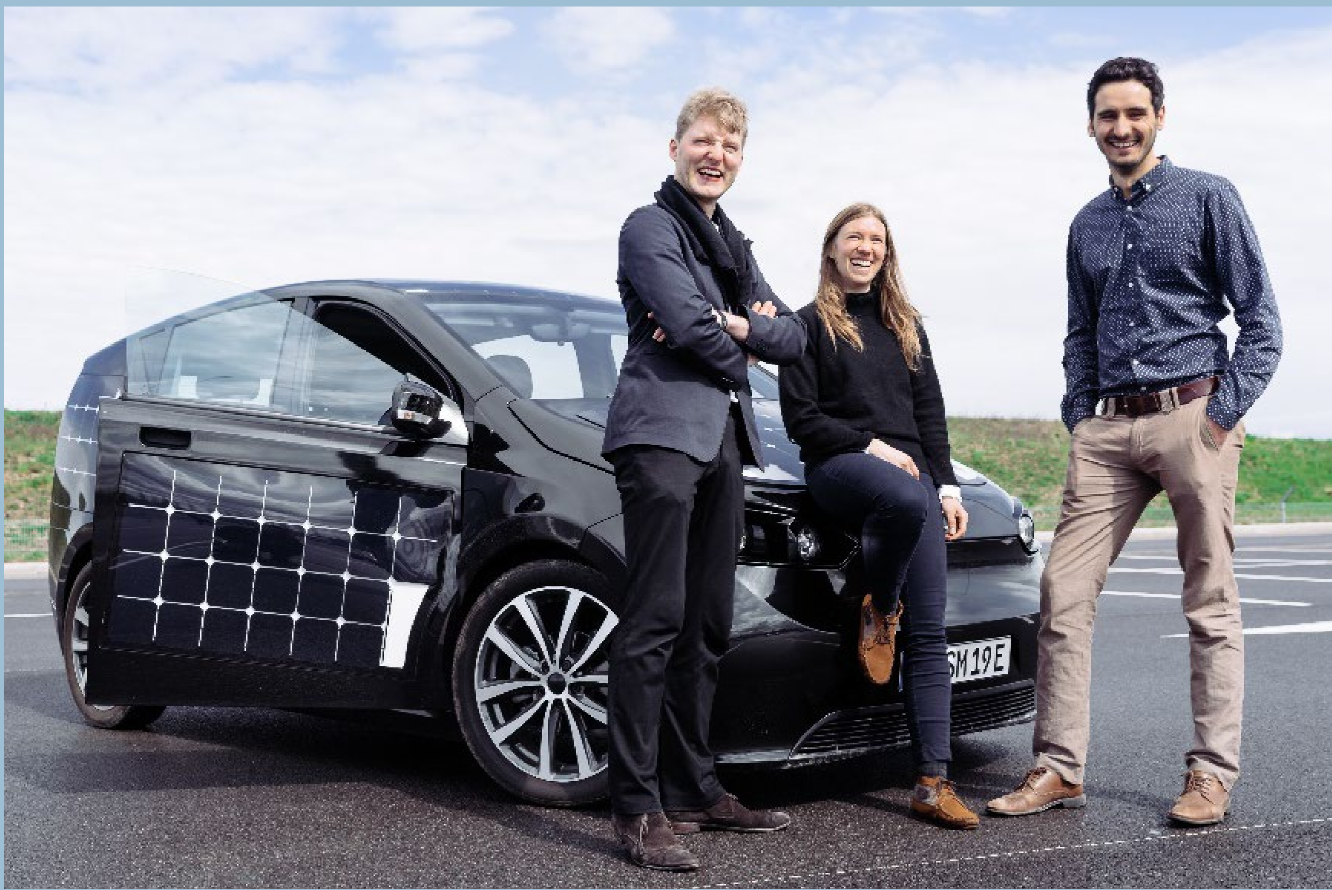

New players in the automotive industry

Waymo, Build Your Dreams and Sono Motors

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Impressum

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1 Summary

The automotive industry in Germany has been established for decades. New suppliers have hardly played a role since Volkswagen entered the market after the Second World War. This is currently being changed by new suppliers, mainly in the field of electric mobility. The development of Tesla from bankruptcy candidate to a gamechanger has already been reported in this project (Clausen & Olteanu, 2020). But Tesla is not alone. One of the financially strongest companies in the world, Google or its holding company Alphabet, is in the process of making autonomous driving ready for series production with its spin-off Waymo. Additionally, various Chinese manufacturers such as BYD, SAIC/MG or Geely/Volvo are also making the leap into the European market. In Munich, the start-up Sono Motors is working on a social-ecological vision of an efficient electric car with a European supply chain. Against this background, it seems appropriate not only to look at the diffusion of these innovations in the large car factories, but also to take a look at the niche players themselves, who are increasingly working their way into the market. Since it is not only the speed of diffusion of individual innovations that depends on the market success of the niche companies, but ultimately also questions with implications for the number of jobs and the employment situation: which manufacturer will conquer which market shares, which technologies will prevail and which supply parts will be needed in the future and - also of utmost importance - which supply parts will no longer be needed.

In the HBS project 'Structural Change in the Automotive Industry - Transformation of Value Creation in the Automotive Industry' the Fraunhofer Institute for Systems and Innovation Research and the Borderstep Institute analyse the interaction between niche players and established players in the automotive industry. This study characterises the companies Waymo, BYD and Sono Motors and asks how their activities will affect the future of the automotive industry.

While Tesla is currently in a phase where the company is acting as a gamechanger, the influence of the companies focused on in the three case studies presented here is far more uncertain. The present report adds further case studies to the already published account of Tesla as a start-up (Clausen & Olteanu, 2020). Since a look at the development of electromobility to date is also helpful for understanding with regard to the start-ups BYD and Sono Motors, two subchapters are taken over unchanged from the Tesla report. These are subchapters 3.1 'Beginnings and first providers of electromobility' and 3.2 'Key events and promoting factors'. Subchapter 3.3 complements these explanations with an introductory presentation of autonomous driving, which is indispensable for understanding the Google spin-off Waymo.

As chapter 4 of the study shows, Waymo will not develop into an automotive supplier, but rather into a supplier of hardware and software components for autonomous driving. However, it is largely unclear when fully autonomous driving will become significantly more widespread in the vehicle population. This means that the question of when and how Waymo will affect the car industry can at best be speculated on at this point in time.

The situation is similar with the Chinese company BYD described in chapter 5. Although BYD is increasingly focusing on electromobility, its impact on the European industry is debateable. As BYD is

at best a medium-sized company in China, as well as worldwide, with a production volume of about half a million vehicles per year, its impact on the industry is limited in terms of volume and as long as no additional factories are opened. The announced export of the new top-of-the-range 'BYD Han' model to Europe is difficult to assess in terms of its market-changing impact. As far as we know, no Chinese company has yet managed to sell large numbers of cars in Europe under its own brand name. Whether BYD, of all companies, will succeed in doing so can hardly be answered ex ante. Also, the price of BYD Han in Germany has not yet become known.

The BYD lithium-iron-phosphate battery technology, with its low cost, high safety and the absence of nickel and cobalt, which is important in terms of both environmental and social criteria, could be a different matter. But how this battery will really perform in the competitive environment is yet to be determined, as does a comparative assessment of this new type of battery in environmental and social balance sheets.

The last company to remain is Sono Motors from Munich, described in Chapter 6. Sono is focusing on solar integration and power sharing, but is also taking a new approach with regard to the social aspects of production. Sono Motors is committed to good working conditions, high social standards and climate protection within the company and in the supply chain (Sono Motors, 2020b). The geographical distribution of the main suppliers focuses on Central Europe (Sono Motors, 2020b). Especially from a trade union perspective, Sono Motors could be a ray of hope in the environment of globalised capitalism. But even here, uncertainty still dominates today. What Elon Musk calls "production hell", through which Tesla has come through, is still ahead of Sono Motors. And the question of whether solar integration and social responsibility in the supply chain outside a small niche will prove to be sales-promoting arguments cannot be answered ex-ante.

Ultimately, the three start-ups Waymo, BYD and Sono Motors have one thing in common: they each represent forces that could change the automotive industry. Waymo stands for the possibilities of digitalisation, BYD for Chinese export strength and Sono Motors for an ecological-social new approach to corporate responsibility. In all three cases, not only the size but also the timing of a relevant impact on the car industry is unclear. But these start-ups are still important. They show that 'change is possible'. Observing start-ups like these is likely to be important for both the big manufacturers and the trade unions in order to be able to properly assess the future of the industry. The example of Tesla has shown where it leads to, if one dismisses them only as candidates for bankruptcy.

2 Introduction and methodology

2.1 Introduction

The starting point for the analyses of niche companies and start-ups is to work on the importance and characteristics of start-ups in general and green start-ups in particular. Important here is Schumpeter's concept of creative destruction (Schumpeter, 1997), in which the entrepreneur is characterised as a person who swims against the current, takes risks and endures resistance, and precisely because of this persistence can be a significant factor in processes of change. Furthermore, "green start-ups", and above all the subgroup of particularly sustainability- and market-oriented entrepreneurs, with their specific goals and motivations, have an essential function in the context of building up sustainable markets (Clausen, 2004; Hockerts & Wüstenhagen, 2010; Schaltegger & Wagner, 2011) and also play a numerically significant role in today's start-up activity (Olteanu & Fichter, 2020). With regard to the origin of digitisation in Silicon Valley, specifics of digital innovations and start-ups in Silicon Valley are also important (Morris & Penido, 2014). When working on the case studies, we therefore also take into account the founders and their environment, evaluate a "green" strategy that may be geared towards sustainability and try to draw conclusions about the exemplary effects of the start-ups with regard to the automotive industry.

An important topic of entrepreneurship research is the question of raising capital, which is a challenge for start-ups in general and for green start-ups in particular (Olteanu & Fichter, 2020). Another important reason for focusing on start-ups is their high importance for the genesis and diffusion of innovations (Fichter & Clausen, 2016).

Chapter 2 begins with a brief overview of the historical development of the electric car niche from 1985 to 2020. An overview of major manufacturers and production figures is given and key events are identified.

For four selected niche manufacturers, Tesla, Waymo, BYD and Sono Motors, case studies are presented. In this brochure the focus is on Waymo, BYD and Sono Motors, while in a subsequent analysis the casestudy of Tesla is going to be highlighted (Clausen & Olteanu, 2021). The case studies retrace the foundation and development of the respective manufacturer, present the founders, describe the innovation strategy and specifics of the vehicle design, and characterise the sales markets and supply chains.

2.2 Impact of start-ups on markets and sectors

One of the objectives of the analysis is to characterise the impact of the start-ups studied on the automotive regime[1]. The impact assessment of a start-up is subject to various specific challenges. On the one hand, business model, products and services are often subject to short-term and radical

[1] "Regime" is understood to mean the established socio-technical structures with their enterprises, politics, science and the customers accustomed to the established products and services (Geels, 2002; WBGU, 2011). The opposite to the regime are "niches".

changes (Clarke-Sather et al., 2011), which contribute to a comparatively high degree of uncertainty and volatility (Ries & Bischoff, 2012). In addition, as these are relatively new market participants, for some of whom there is none or only few historical performance data available on which to base a valuation (Judl et al., 2015; Skala, 2019). An evaluation may therefore not be able to build on the actual values, but rather consider the potential impact (Trautwein, 2020). The biggest lever for this potential impact is usually the service or product itself (Trautwein, 2020). The effect of the individual service can unfold a transformational force on the economy, environment and society through a corresponding diffusion (Clausen & Fichter, 2019).

The impact assessment in the present case studies thus focuses on performance (product or service) and includes potential ecological, social and economic sustainability in the sense of the Sustainable Development Goals (United Nations, 2018). When assessing impacts, categories differentiate between impacts on **sales markets and competitors**, impacts on the **social environment** and impacts on the **natural environment**.

The term 'effect' is defined here in terms of the theory of change as 'impact', which arises from the linear causality of input, activities, output and outcome (Clifford et al., 2014; Kurz & Kubek, 2018). In particular, this study understands 'impact' as the *intervention difference* (Brest & Born, 2013), which describes the proportion of the overall development that can be attributed to the start-up under consideration: Which market, environmental and social effects would not have occurred without this actor?

The assessment of the effects of the start-ups **on markets and competitors** will be the subject of a section in each of the following case studies. The **effects on the social environment** are examined with a focus on the issue of **working conditions** and the role of **trade unions.**

With regard to the **impact on the natural environment,** however, the impact of the innovations of *electromobility* and *digitisation* is common for all start-ups. The assessment of the difference between an electric vehicle and one powered by an internal combustion engine, as well as the impact of digitisation on the environment, is therefore being investigated and evaluated in the following section.

2.3 The impact of electric mobility and digitisation on the natural environment

With regard to the **assessment of the environmental relief from electric propulsion,** a war of studies has been raging for years. Again and again, studies are published that are extremely critical of the environmental impact of electric drive systems. Under the title "Electromobility and climate protection: the great miscalculation", the renowned Kiel Institute for the World Economy recently published a study of particularly poor quality (Schmidt, 2020). The core results, which were systematically refuted as incorrect by the Fraunhofer ISI (Wietschel, 2020). Buchal et al. (2019, S. 40) also report *"that the CO_2 emissions of electric car drives are about one tenth higher than those of the diesel engine in the favourable case and a good quarter higher in the unfavourable case"*. These authors were additionally sharply criticised for a lack of scientific basis (Hajek, 2019; Schwierz, 2019).

However, the majority of studies paint a different picture. In autumn 2019, the General German Automobile Association (ADAC) reported that the most climate-friendly solution in the electricity mix at that time was the natural gas car, but sees considerable advantages for electric cars in the future scenario with green electricity (ADAC, 2019). If one takes into account that strategic decisions for the product range in 2030 should sensibly be made on the basis of the framework conditions expected in 2030, the picture becomes clearer. The Federal Environment Agency (Umweltbundesamt (Hrsg.), 2016, S. 19) documents, for example, greenhouse gas emissions from passenger cars powered by petrol engines in 2016 of approx. 250 g CO_2/km (approx. 200 g CO_2/km in 2030), from diesel engines in 2016 of approx. 200 g CO_2/km (approx. 170 g CO_2/km in 2030), by plug-in hybrid of approx. 200 g CO_2/km (2030 approx. 120 g CO_2/km powered by renewable electricity) and by battery electric drive of approx. 200 g CO_2/km (2030 approx. 65 g CO_2/km powered by renewable electricity). The Federal Ministry for the Environment also clearly positions itself in favour of electric cars: *"Over a vehicle's lifetime, electric cars are below their fossil-fuelled counterparts in terms of CO_2 emissions. This climate benefit will increase with each year that the energy system transformation in the electricity sector progresses"* (Bundesministerium für Umwelt, Naturschutz und nukleare Sicherheit (BMU), 2019). The available life cycle assessment studies agree that the way electricity is provided has a major influence on the greenhouse gas emissions of battery electric cars (BEV) per km of mileage. Messagie (2017, S. 11) documents the lowest emissions at 4 gCO2/km for the Swedish electricity mix. But even with the Polish coal electricity mix, the electric car performs better than the combustion engine. The following case studies are based on the assumption that the transformation from internal combustion engine drive to electric drive has a positive impact on the environment.

