European Commission

Study on the Electronics Ecosystem

OVERVIEW, DEVELOPMENTS AND EUROPE'S POSITION IN THE WORLD

Annex 3

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CARSA

Digital Single Market

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Decision SARL

This study was written by Olivier Coulon (DECISION), John K. Olliver (DECISION), Guy Dubois (DECISION), Léo Saint-Martin (DECISION) and Marc Vodovar (DECISION).

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Overview

i. Important methodology remarks

- The automotive figures presented in the following automotive report corresponds to a “large acceptation” of automotive electronics. Indeed:
    - The “turnover” figures correspond to the price of the electronic sub-systems sold by the automakers to the customers. Therefore, this turnover includes the turnover of automotive electronics generated by the automakers (including their margin). Contrary to the calculation methodology of the other end-user reports, it does not only correspond to the price of the automotive electronics sub-systems sold by electronics suppliers (Bosch, etc.);
    - The “employment” figures correspond to the sum of the automotive electronics employees at every step of the automotive electronics value chain (automakers + automotive electronics tier 1, 2 and 3 suppliers + automotive semiconductors suppliers). In the other end-user reports of this study, the “employment” figures (mostly measured by the Eurostat SBS industry database), correspond to the equivalent of the employees of the automotive electronics tier 1 suppliers only (excluding automakers, automotive tier 2 & 3 suppliers and automotive semiconductors suppliers).

- As a consequence, in order to be more precise in the measure of the global electronic equipment production and to ease the comparison between the different segments, the figures corresponding to “Automotive electronics” presented in the pyramids and in the overviews have been adapted to feat the methodology of Eurostat used in the other end-user segments. This is the reason why:
    - In 2017, the estimated world production of automotive electronics in this automotive report is 530 B €;
    - In 2017, the estimated world production of automotive electronics used in the pyramids and in the electronics equipments comparisons is 306 B €.

ii. Segment characteristics

Market Size

Automotive electronics production represented 306 billion euros in 2017[1], that is **16% of the world electronic production**[2]. In other words, Automotive is the fourth global electronic market in 2017 **after telecommunication (€ 405 M, 21%), industrial (€ 383 M, 20%) and data processing (€ 379 M, 19%).**

Growth

Automotive electronics production registered a strong compound annual growth rate (CAGR) within the 2012-2017 period compared to the other electronics applications (Audio-Video, Home appliances, Data processing, Telecommunications, Aerospace/Defence/Security, Industrial/Medical), with a CAGR of 6%. Automotive electronics benefited from the third highest CAGR after Health & Care (10% CAGR), and the industrial segment (7.6% CAGR).

Furthermore, automotive electronics production is expected to register the highest CAGR within the **2017-2022** period compared to the other electronics applications, with an estimated **CAGR of 10%**[3].

As a consequence, automotive is expected to represent € 493 B by 2022 and to outreach the telecommunication and the PC & data processing segments by 2022-2025.

The global automotive electronics production is driven by two main factors:

- The world automotive production in unit, driven by emerging markets, benefits from significant growth with an estimated average annual growth rate of more than 3% over the 2017-2022 period;

- The average percentage of electronics in the added value of an automotive will also benefits from high growth over the period 2017-2022 (5% CAGR). Its main driver will be Advanced Driving Assistance Systems (ADAS) but also Infotainment and the main beneficiaries of this growth will be embedded software developers.

Automotive IC is the end-user application that is growing the fastest with 13.4% compound annual growth rate over the period 2016-2021. Although automotive IC sales only represent 7.7% of total IC sales in 2017 (far less than computer, communications and consumer applications), this market is expected to account for nearly 10% of total IC sales in 2021, which would make it the third-largest end-use application for ICs, slightly ahead of the consumer segment.

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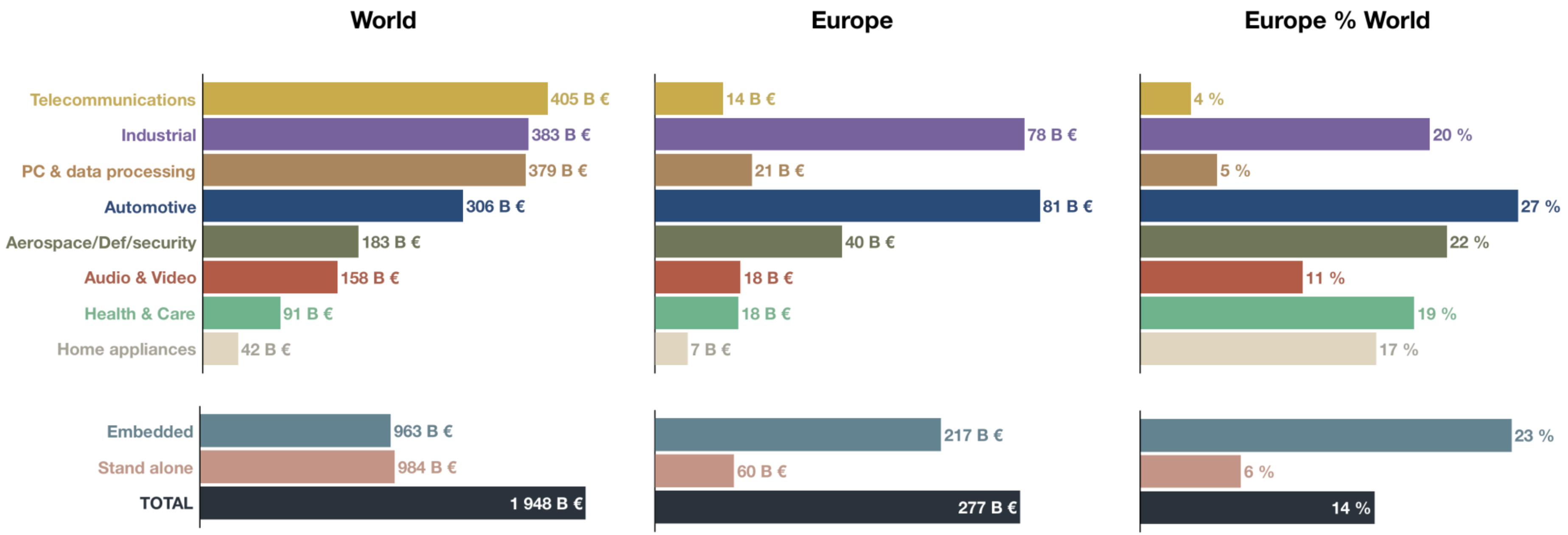
[2] DECISION Études & Conseil
[3] DECISION Études & Conseil, IC Insights

Electronic equipment production by segment in 2017 (M €)



Source: DECISION Etudes & Conseil

iii. Employees, turnover and key indicators in the EU

Automotive

In 2017, the automotive industry provided between 2 and 2.5 million jobs and generated 371 B € in the EU. 80% of the growth in this industry is expected to occur outside the EU but will benefit to the EU's actors.

In 2017, the automotive services provided between 5.5 million jobs and generated 572 B € in the EU.

In other words, the EU automotive sector (industry and services) contributes directly to almost 6,5% of the EU's GDP.

Automotive electronics

In 2017, the automotive electronics sector provided 1 162 000 jobs and generated a turnover of € 145 B in the EU. In other words, the EU automotive electronics sector contributes directly to 1% of the EU's GDP.

- In 2017, the automotive electronics sector provided 307 000 high skilled jobs in engineering offices, R&D offices and headquarters. These skilled jobs generated a turnover of € 55 B in the EU;

- In 2017, the automotive electronics sector provided 855 000 jobs in factories. These jobs generated a turnover of € 91 B in the EU;

- The European automotive IC consumption represented € 9 B in 2018.