In contrast, the **impact of digitisation on the environment** does not clearly lead to environmental relief. In various areas of need it has been repeatedly confirmed that although digital shared use models often change user behaviour, this does not always lead to ecological relief (Bienge et al., 2016, 2019; Gossen et al., 2019). In the context of autonomous driving, such reductions of environmental impact cannot be expected anyway, e.g. from the installation of driver assistance systems, i.e. the preliminary stages of autonomous driving. Even the realisation of autonomous driving itself does not certainly lead to environmental relief. On the contrary, scenarios with increased traffic volumes are also conceivable (Deloitte, 2019).

3 Overview of the development of the electric car niche 1985 to 2020

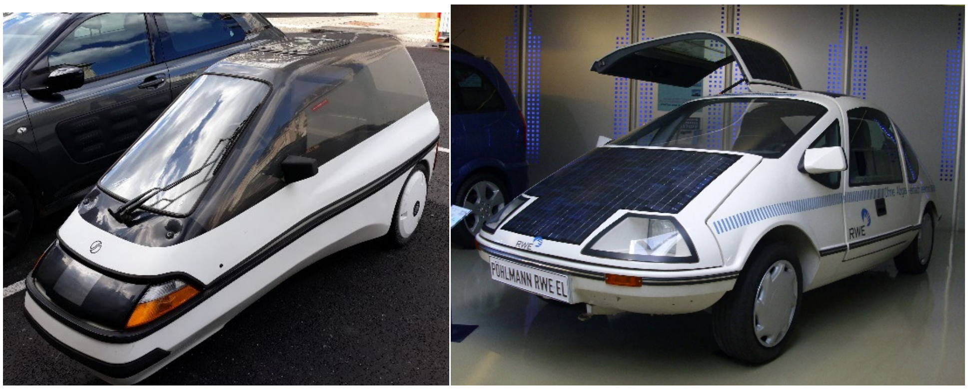
3.1 Beginnings and first providers of electric mobility

Even in the early days of automobility, electric drive was used in parallel with drives by combustion engine and steam drive. However, after the combustion engine had won this competition, it became relatively quiet for 70 years around the electric drive for the automobile. In the wake of the oil crisis and the environmental movement, activities to revive electric propulsion then began. Lemme (1988, S. 24) writes

> *"Not only because oil is becoming scarce, but also because the CO_2 content of the atmosphere is constantly increasing, which can lead to global climate change through the "greenhouse effect". If action is not taken early enough, we are threatened by the greatest environmental disaster in world history and at the same time by our dependence on the last remaining oil-producing countries. …. Not a pleasant situation."*

The utility company RWE considered how to sell the surplus night-time electricity more effectively and saw one possibility in charging batteries of electric cars at night. In 1983, RWE financed Pöhlmann KG in Kulmbach to develop the Pöhlmann EL, a sleek electric car with two engines of 7 kW each, a maximum speed of 115 km/h, charging capacity of 2 kW and a range of 60 to 80 km (Lemme, 1988, S. 29). 14 of them were built partly with PV elements before RWE ceased its activities. One of the few cars that made it into a small series was the Danish Mini EL, later City EL, of which several thousand units were sold.

Figure 1: The Danish Mini El (left) and the Pöhlmann EL (right) developed in the 1980s



Source: Clausen (left), book t (2012) on Wikimedia (right)

The Mini EL was equipped with lead-fleece batteries, was charged at a normal power outlet and achieved a range of up to 50 km with one battery charge. The consumption was significantly below 10 kWh/100 km. Since 1981 Volkswagen built some small series of the Golf Citystromer with lead gel batteries, which also had a range of about 50 km and was not sold openly. The first 'professional' electric car might have been the General Motors EV 1, first equipped with lead-acid batteries, later with NiMH batteries and a range of about 150 km. The aluminium body had an extremely good drag coefficient (C_d value) of 0.19.

Figure 2: The EV 1 from General Motors

Source: www.evnut.com

Just over 1,000 copies were built. However, global sales of electric cars remained more limited. In Norway, the model country for electromobility, new registrations exceeded 500 battery electric vehicles (BEV) per year for the first time only in 2008 (Figenbaum & Kolbenstvedt, 2013, S. III). The International Energy Agency (IEA) estimated the worldwide stock of battery electric vehicles in 2010 at around 20,000 vehicles (OECD / IEA, 2013, S. 10).

The activity of the producers was limited. There were some start-ups such as the Norwegian company Pivco, later Think, which was bought and sold again by Ford after a long start-up phase, went bankrupt in 2006, was rescued and finally went bankrupt in 2011. Other manufacturers such as Honda, General Motors and Volkswagen produced individual small series but never entered the mass market or even, like General Motors in 2003, went out with a bang (Paine, 2006). Until the first 'modern' electric cars appeared on the market, the Tesla Roadster in 2008, the Mitsubishi i-Miev and the Nissan Leaf in 2010, the electric car market, with the exception of the EV 1, was a niche of technically unsatisfactory short-range vehicles with long charging times.

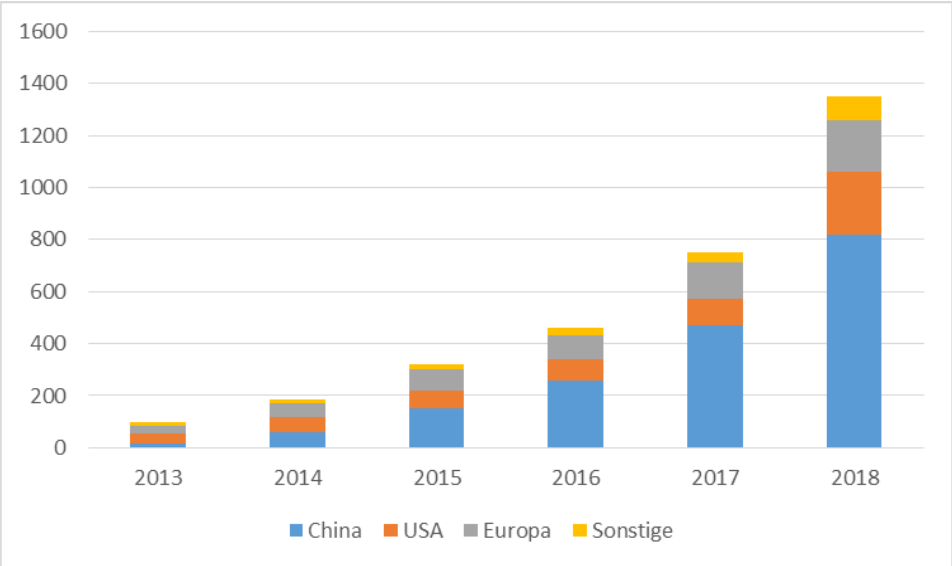
In 2009, Figenbaum and Kolbenstvedt see the trend reversal to a phase in which large manufacturers began to actively develop the market (Figenbaum & Kolbenstvedt, 2013, S. 16). But even after that, sales figures were still low. In the USA, General Motors sold 23,461 Chevy Volts[2] in 2012, Renault-Nissan 10,407 BEVs, including 9,819 Nissan Leafs, and Tesla 2,400 Model Ss (Pontes, 2013b). In Germany, Daimler AG sold 817 BEVs in the same year, including 734 SmartForTwo, Renault Nissan sold 760 vehicles, including 451 Nissan Leaf, 213 Renault Fluence and 96 Mitsubishi i-Miev. Third on the

[2] The Chevy Volt with a 16 kWh lithium-ion battery is actually too big for a plug-in hybrid and is therefore listed here as an electric car with range extender.

market was Peugeot-Citroen with 454 Citroen Zero and 263 Peugeot Ion (Kraftfahrtbundesamt, 2020).

For the following years the Global EV-Outlook of the International Energy Agency records the following distribution of the increasing BEV sales on the three large markets China, USA and Europe (International Energy Agency, 2019, S. 36).

Figure 3: Global development of the market for electric cars (BEV) 2010 to 2018



Source: Production in 1.000 cars, based on data from Global EV-Outlook (International Energy Agency, 2019, S. 36)

These markets were dominated by established manufacturers. Niche manufacturers, with the exception of Tesla, have not made it into the major markets. The Norwegian start-up Think sold almost exclusively domestically, only in the Netherlands in 2012 a number of 6 Thinks sold could be identified in our sample (Pontes, 2013a). In the Netherlands GM was the market leader with 2,456 Opel Ampera and 284 Chevy Volt sold, followed by Renault-Nissan and Peugeot-Citroen. Tesla sold 24 roadsters in the Netherlands in 2012 (Pontes, 2013a).

If one takes the figures from Global EV-Outlook (International Energy Agency, 2019, S. 36) as the size of the world market, the following shares for the largest national markets for BEV are obtained:

Table 1: The largest national markets for BEV 2018

	Production in units	World market share	Market character	National market leader 2018
China	929.477	69%	National	BAIC
USA	238.823	18%	National	Tesla
Norway	42.056	3%	Import	Renault Nissan
Germany	36.062	3%	Import	Renault Nissan
France	29.216	2%	National	Renault Nissan
Japan	25.822	2%	National	Renault Nissan
Netherlands	23.574	2%	Import	Tesla
UK	13.348	1%	Import	Renault Nissan

Source: Borderstep Institute, based on figures from Pontes, José (2020)

The analysis of the leaders in the largest markets reveals four markets with national leaders (China, USA, Japan and France) and four markets with foreign leaders. Renault-Nissan was the market leader in five of the markets in 2018. In two markets, namely the US and the Netherlands, Tesla had ousted General Motors from the market leadership. In China, the market was spread over a larger number of national manufacturers, with BAIC being the market leader.

Of the electric mobility start-ups still active in various national markets in 2012, all but Tesla had either disappeared in 2018 or no longer played a role with extremely low production figures.

Tesla, on the other hand, has made it from a start-up to the world's most valuable car manufacturer within 17 years (Yahoo Finance, 2020) and also leads the ranking of the best-selling BEV. Cleantechnica (2020) documents for 2019 over 300,000 sold copies of the Tesla Model 3, followed by 111,000 copies of the BAIC EU series in second place and about 70,000 Nissan Leaf in third place. BMW makes it to 8th place with almost 42,000 copies of the i3, Volkswagen with the e-Golf to 11th place.

3.2 Key events and supporting factors

The first key events on the road to electromobility were the **oil crises of 1973** and **1979**, which also led to the first research and development efforts to develop renewable energy systems (Clausen, 2019). The impending shortage of oil and thus also of petrol and diesel seems to have unsettled at least some actors in the automotive regime.

A further encouraging factor was the **environmental movement that** had been forming since the **mid-1970s**. However, the Norwegian pioneer of electromobility, Harald Røstvik, already mentioned that there was no consensus at all within the environmental movement on the issue of electric cars, as the preferred forms of mobility for environmentalists were public transport, cycling and walking, and the resource-intensive car was therefore often criticised (Clausen, 2017, S. 15). However, he also pointed at the different positions of environmentalists from urban areas like Oslo and others from sparsely populated regions without well developed public transport.

In California, by contrast, problems with air pollution in the Los Angeles conurbation prompted another key event, the **minimum sales quota for zero-emission vehicles** adopted by the California Air Resources Board (CARB) in **1990** (California Air Resources Board, 1990, S. 22). Similar in China, where air quality together wit CO2 emission is highly hazardous to health, especially in cities, prompted considerations to promote electric mobility (Boguang et al., 2014).

The fact that **small series of electric cars from** various **established manufacturers** from the **1980s** and **1990s have** all been **discontinued** can also be considered a key event. Driving factors behind the termination of activities were particularly noticeable in **2003**. On the one hand was the problem of powerful and affordable batteries, which the regime found almost impossible to solve. But on the other hand, also the lack of motivation to abandon the profitable concept of the car with combustion engine, and the corporate cultural fusion of car and combustion engine, which was not easy to overcome (Paine, 2006).

The influence of the development of **information technology** is clearer. The conviction of Tesla founders Marc Tarpenning and Martin Eberhard that the lithium-ion batteries used in their e-readers as well as in laptop computers could also power cars. That combined with the fact that the rapid scaling of mobile computers and other mobile electronic devices had led to an equally rapid scaling of the production and reduction of the costs of these batteries, led to the **lithium-ion battery** finding its way into electromobility with the founding of Tesla in **2003.** GM had also considered the use of lithium-ion batteries in the EV 1, but never realised it (Wikipedia, 2020a). Due to this clear connection between the digital economy and electromobility, it is by no means a coincidence but rather a logical consequence that Tesla was founded in Silicon Valley.

3.3 Autonomous driving

The question of the impact on the car industry of start-ups that launch autonomous driving systems can only be answered if it is clear what autonomous driving is and what advantages it has or could have. The following sections will therefore give some basic information:

- Definition: What is autonomous driving, including the different levels defined in this context.
- Impact: What is the potential added value of autonomous driving for the natural environment and society, with a particular focus on knowledge available on safety.
- Digression Tesla: What special findings are available on the Tesla autopilot.

3.3.1 Definition: The 6 levels of autonomous driving

The German Federal Highway Research Institute has created the following nomenclature for driving tasks of the driver according to the degree of automation (Bundesanstalt für Straßenwesen, 2012), which was supplemented in the standard SAE J3016 by the level of 'conditional automation' (SAE International, 2014).

Table 2: Levels of autonomous driving

Nomenclature	Driving tasks of the driver
0. driver only	Driver permanently (during the entire journey) executes longitudinal (acceleration/deceleration) and lateral (steering) control
1. assists	Driver permanently executes either the lateral or the longitudinal guidance. The other driving task is performed by the system within certain limits
2. partially automated	The system takes over lateral and longitudinal guidance (for a certain period of time and/or in specific situations)
3. conditional automation	Driving mode-specific execution of all aspects of the dynamic driving task by an automated driving system with the expectation that the human driver will respond appropriately to the system's request
4. highly automated	The system takes over lateral and longitudinal guidance for a certain period of time in specific situations
5. fully automated	The system takes over lateral and longitudinal guidance completely in a defined application.

Sources: Federal Highway Research Institute (2012) and SAE International (2014)

The five stages of automated driving show that the path from human driver to autonomous vehicle will not involve an abrupt change from one system to another. Rather, a continuous process can be expected in which more and more vehicles with ever increasing levels of automation will be on the roads.