Table – 2017 – Automotive Electronics – EU key indicators

	Eurostat SBS industry database - 2015	DECISION - 2017
Turnover (€M)	34 400	**145 500**
Number of employees	238 408	**1 162 000**
Added value at factor costs (€M)	7 900	**38 505**
Net investment in tangible assets (€M)	1 300	**6 336**

Source: DECISION Études & Conseil

iv. The EU's position in the world

A. Key message

The EU automotive sector is very strong. Yet, the EU automotive electronics sector is even stronger, not only in terms of high value-added activities (engineering, R&D, etc.), but also in terms of factory production.

In 2017, Automotive electronics is the first electronics end-user segment in Europe, ahead of the industrial segment and the Aerospace/Defence/Security segment.

B. GDP

The European Union's GDP was estimated to be **€ 15.35 trillion** (nominal) in 2018, representing **22% of global economy** (nominal global GDP).

C. Automotive production

In 2017, **20% of the cars produced globally are assembled in the European Union**, which makes the European Union the second vehicle assembly region at the global scale after China (29%) and before North America (18%). Furthermore, the EU car assembly compound annual growth rate in the 2012-2017 period (3%), is equal to the global car assembly growth during the same period (3,2%). Such automotive assembly in the EU is a major factor of development of automotive electronics in the EU because for supply chain management purpose, carmakers prefer suppliers who produce close to the car assembly locations.

In 2016, **35% of the motors produced globally were made by firms whose principal shareholders were headquartered in an EU Member state**, which makes the European Union the first region at the global scale regarding that criterion before Japan (23%), the North America (15%) and China (12%). The annual growth of these EU producers in 2016 was in line with the global growth of the automotive production (respectively 4% and 5%).

D. Automotive electronics production

In 2017, **28% of the global automotive electronics turnover was generated in the EU**. The same year, 26% of the of the people employed in automotive electronics at the global scale were located in the EU. In other words, the EU is the first region at the global scale in automotive electronics production (hardware and software), both in terms of turnover and employment, before China (18%) and North America (18%).

- In 2017, **the EU automotive electronics turnover generated by office activities (engineering offices and headquarters), accounted for 33% of the global automotive electronics turnover from office activities**. In other words, in 2017, the EU was the first region in terms of automotive electronics office activities (hardware and software), before North America (18%). The same year, 32% of the global employees in automotive electronics engineering offices and headquarters were located in the EU in 2017. The EU is therefore very well positioned in terms of skilled jobs, engineering and R&D activities in automotive electronics;

- In 2017, **the EU automotive electronics turnover generated by factories, accounted for 25% of the global automotive electronics turnover**. In other words, in 2017, the EU was the first region in terms of automotive electronics turnover generated by factories (hardware only), before China (21%). The same year, 24% of the global employees in automotive electronics factories were located in the EU. The EU is therefore very well positioned not only in terms of skilled jobs, engineering and R&D activities in automotive electronics, but also in terms of production from factories;

The estimated EU CAGR 2017-2022 in terms of automotive electronics is 8,5%, slightly below the global average CAGR of 10%. China's production is expected to reach the equivalent of 90% of EU's production in 2022.

In 2017, **40% of the automotive electronics turnover was generated by firms whose principal shareholders were headquartered in an EU member state**, which makes the European Union by far the first region at the global scale regarding that criterion before Japan (24%) and North America (16%). In comparison, in 2017, 39% of the automotive electronics turnover was generated by firms whose principal shareholders were headquartered in Asia (China, Japan and other Asia & Pacific), less than in the EU.

E. Automotive semiconductor production & consumption

Asia-Pacific first passed Europe to become the largest total automotive IC market in 2015. It is forecast to hold a 37% share in 2021, up from an expected 35% share in 2017. The Asia-Pacific automotive IC market is forecast to be 20% larger than that of Europe in 2021;

From 2016 to 2021, although all geographic regions are forecast to enjoy strong automotive IC sales growth, Europe will experience the smallest growth with a 12.5% compound annual growth rate.

In 2017, **28% of the automotive IC turnover was generated by firms whose principal shareholders were headquartered in an EU member state**, which makes the European Union the first region at the global scale regarding that criterion before Japan (24%), North America (21%) and China (16%).

There is a dichotomy between advanced technologies (MPU / MCU), and older technologies in Europe.

- **In terms of production of older technologies, the EU remain well positioned** in particular thanks to the size and the growth of the industrial, automotive and aeronautics/defense/security end-user segments.

- **On the contrary, advanced technologies are no longer manufactured in Europe** (except for the design and for a few very specific advanced technologies), so that Europe will soon become dependent of Asia regarding these technologies (leading to sovereign risks, climatic risks like earthquake, etc.). This dependence should impact the automotive segment within the following decade. Indeed, automotive quality standards are very high, leading to the quasi-systematic adoption of old technologies that have been proven reliable. As a consequence, it traditionally lasts a decade between the production of an IC new technology and its large-scale integration into automotives.

  The manufacture of advanced technologies is leaving the EU because of the lack of public investment to support the manufacture of such technologies compared the US and Asia (in particular China).

  Yet, in terms of capital ownership, the EU players are still well positioned on advanced technologies: Infineon, STMicroelectronics, NXP and XFab. As a consequence, the middle-term risk only concerns the production of advanced technologies in Europe but do not concerns the know-how (patents, skilled-jobs, design, etc.).

Automotive will be impacted by this phenomenon through every new application that involves advanced technologies (ADAS in the first place). Yet, power electronics do not involve advanced technologies and represent a great part of automotive electronics.

v. Four leaders at the global scale

- In 2017 at the global scale, the automotive electronics production was clearly dominated by four countries: China (18% market shares), the USA (13% market shares), Japan (12% market shares), and Germany (10% market shares). Their cumulated turnover accounted for 53% of the global turnover in 2017;

- The automotive electronics turnovers generated by each of these four countries are quite similar in 2017. Indeed, German's automotive electronics turnover (the fourth country) represented 56% of China's automotive electronics turnover (the first country) in 2017;

- The other countries are quite negligible in comparison with those four leaders. Indeed, India's automotive electronics turnover (the fifth country) represented only 3.2% of the global automotive electronics turnover in 2017;

- For already more than 10 years, China is the first country in terms of automotive electronics at the global scale. In 2017, China's turnover represented 18% of the global turnover and almost 20% of the people employed in the world in automotive electronics. China is the first country in terms of automotive electronics factory production, but China is also the fourth country in terms of automotive electronics engineering, R&D and supporting function with 12,3% market shares against 17,4% for the first country (Japan).

vi. The predominance of Germany in the EU

In 2017 and for decades, the EU automotive electronics production have clearly been dominated by one country: Germany. Germany's turnover in automotive electronics accounted for 37% of the EU total turnover in 2017. Besides, 32% of the people employed in the EU automotive electronics industry in 2017 were located in Germany.

- In 2017, in terms of engineering offices, R&D offices and supporting functions, Germany's turnover in automotive electronics accounted for 49% of the EU turnover and 43% of the jobs within the EU;

- Furthermore, for decades, Germany's policy consists in outsourcing low-cost jobs dedicated to automotive production in a few east European countries (Poland, Czech Republic, Slovakia, Austria and Hungary), in order to rise its competitiveness, the profitability of its companies and its ability to export. Germany benefits not only from its geographic proximity with these countries, but also from the high similarities in terms of languages and culture. As a result of this strategy, Germany and its hinterland (Poland, Czech Republic, Slovakia, Austria and Hungary), accounted in 2017 for 56% of the EU's total automotive electronics turnover (€ 50 988 M) and for 53% of EU's total automotive electronics jobs (with 428 736 jobs) in terms of factory production;

- France is the second EU country in terms of automotive electronics. Yet, France's turnover in automotive electronics only accounted for 22% of Germany's turnover and 8% of the EU total turnover in automotive electronics in 2017.

vii. The will of China to take the lead at every step of the global value chain

As presented in the figures below, Chinese carmakers and automotive electronics suppliers are already key players at the global scale.