3.3.2 Added value of autonomous driving for the natural environment and society

How do independent studies assess the effects of autonomous driving? A meta-analysis commissioned by the German Association of Industry and Commerce (Esser & Kurte, 2018) documents a consistently **positive effect** of various driver assistance systems **on traffic safety** (Esser & Kurte, 2018, S. 44)and in the direction of **increased capacity** of roads and motorways (Esser & Kurte, 2018, S. 37). The impact on the **modal split** and **urban transport** is documented as **ambivalent** or **unclear**, since on the one hand motorised individual transport could become more attractive through automated or autonomous driving, but on the other hand more efficient and economical public transport services would also become possible (Esser & Kurte, 2018, S. 50).

A study by the Fraunhofer IAO commissioned by the BMWi (2015)calculates the effect of highly autonomous driving using the monetarisation method and identifies consistently **positive effects** for the impact categories of **fuel consumption, air pollution, accident costs and congestion costs** (Fraunhofer IAO, 2015, S. 272).

Acatech et al. (2018, S. 16)cite traffic accidents with the autopilot in the Tesla Model S as an example that blind trust in supposedly intelligent systems is inappropriate, but do not go into the safety of autonomous cars any further.

Maurer et al. (2015, S. 369) point to the fact that human error has led to accidents in about 93.5% of all accidents[3]. There are also environmental and weather influences (4.6 %), technical errors (0.7 %) and 'other causes'. Maurer et al. also assume that in the case of autonomous vehicles, technical faults will dominate the accidents. The question arises as to whether possible incorrect reactions of the software of an autonomous vehicle cannot be attributed to "human errors" in programming. Maurer et al. (2015, S. 368) consider forecasts of future accident events to be difficult, since numerous as yet unprovable assumptions have to be made for an assessment of the safety potential of autonomous vehicles. Consequently, they ascribe only limited significance to the already existing analyses of the safety potential of autonomous vehicles based on accident data.

Based on Californian data on 53 accidents involving autonomous vehicles in the years 2015 to 2017, Petrović et al. (2020, S. 167) show that the collision types 'side impact' and 'pedestrian' occur less frequently in autonomous vehicles. Furthermore, autonomous vehicles are partly able to compensate for errors made by drivers of conventional vehicles with regard to giving way. However, the introduction of autonomous vehicles increases the proportion of rear-end collisions. The reason for this is that drivers of conventional vehicles are not sufficiently accustomed to the dynamic characteristics of autonomous vehicles during acceleration and deceleration in convoys (Petrović et al., 2020, S. 167). Favarò et al (2017, S. 11)also document, on the basis of Californian data on 26 accidents between 2014 and 2017, a high proportion of accidents in which a conventional vehicle collides with an autonomously driving vehicle from behind. In 62% of the accidents in which an autonomous vehicle is involved in accidents, the vehicle is damaged at the rear, and in a further 23% there is lateral damage (Favarò et al., 2017, S. 11). The fact that in many of the accidents studied, the autonomous vehicle was significantly slower than the conventional one or was even stationary, also suggests that it is more likely to be the conventional vehicles that are responsible (Favarò et al., 2017, S. 12). Nevertheless, it must be noted that in the very small database of Favarò et al., which was compiled in early years of development, autonomous vehicles were about 10 times **more likely to be involved in accidents** than conventional vehicles, both in terms of the number of accidents per vehicle and the distance travelled.

Also of interest is an analysis by the US Insurance Institute for Highway Safety, which analysed a sample of 5,471 representatively selected accidents involving conventional vehicles (Mueller et al., 2020). 33.1 % of the accidents examined here can be attributed to human sensory perception and the (in)ability to act appropriately. They assume that an autonomous vehicle could probably avoid this proportion of accidents. However, a further 61.4 % of accidents are related to questions of planning and decision-making or predicting situations (Mueller et al., 2020, S. 9). Essential for such accidents is e.g. the 'decision' to drive too fast or to change lanes in a risky situation. Such decisions can in principle also be 'imposed' on an autonomous vehicle and would then possibly also lead to accidents. They could only be avoided if autonomous vehicles would follow the traffic rules in every situation, e.g. never exceeding the speed limit or changing lanes in risky situations. This would mean that numerous

[3] A similar figure of 94% is documented by Favarò et al. (Favarò et al., 2017, S. S.8)

decisions would have to be taken away from the vehicle user. It could be assumed that the spread of autonomous driving would be much slower in this case.

3.3.3 Digression: Safety of the Tesla Autopilot

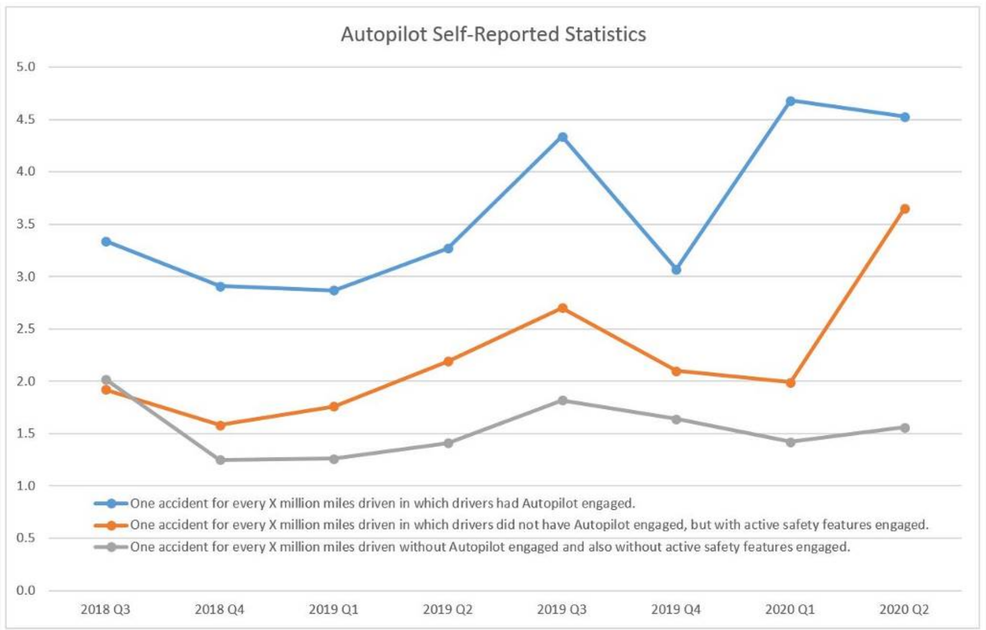
Thanks to the high level of connectivity of Tesla's operational fleet, Tesla has a broad database for analysing accidents. Tesla describes the database as follows (Tesla, 2019, S. 24):

> *Because every Tesla car made since October 2016 is equipped with the necessary sensor suite for full self-driving, each of these cars also support our autonomous driving development. Tesla's vertical integration and scale provides the company with billions of miles of global real-world data that is gathered as Tesla vehicles are driven. This helps us identify edge cases, train our autonomous driving system, and test how a feature would perform in the real-world, without actually activating them.*

As Tesla has built about 973,000 vehicles between October 2016 and June 2020 (Hanley, 2020), the 'test fleet' is now considerable and is growing by about 100,000 vehicles every quarter. On this basis, the Tesla Impact Report indicates a comparatively higher safety of Tesla cars (Tesla, 2019, S. 24): In 2019, Tesla cars with active autopilot only had 0.3 accidents per million miles driven in the USA. The general US average (of all cars) was about 7 times higher with 2.0 accidents per million miles driven. In addition, even those Tesla vehicles in which only the active safety functions were activated had a collision rate in 2019 that was about 4.5 times lower than the US average.

Wikipedia (2020b) has evaluated and graphically presented the self-reported data from the Tesla Safety Report (Tesla, 2020):

Figure 4: Tesla Autopilot self-reported statistics



Source: Wikipedia (2020b)

The figures show two things: Firstly, the distance between two accidents (in mil. miles) with the autopilot switched on (blue) is significantly greater in all quarters for which data is available than when only the active safety functions are switched on (orange) or even both systems are deactivated (grey). Secondly, both the blue and the orange curve rise - with some setbacks - in the long term, which suggests that the systems are learning successfully.

4 Waymo

"We're building the World's Most
Experienced Driver™" (Waymo, 2020a).

Waymo, part of Alphabet Holding, to which Google belongs, is considered the technology leader in autonomous driving according to Navigant Research (Navigant Research, 2019). Like Tesla, Waymo is a 'product' of Silicon Valley. Waymo started with some self-built cars. However, it is currently expected that Waymo could develop into a key company in the supply industry. As a digital software tech company with the financial background of Google, Waymo has considerable potential to become a strong industry change agent.

4.1 Background and framework conditions

In Silicon Valley, about 1.7 million jobs have been created over the last 60 years (Silicon Valley Institute for Regional Studies., 2020). Today, the Valley is a huge IT cluster based on entrepreneurship, initiative, networks and science (Gandenberger et al., 2020). Compared to established technology regimes, Silicon Valley is programmed for permanent change and has a consistently high number of start-ups. The great success of many of these start-ups is one of the reasons why venture capital is much more readily available in Silicon Valley than in Germany (Gandenberger et al., 2020).

A group of company founders have become incredibly wealthy in Silicon Valley since the 1990s. These include Apple founder Steve Jobs, but also Facebook founder Marc Zuckerberg and Google founders Larry Page and Sergey Brin. From the group of tech founders and managers, the website "Inside Philanthropy" (2020) counts a remarkable 281 people or couples who support charitable causes through large foundations or donations. In addition to Bill Gates with his world-renowned Bill and Melinda Gates Foundation and Steve Jobs' widow, the website also features Google co-founder Sergey Brin as a donor for medical research, as a supporter of Russian migrants, and for the fight against poverty and anti-Semitism. Elon Musk, co-founder of PayPal and Tesla Motors, focuses his donations on renewable energy, science and engineering education and health care. Google co-founder Page, from the perspective of "Inside Philanthropy" (2020) seems to channel most of his philanthropic interests through the company's donations. Here one should mention that Sebastian Thrun, who is responsible for the Driverless Car at Google, described the goal of the Driverless Car Project in 2010 as follows (Thrun, 2010):

> *Our goal is to help prevent traffic accidents, free up people's time and reduce carbon emissions by fundamentally changing car use.*

In a nutshell, it can be assumed that Google founders Page and Brin were both technically fascinated by the idea of a Big Data-driven computer that would control autonomous cars, and hoped it would provide a positive impetus for road safety and in the context of climate change. Given their considerable financial resources, they were able to tackle this challenge without delay.

4.2 The founding team and its environment

One of the most important Silicon Valley start-ups was Google, a company created in 1998 by Larry Page and Sergey Brin. Google was founded to market the Google search engine, which has since then become the most widely used web-based search engine. In 2020, the market capitalisation of Google's Alphabet holding company, founded in 2016, exceeded the $1 trillion mark for the first time. Only Apple, Microsoft and Amazon are valued even higher on the stock exchanges.

For many years, Google's services have also included geographical information, as a significant proportion of search queries have a geographical character. Following a number of development projects and acquisitions, Google Earth and Google Maps were available in initial versions in 2004 and 2005 respectively. The Google Street View, which is sometimes quite controversial in Europe, was introduced in the USA in 2007. It was therefore a logical step to put the accumulating stock of geographical data and especially the detailed street information from Street View into the context of automobility.

German computer expert Sebastian Thrun and French engineer Anthony Levandowski joined Google in 2007 to create a virtual map of the country. The idea came from Larry Page as one of the company's founders (Bilger, 2013).

In February 2008 Levandowski received a call from a producer of the Discovery Channel series 'Prototype This! '. The television series wanted a self-propelled pizza delivery van (Bilger, 2013). Within five weeks Levandowski and a team of Berkeley graduates and other engineers had converted a Toyota Prius for this purpose. They named the vehicle 'Pribot', put together a guidance system and persuaded the California Highway Patrol to let the car drive across San Francisco's Bay Bridge. It was the first time that an unmanned car legally drove on American roads (Bilger, 2013). The event gave Google, which had been in the background during the action, the necessary impetus. Within a few months, Larry Page and Sergey Brin gave the green light for a project for driverless cars. Thrun reports (Bilger, 2013): "They didn't even talk about the budget, they just asked how many people I needed and how I could find them. ”

4.3 Investors

From the beginning in 2009 until the official launch of Waymo 2016 and also since then until spring 2020, all costs were financed by Google.

Only then did Waymo initiate a first external financing round. Waymo - as a spin-out of Google Holding Alphabet - raised $2.25 billion in this financing round from various investors including Silver Lake, the Canada Pension Plan Investment Board and Mubadala Investment Company (Abu Dhabi sovereign wealth fund). Other investors include Magna International, Andreessen Horowitz and AutoNation as well as Alphabet itself (Hawkins, 2020). According to Waymo, the main purpose of this round of financing was to accelerate the commercialisation of Waymo One, an automated taxi service (Hawkins, 2020).

4.4 Strategy and objectives

As mentioned above, Sebastian Thrun described the goal of the Driverless Car Project, which he led, as follows in 2010 (Thrun, 2010):

> *Our goal is to help prevent traffic accidents, free up people's time and reduce carbon emissions by fundamentally changing car use.*

The starting point of today's official Waymo strategy is the assumption that a car controlled by a computer is safer than a car controlled by a human. The mission (Waymo, 2020a) also based on this assumption:

> *Waymo's mission is to make it safe and easy for people and things to get where they're going. The Waymo Driver can improve the world's access to mobility while saving thousands of lives now lost to traffic crashes.*

But for Waymo it's not only safety that counts. As the image film shows, autonomous driving also gives blind and underage people the opportunity to drive unaccompanied (Waymo, 2020a):

> *Fully self-driving vehicles hold the promise to improve road safety and offer new mobility options to millions of people. Whether they're helping people run errands, commute to work, or drop off kids at school, fully self-driving vehicles hold enormous potential to transform people's lives.*

The title of the Waymo website is "We're building the World's Most Experienced DriverTM" (Waymo, 2020a). It allows the assumption that the central goal of Waymo is not product development but rather software development.

Goulding also refers to a statement by Waymo CEO John Krafcik on his blog in the context of the early 2020 financing round. In this statement Krafcik stated that Waymo's future focus could be on driverless technology and Waymo would leave the rest of the car production to others in the industry (Goulding, 2020). This possible development reminds Goulding of the 'Intel Inside' business model. The advantage of this strategy would be that Waymo could use the more than 100 years of experience of traditional car manufacturers (Goulding, 2020). Whether this means experience in designing and building cars or experience in lobbying in the political arena remains open. As one of the major challenges for autonomous driving is the support and approval of governments and regulators at federal, state and local level, the ability to influence government decisions would at least be a potentially very important competence.

In addition to the sale of software and hardware to car companies, a second way of commercialisation would be to offer services with self-driving taxis or trucks. With the focus on the transport service Waymo One, the financing round in spring 2020 was also launched.

If you take the title of Waymo's website "We're building the World's Most Experienced DriverTM", Waymo's core strategy is likely to be a long-term project to develop a software solution, which ultimately cannot be separated from the necessary hardware such as Lidar ("Light Detection And Ranging" - method for optical distance and speed measurement) (Waymo, 2020a). In contrast, offering self-designed and produced cars does not (any longer) seem to be the goal of Waymo.

4.5 The product

Software for autonomous driving can only be developed if real cars are available. After the first test vehicles were converted Toyota Prius (Bilger, 2013), Google presented a small electric two-seater in 2014 (Auto Bild, 2018). This car gave rise to the expectation that Google would not only produce and market the software but also the matching vehicles. In 2016, however, Google apparently abandoned plans for its own car (Auto Bild, 2018). Since then, the spin-out Waymo, founded in December 2016, has been concentrating on developing the software needed for autonomous driving. However, this also required hardware development. This is described by the head of the Lidar team in 2019 (Verghese, 2019):

> *For over a decade, Waymo has been developing self-driving technology with a mission to make it safe and easy for people and things to move around. In the earliest days of our program, we developed our own software, but purchased off-the-shelf sensors to power our self-driving vehicles. As our testing matured, we quickly learned that existing sensors simply didn't serve our needs. So in 2011, we began developing our own set of sensors from the ground up, including three different types of lidars - the sophisticated sensors that measure distance with pulses of laser light.*

Waymo began offering these sensors to the market in spring 2019. Interested parties were suspected in robotics, safety engineering and agricultural technology, among others (Verghese, 2019). The Waymo 3D lidar sensors are distributed as 'Laser Bear Honeycomb', but are not sold to customers in the automotive sector (Verghese, 2019). In mid-2020 the actual customer base for the system was not yet known (Yoshida, 2020). Yoshida's intention to sell the hardware technology is based on the hope that successful sales will generate economies of scale and learning effects that will make the system less expensive and enable it to be used in different application contexts (Yoshida, 2020).

In addition to the sensors, the company's key products are the software, "the World's Most Experienced DriverTM", and the services that can be provided with this driver.

4.6 Production figures

The production level of Waymo systems for autonomous driving is still low eleven years after Google started the Driverless Car Project. The first project 'Driverless Car' was tested undetected on the road for almost two years using seven Toyota Prius vehicles before the New York Times revealed its existence on 9 October 2010 (Markoff, 2010). Google reported the same day on its blog on its initiative for self-propelled cars. In the following years there were further development steps and more and more new test vehicles.

In 2014, Google presented an electric vehicle it had developed itself, which was used for further trials (Google, 2014).

Figure 5: The Google Car

Source: Wikimedia (Grendelkhan / CC BY-SA (https://creativecommons.org/licenses/by-sa/4.0)

At the end of 2014, 'The Mercury News' from San Jose in Silicon Valley reported a total of seven test fleets of autonomous vehicles, with Google operating the largest fleet of 25 vehicles (O'Brien, 2014). The following seven companies had been approved by the Department of Motor Vehicles of the State of California to test self-propelled cars on public roads (O'Brien, 2014):

Table 3: Test fleets of autonomous vehicles in California December 2014

Company	Number of vehicles	Number of drivers
Google	25	107
Volkswagen/Audi	3	25
Mercedes-Benz	3	12
Nissan	3	9
Delphi Automotive	2	9
Bosch	2	2
Tesla	1	2

Source: O'Brien (2014)

In 2017, a cooperation between Fiat Chrysler Automobiles and Waymo was established. Within the framework of this partnership, a fleet of initially 100 autonomous Chrysler Pacifica minivans (DeBord, 2018) created. In the same year, the fleet was expanded to approximately 600 vehicles (Lynch, 2017).

At the New York Auto Show in early 2018, Waymo and Jaguar announced their intention to put a fleet of 20,000 all-electric Jaguar I-Pace cars on the road (DeBord, 2018; Waymo, 2018b).

In January 2019, Waymo announced the opening of the world's first factory for the mass production of autonomous level 4 vehicles (Waymo, 2019). A former American Axle & Manufacturing factory in

Detroit was selected. Waymo's goal was to attract Detroit-trained automotive workers whose jobs in the conventional automotive industry had been lost in previous years (Waymo, 2019). In March 2020, Waymo reported that the first converted vehicles had been delivered from this factory (Waymo, 2020b). In the accompanying photo in front of the factory, the message depicted the Chrysler Pacifia, the Jaguar I-Pace and a Peterbilt truck (Waymo, 2020b).

At this stage, it does not seem likely that Google would seek to produce cars independently. Similarly, it does not appear likely that Google's hardware and software for autonomous driving would already today constitute a ready-to-sell product which could be independently installed in their vehicles by other manufacturers such as the partners Fiat-Chrysler and Jaguar, a company belonging to the Indian Tata group. Rather, the opening of the 'conversion factory' in Detroit shows that Waymo is creating structures that will allow medium volumes of vehicles to be converted for test fleets over the next few years.

4.7 Sales and procurement markets

Waymo does not seem to sell the converted vehicles so far, but rather to operate them in test fleets with different business models. Therefore, it is not possible to make any substantiated statement about the sales markets.

In the Phoenix test area, Waymo's driverless transport service Waymo One, which is operated by Waymo, has so far been free. But apparently a price is being considered (Lewalter & Wiesmüller, 2019). The trucks converted by Waymo are currently used in the Google fleet (Waymo, 2018a).

Waymo is said to cost Alphabet nearly $1 billion a year and, with its limited commercial taxi service Waymo One in the suburbs of Phoenix, Arizona, generates at best a meagre amount of revenue (Hawkins, 2020). So there is not yet a significant market for the service.

Procurement markets include Waymo's partners who supply raw vehicles. In the passenger car sector these are Fiat-Chrysler and Tata-Jaguar. In the truck sector Waymo Via converts trucks from the American manufacturer Peterbilt. However, no formal partnership has been announced so far (Auto-Motor-Sport, 2020a).

In addition, computers and sensors are procured, as far as these are not built by Google itself. The specific suppliers could not be identified in this case study.

4.8 Tech companies, labour and unions

The population of Silicon Valley has risen from about 500,000 inhabitants in 1950, to about 1.8 million in 1970, and now nearly 3 million (Silicon Valley Institute for Regional Studies., 2015). The number of jobs was around 1.7 million in mid-2019 (Silicon Valley Institute for Regional Studies., 2020). An outstanding ability of the tech companies based there is that they not only produce innovations, but also scale them and thus help to create new jobs. Google alone currently employs over 100,000 people at 170 locations in 60 countries (Google, 2020). Many of these jobs require high qualifications. For example, 16% of Google's job offers require a doctorate; by 2015, Google already had

34,000 positions filled with PhDs (Hess, 2017). In addition, Silicon Valley's tech industry has made many of its founders and executives rich. Today, 76,000 millionaires or billionaires live in Silicon Valley (SJSU Human Rights Institute, 2020).

But the job boom that has been going on since the 1960s also has its downsides. One of them is an inequality of distribution between the different ethnic groups: While the average annual income of employees of European descent in the Valley is $ 82,810, Asian-Americans earn only $ 63,136, African-American employees $ 40,886 and those of Latin American descent only $ 28,860 (SJSU Human Rights Institute, 2020). The minimum wage in the communities of Saratoga and Los Gatos, which are heavily populated by these groups, is only 12 $ (approx. 10 €).

The other side of the coin is a culture of co-determination which is extremely weak by European, and in particular German, standards. Nevertheless, the *Tech Workers Coalition,* founded in 2014, documents a long series of collective and trade union initiatives around tech companies (Tech Workers Coalition, 2020). However, there are only two entries for Waymo's parent company, Google. For example, in November 2019, some 2,300 employees of a Google catering company decided to join a union:

> *Approximately 2,300 contract workers employed in food service at Google have voted to unionize under a local chapter of Unite Here. Workers expressed dissatisfaction with their low wages, which start at $35,000 in the Bay Area, and lack of benefits compared to full-time Google employees. Some reported incidents of discrimination and bullying. The workers are officially employed by Compass Group, a third party contractor. The vote followed a two year effort. (Entry as of Nov. 19th 2019 on Tech Workers Coalition 2020)*

In December 2019, four direct Google employees who had been campaigning for trade union representation were dismissed (Tech Workers Coalition, 2020). There are no entries about the Waymo subsidiary in the Tech Workers Coalition archive (Tech Workers Coalition, 2020). The same applies to the website of the United Automobile, Aerospace and Agricultural Implement Workers of America (UAW) (www.uaw.org), which does contain critical entries about competitors such as Tesla.

Without going into depth at this point, it should be noted that, from a history of rather neoliberal entrepreneurship, Silicon Valley tech companies are good at scaling innovation and creating jobs, but lack a culture of participation or union activity. The dilemma for trade unions, as these tech companies penetrate Europe, is that while this is welcome in terms of much-needed additional jobs, it is a major challenge in terms of union representation.

4.9 Impact on the car industry

At present, work is being carried out in various cooperation projects to improve and test the technology of autonomous driving. For example, Waymo will work with Fiat Chrysler on light commercial vehicles with the ability to drive autonomously at Level 4 to enable the transport of goods (Breana, 2020). A further partnership to develop Level 4 vehicles has been announced by Waymo and Volvo (Herger, 2020). A cooperation of Waymo with Tata-Jaguar would also be obvious with regards to building the test fleet of 20,000 Jaguar i-Pace (DeBord, 2018; Waymo, 2018b).

German corporations, on the other hand, do not seem to be moving towards Waymo. Daimler is co-operating with NVIDIA in hardware development (Daimler, 2020) and for several years with Bosch (Navigant Research, 2019) development of autonomous driving. A cooperation with BMW started in 2019 but was terminated in 2020 due to the high costs (Manager Magazin, 2020), which is surprising considering the necessary long-term orientation of such strategic projects.

Volkswagen is cooperating with Ford on autonomous driving, electric cars and light commercial vehicles (Harris, 2020). Volkswagen and the Autonomous Driving Start-up AutoX in China also announced a strategic cooperation in the Autonomous Driving Demonstration Zone in Jiading, Shanghai. Volkswagen will provide traffic portals for the fleet and AutoX will provide a technology platform (B. Wang, 2020).

Navigant Research has been measuring and comparing the success of the various collaborations for several years (Navigant Research, 2019). The three 'leaders' here are Waymo, GM and Ford. The German automotive industry is part of the very dense 'chasing group': Among the chasers is Volkswagen, whose cooperation with Ford could further improve Volkswagen's prospects, and also Daimler-Bosch and BMW-Intel-FCA. Figure 7 shows this comparison graphically.

Figure 6: Navigant Research Leaderbord Grid

Source: Navigant Research (2019)

In addition to the sooner or later expected market introduction of autonomous vehicles, one effect of Waymo's driving agenda are the required necessary investments of billions of dollars in software and hardware for the entire automotive industry. Furthermore, the question arises whether the necessary hardware for autonomous driving should already be installed today, in order to be able to realise autonomous driving step by step through subsequent updates. Due to the delayed benefit, however, this equipment could only be reflected in the sales price to a limited extent. Volkswagen stated in 2019 that the VW ID3 was designed for autonomous driving at Level 4 (Volkswagen 2019). On Goingelectric it was assumed that one of the three ICAS high performance computers in the VW ID. 3 was intended exclusively for driver assistance systems, and that driving at Level 3 might be possible (Musikhattu, 2018). However, the sensors are probably not sufficient for semi-autonomous driving functions such as those in a Tesla Model 3. The ID.3 does offer functions such as a lane departure warning system or an emergency brake assistant with pedestrian detection, but rather no autonomous driving functions (electrive.net, 2019b).

5 Build Your Dreams (BYD)

China was the world's largest market for electric cars in 2018 and 2019, with almost one million battery electric cars sold in each year. In 2019, a further 232,000 plug-in hybrids (PHEVs) were added to the 972,000 BEVs (Kane, 2020). The private company BYD holds the highest market share of 19% in the Chinese market for electric cars, 94% of sales of which are generated by Chinese companies (Müller & Schenk Müller, 2018). In second and third place are the state-owned SAIC with 14% and BAIC with 13% (Kane, 2020).

For this case study, BYD was chosen as the market leader. In the comparative case study, the company is also of particular interest as it entered the automotive manufacturing sector in 2003, the year Tesla was founded, and shows similar entrepreneurial dynamism.

5.1 The development of the company

After its foundation in 1995, BYD produced rechargeable nickel-cadmium batteries (Kasperk et al., 2011). In 1997, BYD started the production of lithium-ion batteries and became the main supplier of Motorola in 2000 and Nokia in 2002 (BYD, 2011). In January 2003, BYD acquired Tsinchuan Automobile Company Limited (BYD, 2011) order to obtain a license for automotive production (Kasperk et al., 2011). BYD was new to the car business, but proved to be able to learn quickly. In April 2005 the production of a BYD limousine called F3 started (BYD, 2011) and already in 2006 a prototype of the F3e with lithium iron phosphate battery was successfully produced (BYD, 2011). In quick succession, factories and branches were established in other countries. In Europe, sales offices were opened in Denmark and Hungary in 2006 and in Romania in 2007 (BYD, 2011). In 2008 BYD started the production of solar batteries and introduced the 'F3 Dual Mode', the first plug-in hybrid to the market (BYD, 2011). In May 2009, the BYD e6 was presented to the public for the first time and BYD agreed to cooperate with Volkswagen focusing on batteries and electric vehicles (BYD, 2011). In just one year, BYD's car sales rose from around 170,000 in 2008 to around 450,000 in 2009 (Demandt, 2020a), establishing BYD as a mid-sized manufacturer. Since 2009, sales have fluctuated steadily around 500,000 cars each year (Demandt, 2020a).

In 2010, an agreement was reached with Daimler to jointly produce electric cars for the Chinese market and the company *Shenzhen BYD Daimler New Technology Co, Ltd. was* founded, which markets cars under the name 'Denza' ((BYD, 2011). The brand sold its first 132 cars in 2014. Sales rose to 4,685 in 2017 and fell back to 2,089 cars by 2019 (Demandt, 2020b). The sales figures indicate that the joint venture has so far been of no high commercial significance either for Daimler or for BYD, but is a strategic project for the future.

In 2010, the K9 was also the first battery electric bus to be produced. The BYD e6 received approval in the Netherlands in 2010 (BYD, 2011). In 2011, testing of the K9 electric bus began in Shenzhen and Changsha (BYD, 2011). In 2013 a factory for lithium iron phosphate batteries was opened in the USA (Masiero et al., 2016).

The initially slow and, as of July 2019, significant reduction in Chinese subsidies for BEV also affected BYD. In May 2020, BYD announced that it would start expanding into Europe, initially into Norway (Page, 2020). BYD currently has 229,000 employees and a turnover of $17.6 billion (Forbes, 2020a).