In its plan named "Made in China 2025", China clearly announced its willingness not only to maintain and develop its position of automotive electronics manufacturing superpower, but also to take the lead at every step of the global value chain.

In order to achieve this ambitious goal, China exploit every opportunity:

- First, China uses its huge domestic market to set up Chinese leaders in every industrial segment. Indeed, this huge domestic market enables incredibly high scale-economies. Once the Chinese government reserved a great proportion of its domestic market shares to a specific Chinese company, such a company automatically benefits from the required scale-economies to become a global leader in its segment. Among the policy tools used by the Chinese government to protect its domestic companies, there are:
    - The prohibition for any foreign company to buy more than 50% of the shares of a Chinese company;
    - The Chinese government is very proactive in terms of regulations to fight against pollution (including CO_2 and NOx emissions). Yet, the Chinese government usually provides the technical specifications of such new regulations to foreign producers only 3 months before their entry into force. The Chinese government provides the technical specifications to Chinese producers significantly earlier in order to give them competitive advantages.
- Second, China uses the power of attraction of its huge domestic market to set up joint ventures in China with as many foreign companies as possible. Indeed, since 1994, foreign group moving to China must to form joint ventures in which they cannot hold more than 50% of the shares, the other 50% being hold by Chinese shareholders. This legal structure has many advantages for China:
    1. It allows Chinese counterparts to accelerate technology transfers;
    2. It allows Chinese counterparts to impose the set-up of engineering offices, R&D offices and regional headquarters in China;
    3. It leaves the door open for an eventual future redemption of the rest of the shares by Chinese players.
- Third, on every segment, once Chinese players gained sufficient negotiation power at the global scale upward the value chain, they thrive to progressively impose Chinese suppliers at the bottom of the value chain.
- Finally, China is not only implementing strategies to take the lead on the supply chain from the top. China already took the lead on the supply chain from the bottom (raw material production) and is using this leading position as an asset. In September 2017, the European Commission published "the 2017 list of Critical Raw Materials for the EU"[4]. This document insisted on the fact that:" China is the most influential country in terms of global supply of majority of critical raw materials, such as rare earth elements,

[4] Communication from the commission to the European Parliament, the Council, the European Economic and Social Committee and the committee of the regions on the 2017 list of Critical Raw Materials for the EU, Brussels, 13.9.2017, COM (2017) 490 final.

magnesium, tungsten, antimony, gallium and germanium among others (…) The risks associated with the concentration of production are in many cases compounded by low substitution and low recycling rates." A great amount of such critical raw materials is essential in the automotive electronics industry and China uses its monopoly position to sell some resources up to 20% more expensive to its foreign customers. To the extent that the USA filed a complaint in 2016 before the World Trade Organization (WTO), accusing China of "disadvantaging US producers". In addition, since the early 2000s, Beijing has reduced exports of various materials, such as molybdenum, fluorine, magnesium or yellow phosphorus. These maneuvers place Western manufacturers in a dilemma: should the production tools be maintained permanently in their current locations, with the associated risk of shortages coming from China? Or is it necessary to relocate to China in order to benefit from unlimited access to raw materials? Cheap labor from inland areas, the low cost of capital - driven in part by a policy of devaluation of the yuan - and the strong potential of the Chinese market have already convinced many of them to relocate to China.

In other words, China combines three elements to take the lead of the global automotive electronics supply chain:

- Key positions at the bottom of the supply chain thanks to materials and equipments manufacturing;
- Key positions at the top of the supply chain thanks to its huge domestic market;
- Smart and very proactive industrial policies.

China is particularly proactive in terms of electric battery production. In 2015, the "Made in China 2025" plan made automotive electric battery itself an industrial priority. China is expected to produce 80% of commercial batteries sold in the world by 2020. The aim of China is not only to sell batteries to the world but to use its position of world leader in terms of electric battery production to progressively become the world leader in terms R&D, engineering and production of electric vehicle. Among the 10 world first producers of battery electric vehicles (BEV), 6 are already Chinese: BYD, Shanghai Automotive Industry Corporation (SAIC), Dongfeng Motor Corporation, Geely, FAW Group and Beijing Automotive Industry Holding Co. Brussels announced October 11, 2017 the creation of a European Battery Alliance to counter the Chinese lead.

Chinese figures at every step of the value chain

- **Automotive**
  - In 2017, **29% of the cars produced globally were assembled in China**, which makes China the first country at the global scale in terms of car assembly location before the USA (12%);
  - In 2016, **12% of the motors produced globally were made by firms whose principal shareholders were headquartered in China**, which makes China the fifth country at the global scale regarding that criterion after Japan (23%), Germany (16%), the USA (15%) and France (14%) but before South Korea (8%). Furthermore, those figures do not consider the mandatory joint ventures for foreign companies investing in China. Finally, China is the country with the highest growth in terms of automotive capital ownership.

- **Automotive electronics**
  - In 2017, **18% of the global automotive electronics turnover was generated in China**. The same year, 19% of the of the people employed in automotive electronics at the global scale were located in China. In other words, China is the first country at the global scale in automotive electronics production (hardware and software), before the USA (13%);
  - In 2017, **the Chinese automotive electronics turnover generated by factories accounted for 21% of the global automotive electronics turnover**. In other words, in 2017, China was the first country in terms of automotive electronics turnover generated by factories (hardware only), before the USA (13%);
  - In 2017, **the Chinese automotive electronics turnover generated by office activities (engineering offices and headquarters), accounted for 12% of the global automotive electronics turnover from office activities**. In other words, in 2017, the China was already the fourth region in terms of automotive electronics office activities (hardware and software), after Japan (17%), Germany (16%) and the USA (14%), but well above France (3.6%);
  - The estimated Chinese CAGR 2017-2022 in terms of automotive electronics is 14.2%, significantly above the global average CAGR of 10%. China should therefore remain the first country of the world in terms of automotive electronics for decades;
  - In 2017, **8% of the automotive electronics turnover was generated by firms whose principal shareholders were headquartered in China**, which makes China already the fourth region at the global scale regarding that criterion after Germany (24%), Japan (24%) and the USA (10%), but before the UK (7.7%) and France (6%). Furthermore, those figures do not consider the mandatory joint ventures for foreign companies investing in China. Finally, China is the country with the highest growth in terms of automotive electronics capital ownership.

- **Automotive semiconductor production & consumption**
  - In 2017, **16% of the automotive IC turnover was generated by firms whose principal shareholders were headquartered in China**, which makes China the third country at the global scale regarding that criterion after Japan (24%) and the USA (17%);
  - From 2016 to 2021, although all geographic regions are forecast to enjoy strong automotive IC sales growth, China will experience the highest growth with a **compound annual growth rate of more than 14.5%**.

viii. The attempts of the United States to tackle Chinese' rise

The USA was until recently the world leader in terms of automotive electronics. The USA remains the first competitor of China with 13% of the global production of automotive electronics.

For a few years now, the United States has become aware of the threat that represent the invasion of China at every step of the automotive electronic value chain. The trade reforms undertaken by Mr. Trump since early 2019 are a consequence of this awareness. A list of 5 745 Chinese products (including a large share of electronic products), has been set up by the USA. It represents an amount of $ 200 B dollars to compare with the total amount of the USA' importations: $ 505 B in 2017. These products will be taxed at a rate of 10% until January 1st, 2019. Thereafter, tax rates should rise up to 25%. The USA is adopting the same policy as the one set-up in the 1980s by Ronald Reagan towards Japan that was at that time on its way to become the first country in the world (in terms of GDP). The USA successfully imposed drastic raises of tax rates (up to 100%), on a large number of Japanese products (mainly electronic products: cameras, camcorders, etc.). Under the current American pressure, the Chinese government already proposed several concessions, among which the possibility for foreign companies to hold more than 50% of the shares of a Chinese company (proposal made in May 2019).

ix. EU - Policy recommendations

A. Policy recommendations to support the MNE ecosystem

If the EU is to preserve its market shares and the markets shares of its players, in particular from the rise of China, the EU needs in the first place to put the state (that is the national states and the EU commission) back above the markets and the private companies (domestic and foreign). It means that the EU strategy needs to be developed and set up with the willingness to ensure a long-term positive development (not only economic, but also ecologic and social) for the 28 members states citizens and not only from the point of view of significant private companies, without fear of disturbing private markets (often leaded by foreign companies).

Those are the strategies of the United-States and China. It implies to:

- **Set up a proactive capital-ownership policy**. Such a policy consists in proactively influencing the capital-ownership of domestic and foreign companies in order to protect and enhance the EU's interests with three axes:

    1. Prohibiting when necessary the purchase of EU owned companies by foreign investors. For instance, Wolfspeed (subsidiary of Cree, US owned company), has acquired Infineon AG Radio Frequency (RF) Power Business for approximately € 345 million in March 2018. Yet, in 2016, Infineon thrived to purchase Wolfspeed for $ 850 million but this deal had been prohibited by the USA (through the Committee on Foreign Investment in the United States);

    2. Supporting and/or leading the purchase of foreign companies that have been identified as having key capabilities, know-how and/or patents and that may be complementary with EU owned capabilities, know-how and/or patents. An example of such as strategy has been the attempt of Qualcomm (supported by the USA), to purchase NXP in 2017 and 2018;

    3. When it proves possible, prohibiting the purchase of a foreign company by another foreign company when such a merger would lead to the set-up of a too powerful competitors for EU players. An example of such a strategy has been the political blockage by China of Qualcomm's $44 billion deal for NXP.

- **Being able to enhance smart protectionism to ensure the set-up and/or the maintaining of EU leaders inside the EU market**. With 500 Million wealthy citizens, the size of the EU market is comparable to the size of the Chinese domestic market and the US domestic market. Therefore, the EU has the structural capability to set up the same strategies as China and the USA: that is to use its huge domestic market to set up EU leaders in every industrial segment using smart protectionism rules.

  One of the best examples of smart protectionism tool is the **combined use of standardization, certification and prescription**. Standardization consists in defining a list of technical characteristics regrouped in a "standard". Certification consists in setting up a public authority whose role is to analyze the products of private companies in order to determine if a specific product can be considered as being part of a standard. Finally, prescription consist in imposing to public and/or private organizations the use of products that have been considered has being part of a specific standard by the certification authority. Why can the combined use of standardization, certification and prescription be useful to protect the EU's interests? Because the European players are among the most competitive players of the world in terms of R&D, patents and know-how, but often face difficulties to compete foreign players on the single criteria of the price. Promoting European standards at the forefront of technological innovation and imposing those standards to the European actors is a very efficient way to indirectly provide competitive advantage to the EU providers and thereby to "reserve" the EU market to EU suppliers.

  The use of **contracts to equip public services with EU-owned solutions** is another example of smart protectionism.

- The Chinese example demonstrate the importance of maintaining independent capacities of production and know-how at every step of the value chain in order to remain a key player on any type of electronic segment. The EU should focus on **regaining significant and independent production capacities in particular at the level where the EU is weak: raw materials and SC foundry**.

B. Policy recommendations to support the automotive electronics ecosystem

a. Likely scenario – Following the world trend leaded by China

Over the 2017-2022 period, automotive electronics will benefit from three major drivers of growth: ADAS, Infotainment and electrification of powertrains:

- **ADAS (Advanced Driver Assistance Systems) and Infotainment will be the two main drivers of automotive electronics growth during the 2017-2022 period**. During this period, ADAS will contribute to 30% of automotive electronics growth and Infotainment will contribute to 32% of automotive electronics growth. During the 2022-2030 period, ADAS should become the first automotive electronics' driver of growth;

- In 2014, automotives represented 18% of the global CO_2 emissions. To fight pollution, states are implementing very restrictive pollution emissions standards. Such standards are launching a trend of **electrification of powertrains: in new cars produced, electric batteries are progressively gaining in importance. That electrification of powertrains leads to a slight increase of the electronic contents of cars, but to a very high rise of automotive semiconductors contents and of the automotive electric batteries' market.**

If the EU do not set up a significant proactive public policy, it is likely that the EU private automotive electronics companies will follow these three trends in order to benefit from the related potential growth.

Yet, those trends should lead:

1. To the success of China in its attempt to take the lead on the automotive electronics value chain

- On the one hand the current global automotive electronics market is shifting to China and on the other hand China is demonstrating every day its political capacity to take advantage of its advantageous position. Thus, European manufacturers will thrive to take strong position in the Chinese market, Chinese producers will gradually benefit from technology transfers and Chinese customers will gradually drive European producers out of the Chinese market;

  This phenomenon is already particularly obvious regarding electric vehicles: Among the 10 world first producers of battery electric vehicles (BEV), 6 are already Chinese: BYD, Shanghai Automotive Industry Corporation (SAIC), Dongfeng Motor Corporation, Geely, FAW Group and Beijing Automotive Industry Holding Co.

2. To an ecological disaster

- **More than 90% of ADAS and infotainment systems** answer customers' needs of comfort, that is more embedded entertainment and a less intensive attention paid to the road from the driver. In other words, ADAS and infotainment trends **are absolutely not economically and socially useful**. The only exception concerns connected cars that should strengthen business competitiveness through the enhanced ability to make professional phone calls and audio/video conferences inside cars. Yet, **ADAS and infotainment systems are all very consuming in terms of critical raw materials and very polluting at every step of their production processes**.

- **Battery electric vehicles are not useful to fight climate change**

  The most common argument to promote the ecologic advantage of battery electric vehicles is the diminution of the global oil reserves. Yet, such reserves should still last for more than a hundred year and the development of shale gas rise the potential level of oil supply.

  If battery electric vehicles are indeed useful to reduce oil consumption, such vehicles are absolutely not useful to fight the current global warming. Indeed, the only current economically sustainable solution to develop battery electric vehicles is to associate every sale of BEV[5] with the installation of a fast-charging station at the client's home. A fast-charging station at home combined with the already large BEV ranges (400 km or more), answer nearly all the needs of the owner of a BEV at non-prohibitive cost. Yet, this solution is absolutely not ecologically sustainable. Indeed, fast-charging stations lead to a very high electricity consumption and if all the fat-charging stations are used between 18:00 and 23:00, the electricity consumption peak is going to surge, implying a very great increase of the electricity production infrastructures (nuclear plants, coal-fired plants, etc.).

  Even if the issue of "recharging network" were solved, the sustainable development of BEV would suffer from major boundaries in terms of raw materials and electric battery weight.

  Raw Materials issues

  Although a BEV do not require petrol or diesel to operate, it requires electricity that is often produced through non-ecologic processes. Nuclear plants and coal-fired plants are still the two first mean of electricity production at the global scale. The alternative sources of electricity named "renewable" are also very polluting if the whole life-cycle of the products are considered: the production process of solar panels is very polluting, the production of wind turbines of significant sizes requires rare earth that are very polluting to extract and very difficult to recycle, etc.

  Even if the electricity were sustainably produced, BEV production requires a great amount of non-ecologic raw materials: lithium, cobalt, tungsten, rare earths, etc. An automotive lithium-ion battery requires up to 3.5 kg of rare earths, 10-20 kg of cobalt and up to 60 kg of lithium to be produced. The extraction of such raw materials is very polluting and energy consuming. Inner-Mongolia, the Chinese region specialized in rare earth extraction, is one of the most polluted regions in the world. The main impact of the development of BEV is therefore the delocalization of pollution to some emerging countries rather than the reduction of pollution.