5.2 Background and framework conditions

The promotion of R&D for the key technologies of electric cars began in China as early as the period of the 8th Five-Year Plan (1991-1995) and continued under the 9th Five-Year Plan (Tyfield et al. 2014). The Chinese government had recognised that the Chinese automotive industry could not keep up with the competition from abroad, which was focused on combustion technology. By changing to electric propulsion, the government saw a chance to reduce this gap in know-how and, if possible, even to turn it into a lead by leapfrogging (Sun 2012). The comparatively low rate of motorisation in China is an advantage, as the mass market is not yet committed to the combustion engine in the long term (Beigang & Clausen, 2017).

The long-term policy to promote electric propulsion began to have a significant impact on sales figures for the first time in 2014. While the number of BEVs sold had risen slowly and steadily to 14,604 in 2013 by that time, it rose to 45,048 in 2014, 247,482 in 2015, 409,000 in 2016, 652,000 in 2017 and reached a peak in 2018 with 984,000 for the time being. In 2019, 972,000 BEV were sold (Kane, 2020).

The momentum in sales was driven by a number of purchase incentives and other measures by the national and local governments (Masiero et al. 2016, S. 8). By combining different programmes, the volume of support for BEV was up to a maximum of 120,000 CNY (approx. 16,000 euros). In many cases these subsidies made up a large share of the vehicle price, which for many vehicles is between 100,000 and 220,000 CNY (approx. 13,500 - 30,000 euros) (Fulton et al. 2012, p. 11). At the same time, considerable investments have been made in charging infrastructures since 2012 (Beigang/Clausen 2017, p. 12).

In addition to financial support, regulatory law also plays a decisive role. In some Chinese cities there are so-called number plate lotteries or auctions, from which BEV were partially exempted. So instead of having to hope for registration for years, the purchase of a BEV was a way to get a registered car quickly (Müller & Schenk Müller, 2018). The Chinese government also decided in 2017 to introduce nationwide green number plates for New Energy Vehicles (NEVs), which will give car owners various advantages (Müller & Schenk Müller, 2018).

In mid-2019 it was announced that the high subsidies for BEVs would be significantly reduced, but at the same time all local authorities would be prohibited from applying the quota system for new registrations to new energy vehicles in future (electrive.net, 2019a). Similar to Norway, China is thus reducing those subsidies that are a heavy burden on the state treasury in favour of a subsidy policy that works on the basis of regulatory law.

5.3 The founding team and its environment

Wang Chuan-Fu was born in 1966 in a farming village in one of the poorest provinces of China. His parents died when he was young, and he was raised by his older brother and sister (Forbes, 2020c). Wang Chuan-Fu made the leap to the Central South University of Technology and continued his studies at the Beijing Non-Ferrous Research Institute (Bloomberg, 2020), where he received training in battery technology (Forbes, 2020c). In February 1995, Wang Chuan-Fu and his cousin Lu Xiangyang founded Build Your Dreams (BYD) in Shenzhen, China (BYD, 2011; Forbes, 2020c). Lu had previously worked as a banker and built up an investment company parallel to BYD (Forbes, 2020d). Wang, a chemist, raised about $300,000 from relatives and started producing rechargeable batteries with 20 employees (Masiero et al. 2016). BYD moved to a larger facility in September and employed 300 people (BYD, 2011). Wang is a member of the Chinese Communist Party and has been on the Forbes Rich Peoples List since 2012 (Bloomberg, 2020). Currently, Forbes estimates his assets at $7.1 billion (Forbes, 2020c), that of cousin Lu Xiangyang at $4.5 billion (Forbes, 2020d).

Wang's entrepreneurial skills were also evident in the Corona crisis. In January 2020, he set up a working group of 3,000 engineers and technicians to design and build new production lines for manufacturing face masks and hand disinfectants (BYD Care, 2020). Today, the Shenzhen-based electric vehicle manufacturer claims to be the world's largest producer of surgical masks, producing 5 million units a day (Fortune, 2020).

5.4 Investors

Wang Chuan-Fu and other family members were the first equity investors in the company (Masiero et al. 2016). Little is known about other sources of financing of BYD. The only financing round documented in the financial portal Crunchbase (2016) was a post-IPO equity round on 18 July 2016. Samsung Electronics participated with $450 million. Further proceeds were generated through the issue of shares. In 2002, BYD went public on the Hong Kong Stock Exchange (BYD, 2011). The shares are now distributed among the founders as well as institutional investors and the general public. The founder Wang Chuan-Fu holds 18.83% of the issued share capital, his cousin Lu Xiangyang 14.73%. and BYD Director Xia Zuo-quan 3.72%. The three directors of the company together hold 37.28% of the share capital (BYD 2020, p. 42). As external investors, Warren Buffett's Berkshire Hathaway holds 8.25%, Youngy Investment 5.96%, LL Group 2.76% and Citigroup 1.93% (BYD 2020, p. 42).

BYD is involved in numerous companies that offer R&D, service, financing or leasing in the field of 'New Energy Vehicles' (BYD 2020, p. 116ff). Particularly striking is the participation in Shenzhen Denza New Energy Automotive Co, Ltd, which BYD owns jointly with Daimler and in which, despite very low production figures, joint investments were again made in 2019 (IT Times, 2019). In 2010 Denza introduced a large SUV, the Denza X. A possible goal of this joint venture could be to establish the Mercedes luxury class in China under a local name (Zipser, 2019). In 2019, Denza also acquired a stake in BYD Toyota EV Technology Co, Ltd, which also aims to develop electric cars for the Chinese market (Hebermehl, 2020).

5.5 Strategy and objectives

BYD's initial strategy was clearly to win the cost competition. Wang Chuan-Fu replaced the machines commonly used in other countries with labour that was very cheap in China, thus achieving lower production costs than the international competition (Kasperk/Wilhelm/Wagner 2011, p. 10). In doing so, he did not follow the 'Western' established companies but followed an explicitly Chinese path (Wang/Kimble 2010 p. 77, p. 83).

Through a strong fragmentation of work processes, BYD achieved a very simplified work processes. In addition, the strategy of vertical integration was specifically pursued. By 2011, BYD had acquired a total of almost 200 companies in order to be able to rely increasingly on internal strengths and synergies (Kasperk/Wilhelm/Wagner 2011, p. 10). The internal development of production processes also enjoys a high priority. For example, two thirds of all engineers for battery technology at BYD work on the design of processes (Kasperk/Wilhelm/Wagner 2011, p. 10). In 2008, BYD generated 30% of its turnover with IT, 25% with automobiles and 23% with batteries. It was already Wang's goal at that time to be the largest car manufacturer in China in 2015 and to become the world market leader in 2025 (Kasperk/Wilhelm/Wagner 2011, p. 10). Zheng et al. (2013) describe the elements of the BYD strategy in very similar terms.

In 2015 BYD presented the 7+4+1 market strategy (BYD, 2015). It consisted of successively electrifying all means of transport that currently dependent on fossil fuels. The 7 refers to road transport (taxis, private cars, city and interurban buses, refuse collection vehicles, freight logistics and construction logistics). The 4 refers to off-road environments (ports, warehouses, mining and airports). The 1 stands for towing vehicles such as articulated lorries.

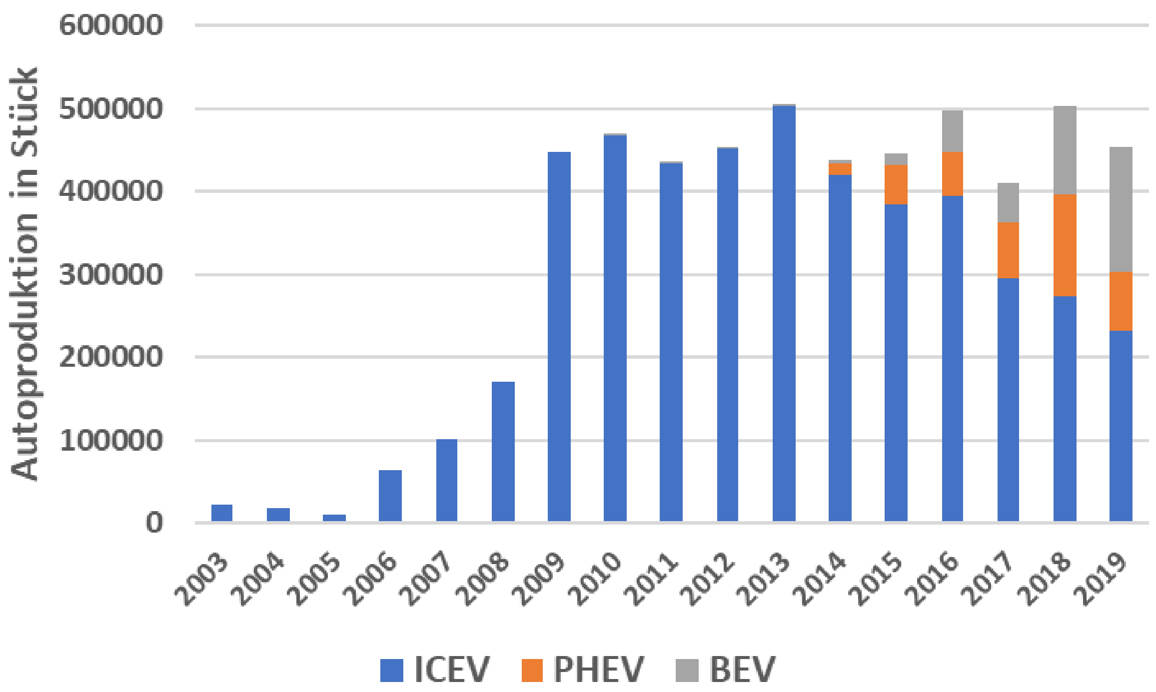
After BYD 2019 has become the largest manufacturer of BEV in China with the strategy described above (Kane, 2020) it seems that currently the company shows signs of a slight strategy adjustment: namely the promotion of exports. As late as 2019 Kane (2019) reported export figures of 543 buses, 50 trucks and 100 forklift trucks. In relation to almost 230,000 BEVs and PHEVs produced, these are extremely low figures, which Kane justifies by the fact that until mid-2019 the considerable domestic demand could hardly be satisfied. However, now that the major cuts in subsidy policy described above have been made in mid-2019 (Müller & Schenk Müller, 2018) assumed that not only BYD will focus more strongly on exports to open up further growth opportunities. Several authors currently report that BYD is preparing to enter the European market (Leichsenring, 2020; Page, 2020).

5.6 Products and production figures

In the first three years after BYD acquired Tsinchuan Automobile Company Limited and renamed it BYD Auto Company Limited, the company produced only small quantities of internal combustion engine cars and in 2006 produced a first electric prototype. After 2005, when only 1,000 cars were produced, sales rose rapidly to 448,000 internal combustion engine cars in 2009. After policies to promote new energy vehicles in China took effect in 2013 (Beigang & Clausen, 2017), BYD increasingly sold PHEVs and BEVs. In 2019 sales of BEVs and PHEVs then reached almost half of BYD's production.

Sales of vehicles with internal combustion engines have been declining continuously since 2013. Car sales (all engines) accounted for 49% of BYD's turnover in 2019 (BYD, 2020, S. 3).

Figure 78: Annual production from BYD of PHEV, BEV and internal combustion engine vehicles (ICEV)



Source: Figures up to 2009 Demandt (2020), figures from 2010 BYD (Y. Xie, persönliche Kommunikation, 13. Oktober 2020)

BYD seems to want to compete with Tesla with the latest product from BYD, the BYD Han. Like the Tesla Model 3, the car is offered with two-wheel and four-wheel drive and has an equivalent range of 610 km according to the New European Driving Cycle (NEDC) (Leichsenring, 2020). Similar to the Tesla Autopilot, the 'DiPilot' assistance system will enable partially autonomous driving (Leichsenring, 2020).

Together with the Chinese driving service provider Didi, BYD recently presented the D1, optically virtually a Chinese Volkswagen ID.3 (Handelsblatt, 2020). The car is primarily intended to be brokered to Didi drivers. It will soon go into production and 100,000 copies are planned for 2021 (Handelsblatt, 2020).

Even the first prototype of BYD's electric car, the BYD e6, was not equipped with a classic lithium-ion battery, but with a lithium-iron-phosphate battery. Masiero et al. also point out in 2016 that the BYD electric cars are equipped with lithium-iron-phosphate batteries (Masiero et al., 2016, S. 7). For 2020 BYD has announced an eightfold increase in the production of a new type of its lithium iron phosphate (LFP) battery to a capacity of 11 GHW per year (L. Zheng & Lu, 2020). The battery type, which BYD calls a 'blade battery', is cheaper to manufacture and can withstand higher temperatures than conventional lithium batteries. Tesla also equips its Shanghai-built Model 3 sedans with LFP batteries (L. Zheng & Lu, 2020). BYD will also sell its batteries to other vehicle manufacturers in the future, thus competing with the largest Chinese manufacturer CATL (L. Zheng & Lu, 2020). Auto-Motor-Sport writes about the new type of battery to be marketed by the new BYD company FinDreams (Auto-Motor-Sport, 2020b)

> *In tests the battery was fired upon with nails. According to BYD, a conventional lithium battery would have reached temperatures in excess of 500 degrees Celsius under this stress. The "blade battery" only heated up to 30 to 60 degrees.*

The apparently very rapid expansion of capacity to produce the new safe and cheap batteries, as well as higher quality electric cars, suggests that BYD could embark on a rapid expansion course in Europe in the coming years.

5.7 Sales and procurement markets

For several years until 2019, BYD was the largest manufacturer of BEV in China (Kane, 2020). There was hardly any export due to the strong domestic demand. As late as 2019, Kane (2019) reported very low export figures of 543 buses, 50 trucks and 100 forklift trucks, an extremely low figure in relation to almost 230,000 BEVs and PHEVs produced. However, several authors report in spring 2020 that BYD is now preparing to enter the European market (Leichsenring, 2020; Page, 2020).

The structure of BYD's procurement markets differs significantly from those of European car manufacturers. For example, BYD is characterised by a very pronounced vertical integration and thus by a low overall volume of supplies. More than 70% of value creation takes place within the company, which is very unusual in an industry where typically more than two thirds of value creation is with external suppliers (Kasperk et al., 2011; H. Wang & Kimble, 2010, S. 77). The great vertical integration of production together with the strategy of using cheap human labour instead of machines leads to a very high level of employment. BYD has a turnover of $17.6 billion with 229,000 employees (Forbes, 2020a), Tesla employs 48,000 people and has a turnover of $26 billion (Forbes, 2020b).

Not much is known about suppliers. The Chinese company Shenzhen Kedali Industry supplies parts for battery construction (Flannery, 2017). In 2018 BYD held its first ever suppliers' conference at its plant in Hungary, attended by over 100 suppliers (Supply Chain Movement, 2018). The aim of the meeting was to develop local supply to the European factories and to establish R&D partnerships with suppliers.