[5] BEV = Battery Electric Vehicles

Finally, a sustainable development of BEV also requires the set-up of a costly electric battery recycling supply chain, which is already not always the case. A great proportion of lead acid batteries are "recycled" in Africa (13% in Nigeria[6]). Yet, a lead acid battery is recyclable only where a supply chain exists to do so and that is not true in Africa. Poor African citizens end-up by exploiting these old batteries until there is nothing left in it. The dead batteries then corrode and pollute the local groundwater, which is what children drink.

Electric battery weight[7]

Because of the current large mass of electric batteries, the rolling mass of a BEV is about 10 to 20% greater than the rolling mass of a thermal vehicle at equal habitability. Yet, a greater rolling mass leads to heavier braking system and running gear to support battery's weight, to the extent that battery electric vehicles are more consuming than thermal vehicles at equal habitability in terms of raw materials.

3. To a great waste of investment in the attempt to reach automotive autonomous level 5

- Today, private companies invest billions of euros throughout the world in the attempt to produce an autonomous vehicle level 5, that is to say a vehicle that would be driven by an artificial intelligence in absolutely any type of situation. It is very important to understand that these **private companies are thriving to produce such a vehicle because they have neither the financial strength nor the economic incentives to change not only the automotive itself but the complete automotive transport infrastructure network (that is automotive + road networks)**. For instance, if Renault were to invest to build new types of roads in France, that investment would be very costly but above all every competitors of Renault would take profits of the new roads built by Renault. Therefore, only a state may have both the financial capability and the interest to build a new transport infrastructure network. Such a level of investment dedicated to the production of an uncertain autonomous vehicle level 5 is therefore explained by this market failure.

  Indeed, autonomous vehicle level 5 is neither economically sustainable nor desirable from a development point of view.

- **Autonomous vehicle level 5 is not economically sustainable**

  In order to operate, an autonomous vehicle level 5 needs to accomplish three types of actions: perceive the obstacles, understanding the situation perceived and the potential willingness of the different obstacles and finally plan the trajectories of the obstacles. The first step is already mastered: a great number of diverse and very efficient sensors can be integrated into cars at low costs and the current deep learning algorithms are efficient to compute the data collected by all the different sensors. Yet, the two other steps -by far the most difficult steps- are absolutely not mastered by today's software developers and no any credible solution is currently foreseen, leading experts to announce the production of the first autonomous vehicle level 5 for after 2040. In other words, there is currently not a single element that can prove that humanity will one day be able to produce an autonomous vehicle level 5. Indeed, achieving the two final steps is by definition almost impossible because it requires to answer the following question: How to enable an artificial intelligence to understand the infinite number of scenarios that can occur on an open environment as a human brain would and to adopt a specific and evolutive strategy to any of these situations? Investing in the development of autonomous vehicle level 5 is incredibly costly with absolutely no proof of success: it is not economically sustainable.

[6] According to Cleantech Hub
[7] "Un Bilan Litigieux", Guillaume Pitron, Le Monde diplomatique, August 2018

- **Autonomous vehicle level 5 is not desirable from a development point of view.**

  A first common argument in favor of autonomous vehicle level 5 is the possibility for the driver to work and or study in his car. Yet, working in car constantly accelerating and decelerating from 0 km/h to 90 km/h, operating 180-degree turns and crossing roundabouts in urban cities is very difficult and not at all desirable. Another common argument in favor of autonomous vehicle is the reduction of the number of people killed on the road. Yet, the number of people killed on the road in the EU has never been so low (25 000 annual death) and is expected to constantly decrease within the coming decade: it is not a public health problem anymore. Finally, the development of autonomous vehicles should lead individuals to spend more time in their autonomous vehicles (these being less restrictive) and should therefore lead to increase the congestion of road traffic.

- **As a consequence, investments made to develop a fully autonomous vehicle are sub-optimal investments that should penalize the EU's long-term development and that would be better allocated elsewhere.**

- **Yet, as enlighten in the table below, all the advantages of a fully autonomous vehicle are maximized with the train (autonomous or not).**

Economic, ecologic and social benefits	Comparison Autonomous vehicle level 5 VS Train
Capability to work during the transport duration	Train > Autonomous vehicle level 5
Traffic congestion during rush hour	Train > Autonomous vehicle level 5
Speed	Train > Autonomous vehicle level 5
Pollution emissions by individual transported	Train > Autonomous vehicle level 5

  A common argument in favor of the autonomous vehicle is the possibility to develop a "mobility as a service", that is business models in which clients do not own the mean of transport but instead pay a rent in order to get access to the mean of transport. Yet, such a "Mobility as a Service" already exist for decades under the old name of "public transport services". Indeed, rail transportation but even bus transport are functioning on the model of "Mobility as a Service" for almost two centuries. As a consequence, the development of public service railway is more efficient than the development of a "Mobility as a Service" operated by individual cars (even autonomous and/or electric).

A cross analysis combining economic, social and ecological aspects therefore leads to the conclusion that ***neither the growth of ADAS and/or Infotainment systems, nor the development of battery electric vehicle, nor the investment made to develop an autonomous vehicle level 5 is desirable for the EU's development.***

b. Desirable scenario – Assuming a voluntarist and independent EU policy

In this scenario, the EU develops an ambitious, proactive and independent public policy in order to shift European and, if possible, global private actors towards another growth model that is more effective in terms of social, ecologic and economic development.

In this scenario, rather than to follow the global trend towards individual battery electric vehicles with autonomous level 5, the EU chose to develop:

1. For journeys between 100 km and 2000-3000 km

- **Developing rail transportation for goods and people**. That is to say prohibiting vehicles for any types of long transportation (ending any type of highway investments) and set up rail network both for the transportation of people and goods.
    - First, the artificial intelligence required to the functioning of autonomous trains is already fully operational. Indeed, trains are not used in open environments but in controlled and constrained environments with no possible other obstacles than other trains. As a consequence, the two required steps to reach autonomous vehicles level 5[8] are not required to the functioning of autonomous trains because no obstacle is supposed to be on the rails. Furthermore, a network of several trains can be controlled directly through a single artificial intelligence that only needs to prevent the collision between two identified train;
    - Second, trains use the same energy as battery electric vehicles to function (that is electricity), but with an increased ecologic and economic performance;
    - Finally, as enlighten in the table of the previous page, autonomous trains hold all the advantages of autonomous vehicles level 5 but with a higher efficiency.

In other words, the real ecologic transition in terms of transport do not consists in shifting from thermal vehicle to electric vehicles but consists in shifting from individual automotive towards rail transportation (that is to corresponds to the real "Mobility as a Service"). All the expected advantages of an individual battery electric vehicle with an autonomous level 5 used through "Mobility as a Service" are maximized with autonomous trains.

[8] Second step: Understanding the situation perceived and the potential willingness of the different obstacles. Third step: Plan the trajectories of the obstacles.

2. For journeys between 0 km and 100 km

- **Developing a network of small autonomous vehicles level 4 in controlled and constrained environments**. Trains cannot not transport individuals directly in front of their houses and a rail network needs to be completed by another transport network. Automotive appears to remain the best option to answer this need, but in a form that is radically different form the actual one.

  - **Lower vehicles' weight**. Vehicles' weight is one of the two first consumption (and therefore pollution) factors with vehicles' speed. If long journeys are reserved to trains and if automotive are dedicated to journeys of less than 100 km, then automotives can be smaller with smaller weight without economic and social costs but with great ecologic benefits;

  - **Lower vehicles' speed**. Vehicles' speed is one of the two first consumption (and therefore pollution) factors with vehicles' weight. If long journeys are reserved to trains and if automotive are dedicated to journeys of less than 100 km, then automotives can be slower with smaller motors without economic and social costs but with great ecologic benefits;

  - **Avoid the trap of autonomous level 5 in open environment and focus on autonomous level 4 in controlled and constrained environment**. Today, a full autonomous vehicle is neither possible nor conceivable in an open environment. Yet, the artificial intelligence required to the functioning of fully autonomous vehicles on controlled and constrained environment is already fully operational. The turning point thus consist in considering the automotive network as a whole (that is automotive + road network and related infrastructures), rather than to only focus on the individual automotive itself. Although it is not possible to develop fully autonomous vehicles on our current old road network, it is already possible and desirable to develop fully autonomous vehicles on a new type of road network dedicated to autonomous vehicle. By adopting this strategy, the development of fully autonomous car networks can be envisaged without delay. Still, it must imperatively be coupled with a public policy of valorization of rail transport over long distances (both in freight and passenger transport) and the development of hubs intended to make the link between autonomous cars and trains (dense parking networks around railway stations in suburban areas). Finally, the development of such a new automotive network should be coupled with the new technology developments in terms of automotive infrastructures, such as wireless dynamic charging solutions for battery electric vehicles.

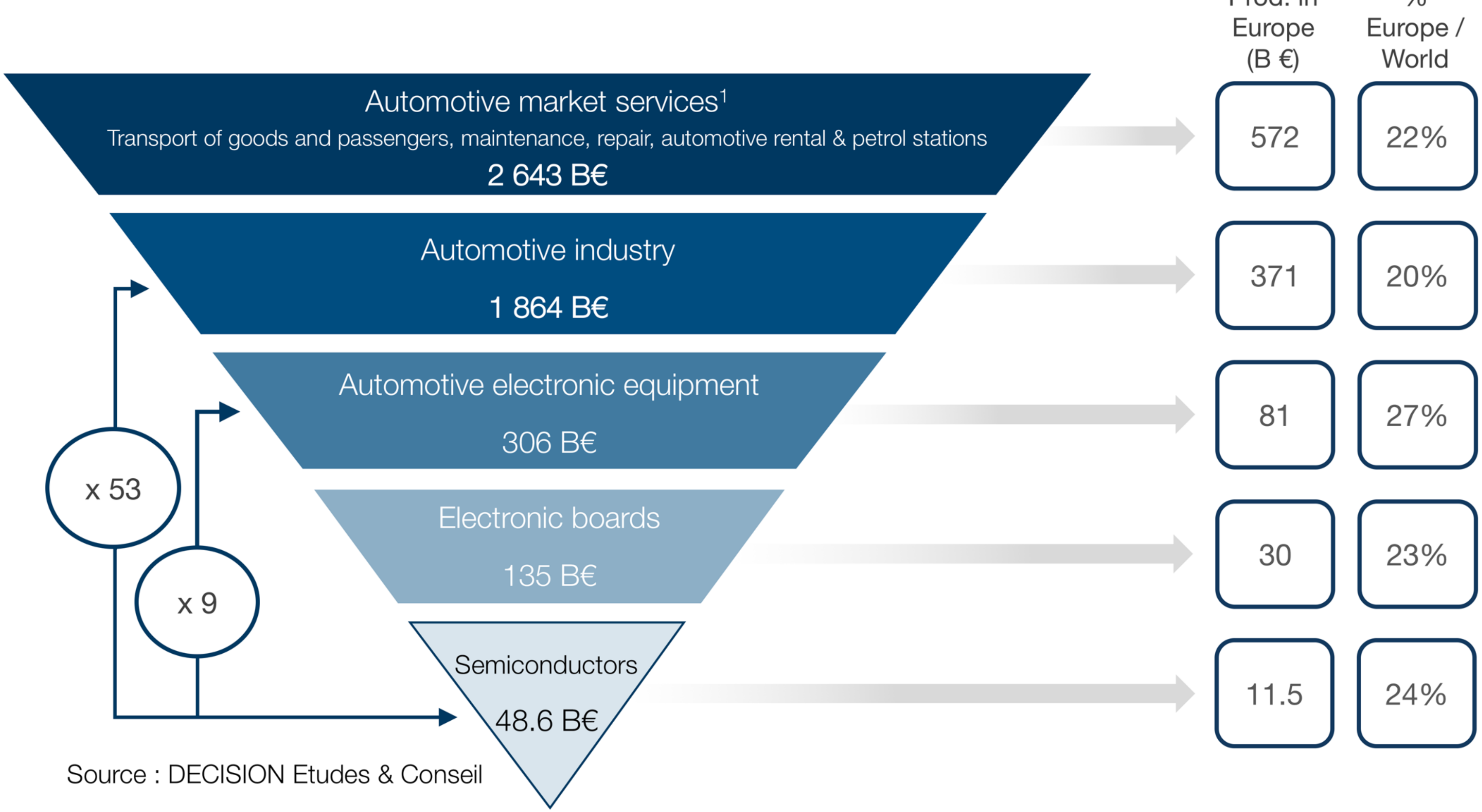
Both the development of rail transportation and autonomous level 4 in controlled and constrained environment requires large public infrastructure investments to succeed. This is why such a strategy can only be successful if it is leaded by ambitious, proactive and independent public policies with direct public investments to reshape the European transport infrastructure network. A start could be to set up pilot regions.

All the countries of the world will focus their public and private investments in the car itself to make it intrinsically fully autonomous, which is extremely expensive and economically, ecologically and socially absurd.

The European Union therefore has the opportunity to take a considerable lead over other countries provided that it makes sufficiently strong public investments in the right direction.

This solution - the most effective if the right investments are made - is already intuitively adopted by a few automakers. For example, the Renault-Nissan alliance is currently actively working on remote control of vehicles by operators.

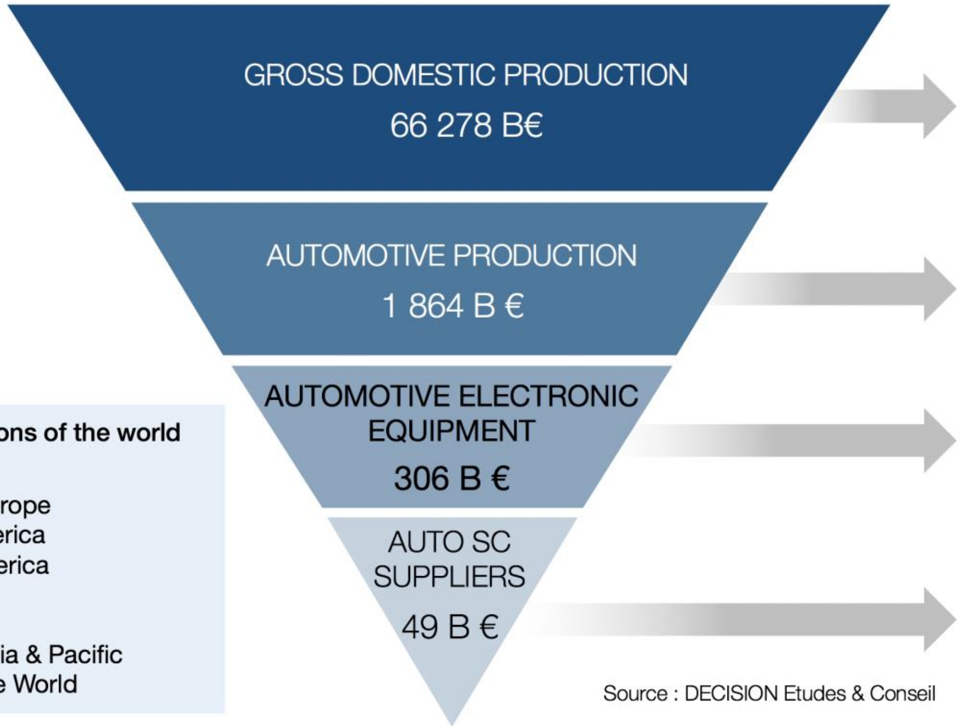
Worldwide Automotive electronics value chain in 2017



Source : DECISION Etudes & Conseil

[1] The services measured in this diagram only corresponds to the "market services", that is the services produced for sale on the market at a price intended to cover production costs and to provide a profit for the producer. Yet, industrial equipment provide a majority of "non market services" once they are sold.