5.8 Working conditions and trade unions

The high share of value creation within the own company, in connection with the 'people not machines' strategy, apparently requires significant efforts in personnel management and leadership. Several scientific studies describe the personnel policy extremely positively. For example, in order to be able to attract and retain highly qualified employees, BYD has developed an ambitious education and training system for all levels of the organisation. Wang and Kimble report on a comprehensive social welfare system within the company, which is deliberately based on the social, cultural and political environment of the Chinese economy (H. Wang & Kimble, 2010, S. 85). The founder Wang Chuan-Fu is said to have once claimed (H. Wang & Kimble, 2010, S. 85)

BYD not only builds products, it is also good at building people, converting university graduates into engineering teams. BYD recruits several thousands of graduates, because we know the manufacturing of cars starts with manufacturing of talent, then equipment, then cars.

Wages and salaries at BYD are said to be above average locally, but Wang and Kimble (2010, S. 86) also report that workers complain about the high workload, for example, in 2010 they had a 12-hour day and only two days off per month. In order to keep the employees, BYD has set up its own education system (kindergartens, schools and vocational schools) and provides the employees with cheap dormitories or flats. There are also canteens, grocery shops and sports and recreation complexes for the employees (H. Wang & Kimble, 2010).

In addition to these positive voices, there is also a 2011 report by China Labor Watch, an organisation founded in New York in 2000 to defend workers' rights in China. In this report, China Labor Watch describes a number of problems based on data collected between August 2009 and March 2010 (China Labor Watch, 2011). The overall poor working conditions are directly linked by China Labor Watch to the cost strategy of BYD (China Labor Watch, 2011). To give an overview, the Management Summary is reproduced here in full:

Recruitment and Resignation: The Baolong campus seeks primarily to recruit female workers; male workers can often only gain employment by offering bribes. At the Pingshan and Dayawan campuses there is discrimination against pregnant applicants as well as candidates with scars or tattoos. At the Baolong campus, rules state that workers who resign after working at BYD for less than 3 months or voluntarily resign can never be rehired at BYD again in the future. The Dayawan campus prohibits workers who resign after less than one month or voluntarily resign from being rehired. The Dayawan campus requires workers to pay for a physical examination during the recruitment process. Although BYD's resignation procedure complies with its legislation, through our investigation, workers on the Pingshan and Dayawan campuses found it extremely difficult to resign during the busy season at the factory. In general, they could only resign through a process that takes up to a month longer than its regulations suggest and require.
Wages and Benefits: The base wage at each of the three factories looked at in this investigation was found to be 1,320 RMB. The three factories pay the local minimum wage, but this salary still does not meet workers' demands for a living wage (See Section Three). As a result, at each of the three factories, overtime is a necessary part of nearly every workday. Managers at the Huizhou Campus generally do not approve leave requests. All interviewed workers reported that although they receive a pay stub each month, they are not clear about how wages are actually calculated. As a result, few workers can check to ensure that the salaries they are paid are calculated correctly and have to accept whatever amount they are paid. Base wages at the Pingshan Campus are divided into 26 levels. Workers must be employed at the factory for at least six months before they can be promoted. Some workers, even after working at the factory for many years, never get promoted. Other workers report that receiving a promotion is very difficult. They can only gain a promotion through guanxi, i.e. having connections with someone higher-up in the factory.
Working Hours: Because orders usually need to be finished shortly after they are received, during the peak season, workers often receive less than three days off, and sometimes none at all, depending on the production speed of the worker. At the Baolong campus, workers work for 144 hours of overtime per month on average. Monthly working hours thus reach 320 total hours. During the peak season, workers might work consecutively for 14 days.
Workers at Pingshan and Huizhou campuses must attend a 15-20 minute pre-shift meeting before they start working everyday. The time spent at the meeting is not calculated into a worker's paycheck. Workers at the Pingshan campus are not paid for their statutory holiday overtime. Workers at the Baolong campus factory must carry an "off-post card" to go to the bathroom or drink water. Each drinking or bathroom break must not exceed 10 minutes. Workers at the Dayawan campus must have someone replace them before they take a bathroom or drinking break. Under these conditions, breaks must not exceed 15 minutes.
Work Intensity: Workers at the stamping workshop line at the Pingshan campus must finish a 3,000 piece production quota each day. 30 workers work three shifts a day, and each worker must work a minimum of 8 hours a day. In order to fulfill this quota, they must finish each piece in 30 seconds or less. Workers at the Huizhou campus sometimes are required to work from 12:30 to 6:00 without any break.

Health and Safety: There have been few serious injuries or accidents in BYD factories. Workers who are in contact with toxic material have no access to a physical examination once they resign. The examination is only provided when they first begin work at the factory. At the Huizhou campus, there were 90 work-related accidents in 2010.
Personal and Sick Leave: The approval process for sick and personal leave at BYD is very strict. It's very hard for workers to get requests approved, and even if a request is approved, the leave is unpaid.
Food and Housing Conditions: Workers at Baolong and Pingshan campuses are provided with free food and accommodation. The value of a month of meals is around 150 RMB. Free accommodation is not provided at the Huizhou campus. Workers are provided with food, but the quality and nutrition level is relatively low. Dormitory environments are acceptable.
Rewards and Punishments: Workers in Baolong and Huizhou campuses may be fined under many conditions. Rewards are seldom given out.
Grievance Mechanisms: Two female workers at the Baolong campus committed suicide in 2009. The trade union did not function appropriately in order to reach out to these two workers and to try to intervene and solve their personal and work-related problems. Workers at the Huizhou campus are not sure about the function and responsibilities of a trade union. BYD's factory hierarchy is very inflexible. The unspoken rule, according to some workers, is that promotions are only granted through guanxi, or connections to higher level employees. Bribery happens frequently and workers have no choice but to follow these practices.

The overall poor working conditions are directly linked by China Labor Watch to BYD's cost strategy. As the company is trying to replace mechanisation with low-paid human labour, it is virtually forced to create the problems described above over and over again. Unless BYD starts to reform this system of producing more goods for less pay, there will be no way to solve BYD's ongoing labour problems (China Labor Watch, 2011).

Both the report by Wang and Kimble (2010), written from a scientific distance, and the study by China Labor Watch are already 10 years old; a period for which significant shifts in both directions are possible for a young dynamic company like BYD.

It is unclear whether and how long BYD will maintain the strategy of "many people, few machines". As early as 2017, BYD and Huawei announced their intention to create a standardised smart factory. Contemporary goals were defined for this purpose:

- Optimisation of production processes for seamless integration of workshops and warehouses,
- Automated production line management to improve the overall production efficiency of the production lines,
- Traceable production data throughout the entire process, thus realising transparency of the production process (Huawei, 2017).

Together with Siemens, BYD 2020 announces a further comprehensive digitisation offensive in development and production. BYD plans to introduce the Siemens Xcelerator portfolio including NX™ software for computer-aided design, Siemens Teamcenter® software as a PLM (Product Lifecycle Management) platform and Simcenter™ software for simulation and testing (Siemens, 2020). To create seamless communication between the digital product and digital production with Industry 4.0, it is also planned to work with the "digital twin" (Siemens, 2020).

5.9 Impact on markets and competitors

The impact of BYD on sales markets and competitors is difficult to assess in view of the fact that there is little competition in the US or Europe. Two aspects could be relevant:

Should the lithium iron phosphate battery prevail over the classic lithium-ion batteries due to its low cost, this could change the whole industry of battery manufacturers and significantly strengthen the relative position of BYD. It seems more likely, however, that both types of battery will coexist for some time. In addition, it is expected that in the next few years more batteries with different characteristics (safety, raw materials, fast charging capability, capacity per weight) will be introduced to the market. It is therefore difficult to predict further developments. However, it seems clear that the market will have to deal with different types of batteries in the future.

The market entry of BYD in Europe will have a clear impact on the sales market. However, the Daimler-BYD joint venture Denza, in which joint investments were again made in 2019 (IT Times, 2019) will not play a role in this, but it seems to be aimed more at establishing the Mercedes luxury class in China under a local name. An example of this is the new Denza X, a very large SUV based on a Daimler model. Also interesting in this context is the recently agreed cooperation between BYD and Toyota, which also aims at producing cars for the Chinese market (Hebermehl, 2020)**.** As far as it can be observed, BYD is therefore aiming to enter the European market initially with its own products such as the BYD Han and not with products of the cooperating companies. This market entry will in all likelihood also have a significant impact on the European market because it will not take place alone. The Chinese company Geely has already taken over Volvo in 2013 (Reuters, 2020a) and started marketing the Polestar luxury class vehicle in Europe in autumn 2020. Geely already produces 2 million vehicles per year and is currently developing, together with Volvo, standardised vehicle platforms for small and medium-sized vehicles, with which a large number of models can be developed quickly and produced at low cost due to economies of scale (Reuters, 2020a). Together with Daimler, Geely will also produce the Smart in China in the future (Zipser, 2019). The MG brand has also been in Chinese hands since 2007 and is now part of SAIC. SAIC and MG are currently preparing to enter the European market with a focus on England and Austria. Among other things, a mid-range electric station wagon from the SAIC range is to be offered in Europe (Conrad, 2020). In addition, SAIC Volkswagen will start production of electric vehicles based on Volkswagen's MEB modular electric kit in autumn of 2020 at the newly built Anting plant and at a second plant in Foshan (Volkswagen AG, 2019):

> *At the same time as the plant in Anting, it is planned to start production of ID. models in another FAW-Volkswagen plant in Foshan, resulting in a total capacity of 600,000 units per year.*

However, Volkswagen is also following the strategy of highly automated Industry 4.0 production in China. "Among other things, more than 1,400 4.0 industrial robots are to be used, as well as technologies with a focus on AI, AR and VR" (Volkswagen AG, 2019). Also, Tesla already produces in its highly automated Gigafactory in Shanghai. Particularly with regards to the fact that sales figures in the Chinese car market have not been rising as strongly in recent years, it can ultimately be assumed that China will increasingly enter the global export business and that cars produced in China will be sold and driven in Europe under various names. BYD, with its strategy of little automated production, relies on other advantages than most of its competitors. It remains to be seen which strategy will prove to be more successful.

6 Sono Motors

"We believe in mobility independent of oil. We believe in a future where every car will be electric and shared" (Sono Motors, 2020e).

In addition to the two companies from Silicon Valley (Tesla and Waymo) and the Chinese company BYD, the present study deliberately also aims to shed light on a German start-up. In the summer of 2020, since the company Streetscooter is currently being closed down by Deutsche Post, only two young companies will be relevant: the start-up eGo-Mobile AG, founded by Günther Schuh, who also founded Streetscooter, and Sono Motors GmbH. The companies are distinguished from each other by clear differences. While eGo-Mobile AG is an Industry 4.0 start-up founded from the RWTH Aachen University, Sono Motors is based on the ideals of a (ultimately anti-capitalist) sustainable economy. Due to its radical transparency, its almost cooperative structure and the extensive financing by its future customers, Sono Motors stands out - also internationally. In the following, the young company will therefore be analysed in the context of this case study.

6.1 Background and framework conditions

Sono Motors was founded in the early 2010s, the time of the black-yellow coalition, when Philipp Rösler (FDP) was Minister of Economics and Peter Altmeyer (CDU) Minister of the Environment. Although numerous reports by the Intergovernmental Panel on Climate Change (IPCC) had made young people aware of the climate crisis, confidence in policies appropriate to the climate crisis was low.

With regard to the start-up environment, above-average physical infrastructure and public funding in Germany is reported (Sternberg et al., 2015), but social values and norms regarding entrepreneurship and start-ups at this time are seen as rather negative. In addition, school-based and - to a lesser extent - out-of-school start-up education was still very weak and of limited quality (Sternberg et al., 2015). Finally, the financing offers for start-ups showed clear weaknesses with regard to environmental innovations and investment in high-risk basic innovations. The financing volumes were also relatively low (Borderstep Institut, 2014).

The idea of setting up an automotive company during this period can, with some plausibility, be judged as not very promising. In 2016, Elon Musk formulated, after all, 13 years after the founding of Tesla and after more than 100,000 cars sold: *"Starting a car company is idiotic and an electric car company is idiocy squared"* (Musk, 2016). So, what kind of people in this period of time have let themselves be carried away by the idea of trying the impossible?

6.2 The founding team and its environment

Laurin Hahn and Jona Christians were in the graduation class of the Rudolf-Steiner School Munich Schwabing (Elaine, 2018) when they started their project 'electric car' in 2012. Waldorf student Laurin Hahn reports: *"There were hardly any electric cars on the German market. Jona and I wanted to know why it was taking so long and simply tried it ourselves"* (Visser, 2017). Initially the two of them fiddled around in their parents' garage for three years (Das Goetheanum, 2020; Elaine, 2018). *"We then started studying, on the side. But we already had other foundations to finance the project"* (Visser, 2017). Laurin and Jona kept their project secret for a long time. In three years they managed to develop the first prototypes. Then they were joined by Navina Pernsteiner, who studied communication design and lived with Laurin in a shared flat (Future Woman, 2018). She was enthusiastic about the idea of building an electric car and on 16th January 2016 this three-person team founded Sono Motors.

The team then directly implemented an idea from Navina: a crowd-funding campaign for financing. The idea behind it: *"Then we will know immediately whether people even want a solar car"* (Future Woman, 2018).

The composition of the founding team and its competencies was therefore comparatively unusual. While in the founding teams of German start-ups more than eight out of ten founders have a university degree (19% Bachelor's, 20% diploma, 31% Master's and 14% doctorate) (Kollmann et al., 2020), at Sono Motors this applied to only one founder. While 85% of the founders with an academic degree have studied either a MINT or an economics subject (Kollmann et al., 2020), the Sono founder Navina represented the 2% of German start-up founders with an artistic degree. None of the team members had any significant work experience or networks in the mobility sector. A fact that did not prevent it from recording successes that are extremely rare in this form in Germany.

Over the past three years, the core team has also been significantly strengthened in terms of initial gaps in skills, experience and networks. Katja Tschakert joined the team in 2018. Since then, she has been heading business development with her experience in the international PV industry and climate protection. Mathieu Baudrit, an experienced PV specialist, has also been in charge of solar integration since 2018. Since 2019, the MIT graduate and former employee of Drive Now Henrik Mitsch has also been managing Mobility IT Services.

6.3 Investors

Little is known about the financing of the project before 2015. The real story of Sono Motors' financing starts with the crowdfunding campaign on the Indiegogo platform proposed by Navina in 2016. The campaign ended on 5th September 2016 and generated a capital of €549,995, subscribed by 1,686 people. Sono Motors' website indicates that the total subscribed capital for this first round of financing was approximately €1 million, to which, in addition to crowdfunding, friends and family contributed (Sono Motors, 2020b). Another €1.5 million was invested by a business angel (Sono Motors, 2020b).