World



The eight regions of the world

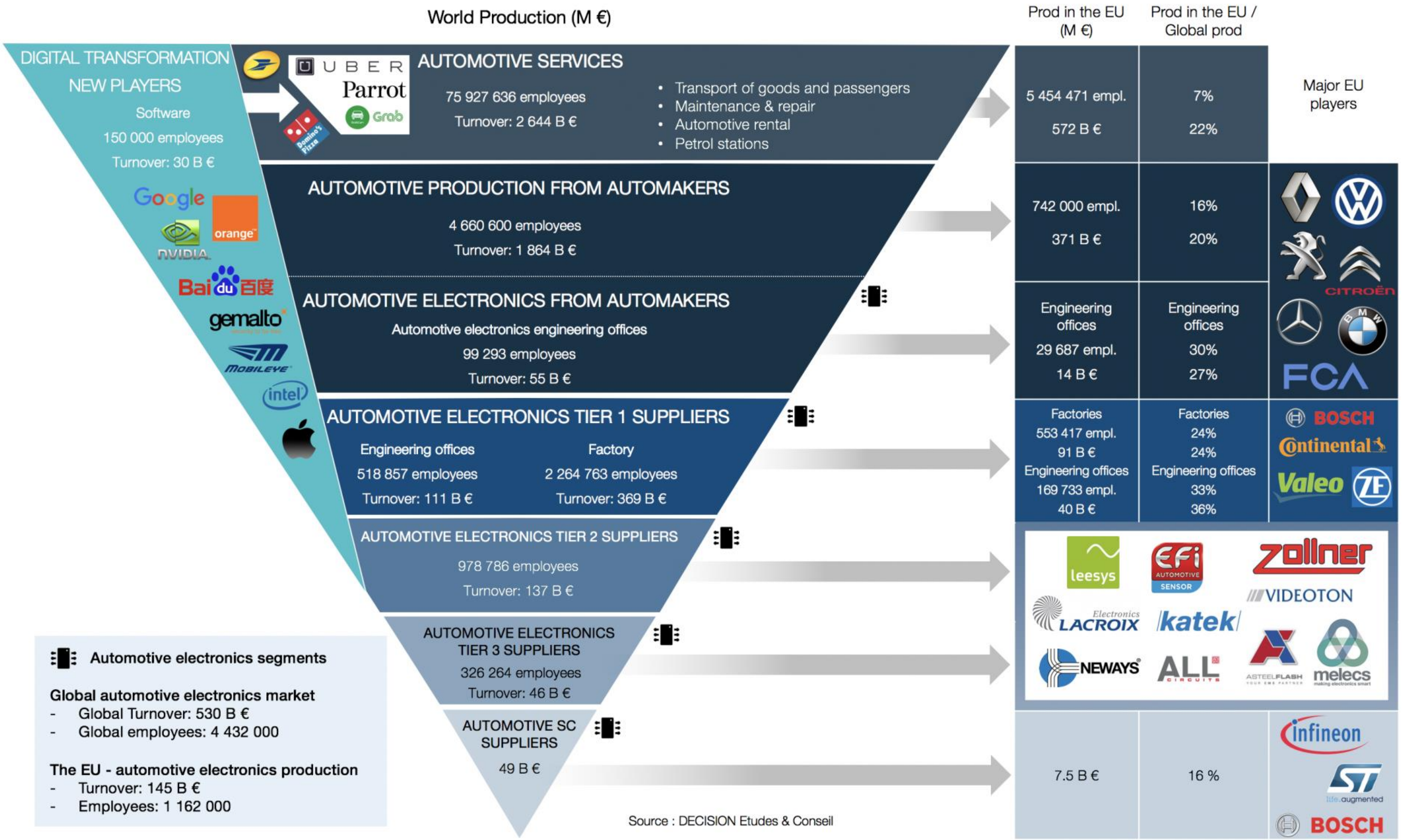
- The EU
- Rest of Europe
- North America
- South America
- China
- Japan
- Rest of Asia & Pacific
- Rest of the World

Source : DECISION Etudes & Conseil

Ranking of the EU

Criteria	Share of the EU	Rank of the (/8)
GDP	21%	2nd (after North Am)
Assembly location	20%	2nd (after China)
Capital ownership	35%	1st
Factory production	25%	1st
Engineering / R&D / HQ offices	33%	1st
Capital ownership	40%	1st
Capital ownership	16 %	3rd (after North Am & Rest of Asia)

Automotive electronics value chain in 2017



Analysis of the automotive electronics value chain (diagram above)

Digital transformation is a global trend that affects every economies and industries: Companies and administrations around the world are digitizing their processes and interconnecting the data networks thus generated.

In automotive electronics, digital transformation leads to a drastic rise of the importance software in the value chain.

In 2017, automotive embedded software represented 7% of the average total car production cost and 27% of the average total automotive electronics production cost per car (hard & soft), that is a global market of € 63 B. Yet, automotive embedded software global growth is well above the global average automotive electronics growth with a CAGR of more than 14% over the 2017-2022 period. As a consequence, the global automotive embedded software market should equal the global automotive electronics hardware market by 2030.

Such growth of automotive embedded software attracts new entrants on the automotive electronics value chain:

1. First, the global software development leaders: Intel, Apple, Google, Baidu. Although those companies do not have a great knowledge of the automotive industry, they hold greater knowledge in terms of software development;

2. Second, telecommunications companies such as Orange or Deutsche Telekom are entering the automotive electronics value chain in line with the development of the connected cars. As a member of 5GAA, Orange currently works with Deutsche Telekom on the interoperability of automotive connected services, to prevent a border crossing from stopping autonomous functions. This requires very fast download capabilities and therefore the existence of a 5G network;

3. Third, companies specialized in electronic security and/or cybersecurity such as Gemalto (bought by Thales) are entering the automotive electronics value chain in order to lead automotives' cybersecurity;

4. Finally, digital transformation also disrupts the automotive services with the entering of new players in the market. Software developers such as Uber, drones' producers such as Parrot, logistics companies and organization such as Grab or La Poste, companies from the food service industry such as Domino's Pizza, etc.

Those new entrants already hold around 50% of the global automotive embedded software market[9] with emblematic actors such as Mobileye (bought by Intel) or Nvidia. Automotive embedded software internal development from automakers represent around € 11 B at the global scale, that is 18% of the global market.

[9] Automotive embedded software market = Software integrated into cars during the production and assembly process. Applications dedicated to automotive services such as Uber are therefore excluded from our definition of automotive embedded software market.