Another crowdfunding campaign on the Seedrs platform already started in 2017. The target was one million €. The campaign generated €1,846,676, which was subscribed by 1,022 people (Seedrs, 2017). The company was already valued at € 59 million at that time (Seedrs, 2017; Sono Motors, 2020b). A second campaign on Seedrs in 2018 generated €5,771,903, subscribed by 762 people (Seedrs, 2018). At the end of 2018, the value of the company was already estimated at € 110 million (Seedrs, 2018; Sono Motors, 2020b).

For further financing, due to the high sums required in the double and triple-digit million range, classic investors were sought that fit the company's objectives and culture. However, this search proved to be difficult. Two of the founders describe the dilemma as follows (Sono Motors, 2019))

> *"In recent months, we have repeatedly found that our goals are completely at odds with those of traditional financial investors," says Laurin Hahn, CEO and co-founder of Sono Motors. "Aggressive growth and fast profits are hardly compatible with a sustainable business and vehicle concept that is designed to provide broad access to affordable and climate-friendly electric mobility. In addition, the provision of venture capital for start-ups with capital-intensive business models does not work in Germany, neither in the early nor in the growth phase. If we had only relied on support measures or the German market environment, Sono Motors would probably not exist in its current form. There is an urgent need for action on the political side. It must be possible to implement such a project for the future in Germany and lead it to economic success. We will continue to fight in any case. For climate-friendly mobility and for our reservation holders," adds Hahn.*

In December 2019, one of the largest campaigns in the history of European crowdfunding began. The campaign was hosted directly on Sono Motors' own website and, after extension, generated investments and down payments of approximately € 53 million from over 10,000 people. Around 75% of the money came from reservation holders, 19% from existing and new investors and around 6% took the form of loans and donations (Sono Motors, 2020h).

Sono says it needs another €205 million to start production. About €70 million of this is to be raised in the form of outside capital, i.e. through bank loans, subsidies or private loans. Once the first serial prototypes have been produced, the company also plans to attract additional buyers and thereby collect down payments for reservations (Sono Motors, 2020b). On its website, Sono Motors also reports on negotiations with potential investors who share Sono Motors' values and goals and want to enter on Sono's terms.

6.4 Strategy and objectives

The company's vision is formulated on the website as follows (Sono Motors, 2020g):

> *We believe in mobility independent of oil. We believe in a future where every car will be electric and shared. From this vision the company Sono Motors was born in 2016. Today, an experienced team of engineers, designers, technicians and industry experts is developing and building a forward-looking electric car with integrated solar cells and innovative mobility services, suitable for everyday use.*
>
> *We must stop wasting the resources of our planet. CO_2 emissions must be reduced. That's why we make sustainable mobility easy and affordable for everyone. For you. For future generations.*

On the question of how Sono Motors envisages traffic in the cities of the future, Laurin comments as follows in an interview (Visser, 2017)

Obviously, it is all about sharing. Individual traffic will be pushed back more and more simply because there is less and less space. That is a very simple calculation. The car only has a future if it is used more efficiently. That is why we are integrating three different mobility services in the Sion from the very beginning, which are combined in our Gosono app: car sharing, ridesharing and power sharing

Power sharing' is Sono's idea to install a type 2 plug and a shockproof socket next to the charging socket in the front cover of the Sono. The Sono's battery can then be used as a source of energy when travelling. A charging cable can also be used to jump start other electric cars that have broken down.

The most important goal for the current year 2020 is to complete and present the two new near-series prototypes and generate further orders (and thus capital) through numerous test drives (Sono Motors, 2020i). The prototypes will be built at Roding Automobile GmbH in Roding, Bavaria (Sono Motors, 2020i). Series production of the Sion will take place in Sweden in a former Saab factory at the Trollhättan site (Donath, 2019).

Sono Motors does not aim to build its own car plants in the foreseeable future (Sono Motors, 2020i). Sono sees itself strategically at the digital interface between cars and customers, as well as in design, construction and marketing; but not in its own production.

6.5 Products and production figures

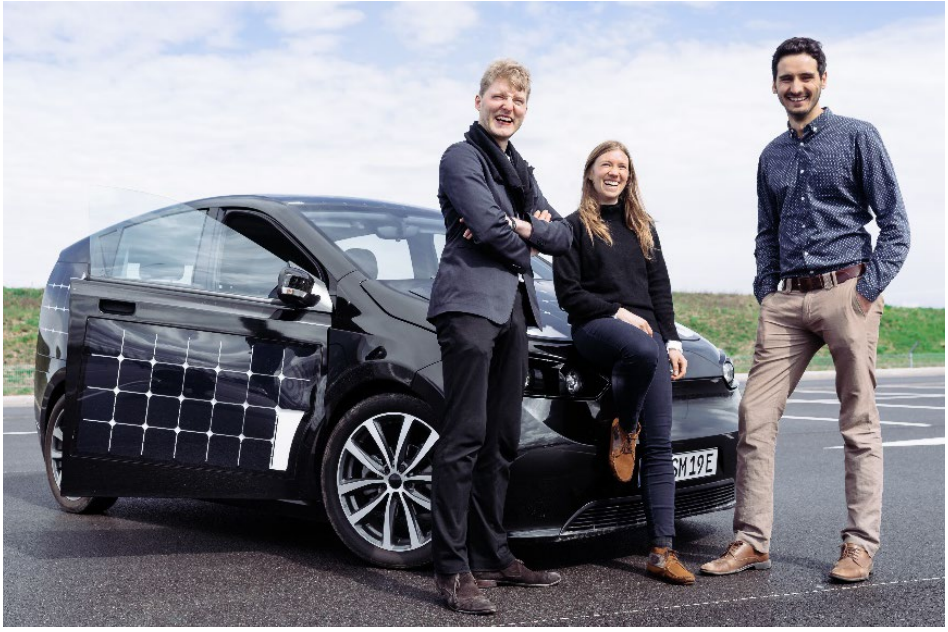
Sono Motors GmbH intends to start series production of its first model, the Sion, in autumn 2021.

The Sion will be a spacious electric car with a range of up to 250 kilometres, with 6 m^2 of solar cells mounted on its body, which will at least partially charge itself when the sun shines.

The Sion is equipped with a 35 kWh lithium-ion battery, which provides a range of 255 km according to the WLTP cycle[4]. In addition, depending on the weather conditions, there is an additional 'solar range' of up to 34 km daily. So if the Sion is only used for short journeys every day, e.g. for the average commuting distance of up to 15 km, the vehicle can theoretically be used from April to September without the need for a charging station or socket. For the long distance, the charging capacity of 50 kW allows the battery to be recharged to 80% in about 30 minutes.

[4] Worldwide Light-Duty Vehicles Test Procedure: A measurement based on real driving data.

Figure 9: Jonas, Navina and Laurin, the core founding team of Sono Motors, in front of the Sion



Source: Sono Motors

The maintenance concept from Sono Motors is original and innovative. First of all, it is based on the fact that owners can solve mechanical problems themselves. To this end, the development deliberately focuses on a simple design (Sono Motors, 2020c). In addition, the disclosure of the workshop manual enables repairs to be carried out in independent workshops. For repairs in the high-voltage and bodywork area, the company plans to cooperate with a well-known, but yet unnamed, service provider from Europe (Sono Motors, 2020c).

Sono Motors is also taking advantage of 3D printing and open design to improve supply chain sustainability: Selected CAD data are made available online free of charge. These can be printed out and used by vehicle owners and workshops with a 3D printer or by a supplier of CNC Milling. This approach supports better social justice, as it enables value creation even for small players and without geographical restrictions. It can also be assumed that the possibility of actively participating in the product within the framework of Open Design, as well as the direct availability - through 3D printing - of vehicle parts, could lead to a competitive advantage in certain market segments (Beltagui et al., 2020). Those parts that are not (cannot) be made available in this way can be re-ordered and resold by suppliers and workshops without the need to obtain a separate licence.

The planned production site in Trollhättan is currently operated by National Electric Vehicle Sweden (NEVS), a company with a majority Chinese shareholding (Donath, 2019). There, the Sion will be produced exclusively using renewable energies. The originally planned start of production there at the end of 2019 is now scheduled for the end of 2021. Sono Motors has planned to build up a capacity of 43,000 cars per year at NEVS and aims to build 260,000 cars in eight years. With this, Sono Motors plans to become a small but very innovative and sustainability-oriented car manufacturer in the medium term.

6.6 Unique selling points

A clear unique selling point of BYD is the high number of employees and the low machine usage. BYD achieves a turnover of 77,000 $ per employee, Tesla with a significantly lower vertical range of manufacture and the highest degree of automation achieves 520,000 $ per person (Tesla Inc., 2020), Volkswagen approx. 447,000 $ (Volkswagen AG, 2020). Ultimately it remains yet to be determined whether the BYD strategy of a large and cheap labour force in the European market will lead to particularly competitive offers or whether it will just be another way.

Another unique selling point is the lithium-iron-phosphate battery with its low cost, high level of safety and the absence of nickel and cobalt, which is important from both environmental and social criteria. It remains yet unknown how this battery will fare in competition, as well as a comparative assessment of this new type of battery in environmental and social balance sheets.

6.7 Sales and procurement markets

As production of the Sion has not yet started, it cannot yet be considered a market in the traditional sense. On the website 'Siondriver', which is run by supporters, there is a map of the geographical distribution of Sion pre-orders as of 31.1.2019. The map raises the plausible expectation that Sion in Germany could develop as a national car manufacturer, similar to Tesla in the USA and BYD in China.

Figure 10: Map of pre-ordered Sions (as of 31.1.2019)

Source: Siondriver (2019)

When considering the procurement market, it should first of all be noted that Sono Motors does not intend to become a car manufacturer with a high vertical range of manufacture. Rather, almost the entire production is to be outsourced to subcontractors and contract manufacturers. This also affects the design and selection of vehicle components, which Laurin reports on (Visser, 2017):

> *We use as many carry-over parts as possible, i.e. components that have already been developed by suppliers and are freely available on the shelf. We do not have to develop these parts from scratch and they are already approved. German manufacturers define themselves through design. We do not do that. We only redevelop what is unique to us, i.e. the solar panels and our maintenance system, of course, but nothing like the steering wheel or gear lever.*

Sono Motors' procurement strategy, just like that of the regime's established manufacturers, focuses on the use of already developed parts, components or kits. The Sono website mentions a number of supplier cooperations, e.g. a cooperation with Elringklinger on battery systems, with Bosch in the context of Connected Car, with Continental in the field of electric drive systems. The development of structural crash and occupant safety is carried out together with ARRK Engineering, and series production is carried out at National Electric Vehicle Sweden (NEVS) (Rudschies, 2020; Sono Motors, 2020e).

With the aim of keeping CO_2 emissions from production logistics low, the focus is on supplier companies in geographical proximity. The largest part of the Sono value chain is located in Germany and the closer European region (Sono Motors, 2020b).

6.8 Working conditions and trade unions

Sono Motors is committed to good working conditions, high social standards and climate protection within the company and in the supply chain (Sono Motors, 2020b). The geographical distribution of the main suppliers is given in September 2020 as follows (Sono Motors, 2020b):

- Germany: 31 suppliers and 65.5 % of the costs
- Italy: 4 suppliers and 8.6% of costs
- Norway: 1 supplier and 4,5 % of costs
- Turkey: 4 suppliers and 4.2% of costs
- Spain: 4 suppliers and 2.7% of costs
- Sweden: 1 supplier and 2.5% of the costs
- France: 1 supplier and 0.5% of the costs
- Finland: 1 supplier and 0.1% of costs
- Switzerland: 1 supplier and 0.1% of the costs

In total, 87.7% of the costs or the procurement stem from suppliers from the European region and Turkey. Added to this is the final assembly in Sweden, which should further increase the share of value added in Sweden and is most-likely not included in the 2.5 % mentioned above. No reliable statement can be made about the actual working conditions in a company not yet in production. However, the high European share of value added suggests that comparatively high standards can be expected in the area of employee rights and occupational safety.

In the current Sono Motors team, which in contrast to the supply chain is already fully operational and can be viewed as such, we may suspect a start-up typical spirit of optimism, which is also reflected on the Sono website under Career (Sono Motors, 2020f):

Who we are: We are a very colourful mixture of experienced and beginners, German and international experts, tie and hoodie lovers. We are all united by the fact that we thrive for what Sono Motors stands for. And that we want to make the world a little better with our work. And the work of each and every one of us has a major impact on our success.

Our vision: Together we are working to combine a new technology with a new way of thinking - the best of electric mobility, solar energy and shared economy. For ourselves, for our neighbours but above all for our planet. Because it is more pressing than ever!

Our working method: Our premises reflect Sono Motors core values: functional, refurbished, simple, cosy, communicative, green, paperless. We work for example with Google, Slack, Trello. In Munich we are close to the technological pulse, the labour market and the ICE train station, but also to alpine pastures, ski slopes, lake landscapes and the "Munich Wiesn".

Team Spirit: Since our culture often thinks in similar terms, it is easy for us to eat, drink, laugh or do sports together. Therefore, we are all on a first-name basis and communicate with each other openly and without reservation. For us, results count, not presence - we trust in the motivation and performance of the individual and leave a lot of freedom for this - but also nobody alone when things get too much.

Salary: Of course, we are a young company and cannot or do not want to compete with salaries of decades-old car manufacturers. But there is no question that we pay in line with the market, also with regard to the cost of living in Munich. We also have a transparent, fair and structured salary policy that takes into account professional and management experience as well as social circumstances (children, caring for relatives, etc.). And: There is no gap between departments or gender. In addition, every new team member currently has the opportunity to participate in the future success of Sono Motors through our employee participation programme.

Your application might not make much sense if you are more the 9:00 - 17:00 type, define yourself by your salary and title, like to assert your opinion against all odds and environmental aspects are basically unimportant to you.

In its 2019 Sustainability Report, Sono Motors reports on the structure of its workforce, its age distribution, fluctuation and the gender pay gap (5% in favour of male employees) (Sono Motors, 2020a). Independent sources about the work at Sono Motors could not be identified.

6.9 Unique selling propositions

The Sion from Sono Motors has various characteristics that are completely new for electric cars and therefore very innovative for the business. The first and central unique selling point is certainly the **solar integration**, i.e. the embedding of solar cells not only in the roof, but also in the rear door, doors, wings and bonnet (Michael, 2020). Sono Motors emphasises that the polymer coating of the solar cells does not splinter and that the modules are built in this way are very light, which is very important in vehicle construction (Sono Motors, 2020d). A total of 6 m^2 of solar modules are used. Over the course of the year they should be able to provide up to 5,800 km of 'solar range'. Sono Motors gives the theoretical distribution of this solar range over the year as follows (Sono Motors, 2020d):

Figure 11: Reach forecast for daily solar range based on meteorological data for Munich

Source: Sono Motors (2020d), Grey: Cloudy sky, Green: Average, Black: Clear sky

However, not only a new technology for integrating the cells into the body parts was developed, but also the necessary control electronics. The company calls this device 'MPPT Central Unit'. MPPT stands for Maximum Power Point Tracking (Michael, 2020) term commonly used in photovoltaics. Development partner was the company Tecnalia from Bilbao (Spain). The device ensures that the charging electronics switch on when it gets light in the morning, prevents overcharging and switches off the charging electronics again when darkness falls.

Another unique feature among electric cars is **power sharing**. For this, Sono Motors installs a type 2 plug and a shockproof socket in the front bonnet of the Sion in addition to the charging socket. The Sion's battery can thus also be used as an energy source.

The third innovative unique selling point is of organisational or digital nature and aims at the **digital sharing of vehicles and electricity**: *"With the Sion and its integrated goSono App. With just a few clicks, you've given up your electricity, offered a ride or shared your Sion. This makes sharing easy and hassle-free"* (Sono Motors, 2020c). Sono Motors is therefore focusing on an app with which carpools can be offered or the car can be rented as a car-sharing vehicle. Electricity can also be supplied. It is unlikely that this third feature will still have a unique selling point when series production starts - at least for car-sharing and ride-sharing. Firstly, Elon Musk has already announced the sharing feature in the second part of his Master Plan in 2016: *"Enable your car to make money for you when you aren't using it"* (Musk, 2016). On the other hand, any car and its seats can participate in ridesharing or private car sharing via relevant apps anyway.

The bottom line is that solar integration and power sharing remain as clear hardware-based unique selling points.

6.10 Impact on the car industry

Considering that Sono Motors is by far the youngest of the start-ups considered in this study, its influence on the automotive industry is still small and statements about a possible influence are ultimately of a speculative nature.

However, it seems likely that at least solar integration could prove to be a pioneering technology. The approx. 30 km of solar range provided in the summer months corresponds almost exactly to the distance that the average car in Germany travels each day. Under certain circumstances, many short-distance commuters may be able to drive for more than five full months without refuelling, but also without charging. Not only in Germany, but especially in southern countries, this feature could become a central sales argument. Especially up to the 40th degree of latitude, the daily solar range should be sufficient for vehicles used over short distances almost all year round. Consequently, solar integration is already being integrated into the Dutch 'Lightyear One', a rather high-priced car that is currently under development (Lightyear, 2020).

The value of power sharing has yet to be established. The examples of use listed by Sono all seem to be aimed at rather small target groups:

- The supply of electricity to the grid and battery of a building that is not connected to the electricity grid is aimed at the very small target group of people who own such a building that is not connected to the electricity grid.
- The electricity levy for camping purposes is aimed only at the presumably small group of travellers who neither stay overnight at campsites (with electricity connection) nor use a motor home (usually equipped with a battery).
- The supply of electricity to equipment and machinery for work in off-grid locations is certainly of interest to certain groups in agriculture, forestry or craft industries, especially as the operation of petrol-driven generators is very expensive.
- Ultimately, although power-sharing is very useful for other people's electric vehicles that have run out of electricity, it does not benefit the owner of a Sion himself. Moreover, it is uncertain how many vehicles with flat batteries will actually break down in the age of numerous digital support services.
- Ultimately, it remains to be seen how big and in what areas Sono Motors will influence the automotive industry. However, the company's extraordinary history suggests that it is developing a range of products and services that customer groups have previously missed in the car market and therefore wish to support financially, even taking into account the riskiness of the investment.

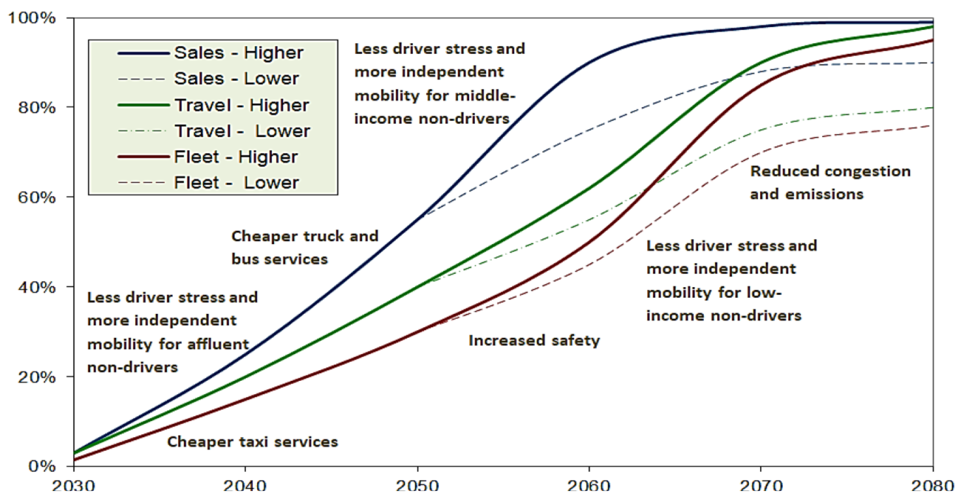
7 Conclusion

7.1 Impact of autonomous driving on the car industry

It should be noted that the concept of autonomous driving combines a large number of different degrees of automation, which require a differentiated consideration. The current data situation does not yet allow such an examination satisfactorily. However, existing empirical studies as well as the self-reported findings of Tesla (2020) autonomous driving has a rather positive effect on society (especially with regard to road safety and congestion) and on the natural environment (e.g. through reduced fuel consumption and air pollution). These assumptions need to be tested by sound scientific monitoring of further developments.

At this stage it is largely unclear when a larger number of systems for autonomous driving will be installed in cars. A Canadian study (Litman, 2020) based on a market introduction of fully autonomous vehicles (Level 5) around the year 2030, predicts a gradually increasing share of the car population, which would cover the total population around the year 2080.

Figure 12: Expected share of autonomous Level 5 vehicles in sales, travel and fleet



Source: Litman (2020, S. 28)

Another 'Technology Roadmap for Autonomous Driving' (funded by the Hans Böckler Foundation), on the other hand, assumes that it can be realised even later: Level 4 from 2045 and Level 5 from 2050 (Roos & Siegmann, 2020).

In addition to the maturity of the software, autonomous driving also requires a vehicle fleet equipped with the correct and powerful hardware (computers, sensors). Governments around the world must also be influenced to grant the appropriate permits. At this stage, it is only certain that these conditions are not yet met.

The situation is different with semi-autonomous driving. In certain traffic situations, such as on the motorway, it is already possible to drive virtually automatically with lane keeping, brake assist and cruise control. Further possibilities exist on private property. For example, Volkswagen works councils expect driverless forklifts or the ability to drive ready-assembled cars out of the hall and into the car park on their own (H. de Vries & C. Sprute, persönliche Kommunikation, 3. September 2020). Furthermore, it would be conceivable that cars could drive onto transport ships by themselves, such as those used for exports to the USA. These functions alone would result in the loss of numerous jobs at the Volkswagen plant in Emden (H. de Vries & C. Sprute, persönliche Kommunikation, 3. September 2020).

In addition to the question as to when which vehicles will be able to drive partially or fully autonomously in which traffic situations, a second question is important: Which combination of software and hardware will win the race in the R&D phase. Will it be Waymo's software with its lidar systems, which has so far been developed mainly through simulations and rather small test fleets, or will the Tesla solution based on cameras, ultrasonic sensors and radar with its permanent practical test in hundreds of thousands of customer vehicles and lower costs (O'Kane, 2018) prevail? This question has not been answered yet either. Apart from all the technical arguments, the decision here could ultimately depend on which system statistically generates the lower accident rate. It is hardly possible to make predictions here.

7.2 China as a new actor of transformation

Not only BYD, but also many other Chinese car manufacturers are working on scaling up the production of electric vehicles. ICT giants and tech start-ups have also been active in China for several years and are increasingly involved in the automotive industry. The Chinese internet company Tencent already has a stake in Tesla since spring 2017 (Riecke, 2017). Tencent was also an early investor in the electric car start-up NextEV (now NIO), which also has a US headquarters in Silicon Valley. The solvent company Tencent also invested in Didi Chuxing, the world's second largest ride sharing company after Uber, and in Lyft, Uber's rival in the US (Boyden, 2017).

With Alibaba and Huawei, two other ICT technology giants from China show ambitions to enter the automotive industry as part of the transformation to electric and digitalised vehicles (Liao, 2020). Alibaba and SAIC were already investing jointly in internet-enabled cars in 2015. Since then, Alibaba has developed the Banma platform, which enables many things from voice-activated navigation to voice-controlled coffee orders and is connected to the Alipay e-wallet. At the end of 2020, SAIC launched a new electric vehicle branch called Zhiji, in which Alibaba is a minority shareholder (Liao, 2020).

The networking of ICT giants in China with the new car industry is also evident in the car company Xpeng, founded in 2014. Among the first supporters were He Xiaopeng, founder of UCWeb and formerly employed by Alibaba, and Lei Jun, founder of Xiaomi. Alibaba, Xiaomi and Foxconn all contributed to the financing of Xpeng, and in 2018 Alibaba's Vice President Joseph Tsai joined the Xpeng board of directors (Lin, 2018; Reuters, 2018). Xiaomi, a fast growing smartphone manufacturer founded in 2010, has also invested in BYD Semiconductor to expand its automotive components business (Sean, 2020).

And Huawei is also becoming active at present, but does not want to produce its own cars, but will concentrate on developing ICT for the automotive industry (Liao, 2020).

Foxconn, known for its partnership with Apple, seems to pursue a different strategy. Foxconn has already announced its intention to invest in a production facility for electric cars (White, 2014). Foxconn was already producing a lithium-ion battery for the BAIC E150 EV at that time and has also worked with Tesla on the development of its touch screen panels (White, 2014). Currently, the contract manufacturer plans to produce a range of components for electric vehicles and to establish itself as a system supplier. Foxconn's electromobility offensive will focus on an electric car platform called MIH, which includes battery and vehicle internet services for third parties (Randall, 2020). Foxconn has already agreed on a cooperation with FIAT-Chrysler in early 2020 to produce electric and Internet-connected cars in China. Foxconn also aims to supply parts for 3 million electric cars in 2027 and thus participate in 10% of the expected electric car market (Reuters, 2020b).

Some actors rely on rapid progress of autonomous driving. The Shanghai start-up Neolix is currently starting to produce fully autonomous small delivery vehicles for the customer Huawei for use in simple and clearly arranged locations such as industrial parks or residential areas (The Brake Report, 2020).

Overall, the information does not allow a clear conclusion to be drawn, but rather represents a cloud on the horizon. The fact that China is increasingly on a par with the West in terms of technology is repeatedly evident again, and the government's strategy of introducing competition in the automotive sector not in the old technologies of combustion engines but in electromobility (Beigang & Clausen, 2017) is having a visible effect. With the Polestar and the BMW iX3, two of the first electric cars, which were produced in China, have arrived in Europe. The E-Smart will soon follow, which will be produced by Geely. Others will follow. Behind the manufacturers is a huge technical-industrial complex with enormous capital strength, whose ability to scale up marketable products can hardly be overestimated. Moreover, the strength of China's large Internet and ICT companies should not be underestimated. Highly digitised products of the Chinese car manufacturers from the Chinese industrial complex can be expected. The central open question will be how quickly Chinese companies can successfully market large quantities in Europe under their own brand names (e.g. BYD) or under European names (e.g. Volvo or MG).

Whether and, if so, how quickly the possibilities of digitisation will have an impact on the use of the car as an autonomous vehicle or in ride sharing or car sharing is as difficult for Chinese providers to predict as it is for European or American providers - including Tesla.

7.3 Influence of the start-ups Waymo, BYD and Sono Motors on the car industry

While Tesla is currently in a phase where the company is acting as a gamechanger, the influence of the three companies focused on in the three case studies presented here is far more uncertain.

The study shows that Waymo will not develop into an automotive OEM, but rather into a supplier of hardware and software components for autonomous driving. However, it is largely unclear when fully autonomous driving will become significantly more widespread in the vehicle population, as was shown in section 6.1. This means that the question of when and how Waymo will affect the car industry can at best be speculated on at the present point.

The situation is similar with BYD. Although the figure 7 clearly shows that the car manufacturer BYD is rapidly focusing on electromobility, its impact on the European industry is unclear. Today, BYD is at best a medium-sized company in China, as well as worldwide, with a production volume of about half a million vehicles per year. Its impact on the industry in terms of volume will be limited until additional factories are opened. The announced export of the new top-of-the-range 'BYD Han' model to Europe is difficult to assess in terms of its market-changing impact. As far as we know, no Chinese company has yet managed to sell large numbers of cars in Europe under its own brand name. Whether BYD, of all companies, will succeed in doing so can hardly be answered ex ante. Also, the price of BYD Han in Germany has not yet become known.

The BYD lithium-iron-phosphate battery technology, with its low cost, high level of safety and the absence of nickel and cobalt, which is important from an environmental and social point of view, could be different. But how this battery will really perform in competition remains yet to be determined, as does a comparative assessment of this new type of battery in environmental and social balance sheets.

The last company to remain is Sono Motors from Munich. Sono is focusing on solar integration and power sharing, but is also taking a new approach with regard to the social aspects of production. Sono Motors is committed to good working conditions, high social standards and climate protection within the company and in the supply chain (Sono Motors, 2020b). The geographical distribution of the main suppliers focuses on Central Europe (Sono Motors, 2020b). Especially from a trade union perspective, Sono Motors could be a ray of hope in the environment of globalised capitalism. But even here, uncertainty still dominates today. The difficulties of the production hell that Tesla has gone through are still ahead of Sono Motors. And the question of whether solar integration and social responsibility in the supply chain outside a small niche will prove to be sales-promoting arguments cannot be answered ex-ante.

Ultimately, the three start-ups Waymo, BYD and Sono Motors have one thing in common: they each represent forces that could change the automotive industry. Waymo stands for the possibilities of digitalisation, BYD for Chinese export strength and Sono Motors for an ecological-social new approach to corporate responsibility. In all three cases, not only the size but also the timing of a relevant impact on the car industry is unclear. But these start-ups are still important. They show that 'change is possible'. Observing start-ups like these is likely to be important for OEMs and trade unions alike, so that they can properly assess the future of the industry. The example of Tesla has shown where it leads to, to dismiss them only as candidates for bankruptcy.

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The automotive industry in Germany has been established for decades. New suppliers have hardly played a role since Volkswagen entered the market after the Second World War. This is currently changing. Not only Tesla is building a new factory in Brandenburg for up to 2 million vehicles a year, but also some Chinese manufacturers such as Geely/Volvo, SAIC/MG and BYD are on the verge of entering the European market. Against this background, it seems necessary, particularly with regard to the topics of electromobility and digitalisation, not only to observe the diffusion of these innovations in the large car factories, but also to take a look at the niche players who are increasingly making their way into the market.