Context - The automotive industry, a growing industry

i. Scope of the study – Automotive

The types of vehicles we define as "automotives" are described below[10]:

- **Passenger cars**. Motor vehicles with at least four wheels, used for the transport of passengers, and comprising no more than eight seats in addition to the driver's seat.
    - Passenger cars production represented 78.9% of the global automotive production in unit in 2017 (with 73 Million units produced).
- **Light commercial vehicles.** Motor vehicles with at least four wheels, used for the carriage of goods. Mass given in tons (metric tons) is used as a limit between light commercial vehicles and heavy trucks. This limit depends on national and professional definitions and varies between 3.5 and 7 tons. **Minibuses**, derived from light commercial vehicles, are used for the transport of passengers, comprising more than eight seats in addition to the driver's seat and having a maximum mass between 3.5 and 7 tons.
    - Light commercial vehicles production represented 20,8% of the global automotive production in unit in 2017 (with 19 Million unit produced)
- **Heavy trucks.** Vehicles intended for the carriage of goods. Maximum authorized mass is over the limit (ranging from 3.5 to 7 tons) of light commercial vehicles. They include tractor vehicles designed for towing semi-trailers.
    - Heavy trucks production represented 4,3% of the global automotive production in unit in 2017 with 4 Million units produced.
- **We exclude from the electronics content analysis:**
    - **Buses and coaches.** Vehicles used for the transport of passengers, comprising more than eight seats in addition to the driver's seat, and having a maximum mass over the limit (ranging from 3.5 to 7 tones) of light commercial vehicles.

      Indeed, buses and coaches' production represented only 0,325% of the global automotive production in unit in 2017 (with 316 258 units produced).

[10] We have adopted the definitions and classifications used by the IOVM (International Organization of Vehicles Manufacturers).

ii. Global and Regional growth trends

A. Global mega-trends in the automotive industry

- **93 Million automotives**[11] have been produced at the global scale in 2017.

- **The average global automotive production growth rate** (in unit) has been 3% over the 2012-2017 period. This significant growth is expected to remain stable over the 2018-2030 period with an average compound annual growth rate of 3% to reach 130 Million cars produced in 2030. This growth is driven by emerging countries with large populations an already significant GDP per capita. China, in the first place, will drive a third of the global growth within the 2018-2030 period. Yet, most of the global growth over this period will come from the other emerging countries: Brazil, Turkey, Mexico, Argentina, Russia, Thailand, Vietnam. Finally, even in developed countries with market that are supposed to be matures, the number of cars per inhabitant continue to rise in line with new uses. For instance, in the EU, people of 60 years old and more are driving 30% to 40% more often than in the 1980s.

- The average car production cost (in euro) is slightly but steadily decreasing over the 2010-2017 period with a compound annual growth rate of -1.3%. Over the same period, the average automotive electronics production costs by car rose with a compound annual growth rate of 2.2%. In other words, **the average electronic cost by car is rising while the average total car cost is decreasing**.

Table – Global Automotive growth

	2010-2017	2017-2022
Automotive growth in value (€)	**2.4 %**	**2.0 %**
Automotive growth in unit	3.7 %	3.3 %
Automotive average cost growth (€)	-1.3 %	-1.3 %
Share of automotive electronics growth (%)	**2.2 %**	**5 %**
Automotive electronics growth in value (€)	**5.3 %**	**10 %**

Source: DECISION Etudes & Conseil, OECD, Eurostat, IOMVM, Industrial & Expert interviews

- **ADAS (Advanced Driver Assistance Systems) and Infotainment will be the two main drivers of automotive electronics growth during the 2017-2022 period**. During this period, ADAS will contribute to 30% of automotive electronics growth and Infotainment will contribute to 32% of automotive electronics growth.

- In 2014, automotives represented 18% of the global CO_2 emissions. To fight pollution, states are implementing very restrictive pollution emissions standards. Such standards are launching a trend of **electrification of powertrains: in new cars produced, electric batteries are progressively gaining in importance. That electrification of powertrains leads to a slight increase of the electronic contents of cars and to a very high increase of automotive semiconductors contents.**

- **The European Union**. In 2017, the automotive industry provided between 2 and 2.5 million jobs and generated 371 B € in the EU. 80% of the growth in this industry is expected to occur outside the EU but will benefit to the EU's actors. In 2017, the automotive services provided between 5.5 million jobs and

[11] Excluding heavy trucks, buses and coaches.

generated 572 B € in the EU. In other words, the EU automotive sector (industry and services) contributes directly to almost 6,5% of the EU's GDP.

In this chapter, we provide a regional comparison of the global automotive production on the basis of three criteria:

- **Automotive Assembly**. The assembly location is important for two reasons. First, it is the place where most of carmakers' employees dedicated to electronic equipments' integration is located. But more importantly, it corresponds to the location of the demand for electronic embedded component/equipment. Yet, there is a great correlation between automotive assembly locations and automotive electronic equipment production locations. Indeed, for supply chain management purposes, carmakers prefer suppliers who produce close to the car assembly location.

- **Nationality of carmakers' principal shareholders**. This criterion is also important for two reasons. First, ownership's nationality provides an indication of the country that potentially owns the industrial knowledge (patents, R&D…). Furthermore, on the long run, investment decisions and employees' locations are highly influenced by ownership's nationality.

- **Automotive potential markets by 2030**. This analysis aims to determine the countries with the highest needs for automotive by 2030 and with the economic capabilities to answer those needs. On the long run, that demand will determine to a large extent automotive assembly locations and therefore automotive electronics production locations.

B. Regional Trends - Automotive assembly

Regional comparisons. 20% of the cars produced globally are assembled in the European Union, which makes the European Union the second vehicle assembly region at the global scale after Asia. Furthermore, the EU car assembly compound annual growth rate in the 2012-2017 period (3%), is equal to the global car assembly growth during the same period (3.2%). Such automotive assembly in the EU is a major factor of development of automotive electronics in the EU because for supply chain management purpose, carmakers prefer suppliers who produce close to the car assembly locations.

Country comparisons. In terms of countries, Germany let alone is the fourth country in terms of vehicles assembly at the global scale after China, the USA and Japan, with 6% of the total. Inside the European Union, the vehicle assembly can be divided into three groups of countries:

- Germany: 30% of total;

- West European Union[12]: 47% of total;

- East European Union[13]: 23% of total.

In other words, the group composed of east European Union countries plus Germany account for 53% of the EU automotive assembly.

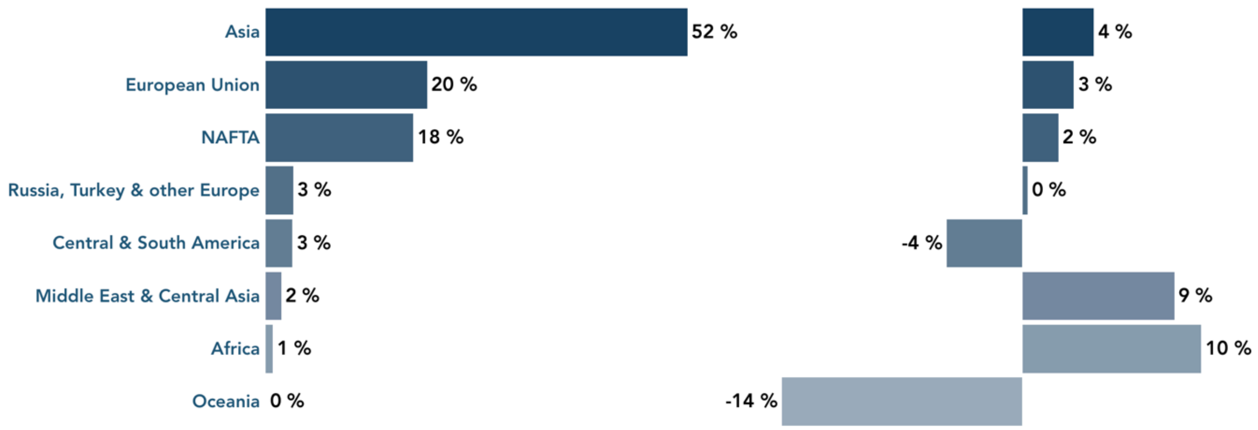
[12] West European Union: Spain, France, the UK, Italy, Sweden, Belgium, Finland, Portugal.
[13] East European Union: Poland, Czech Republic, Slovakia, Romania, Bulgaria, Slovenia, Hungary.

Number of cars produced by assembly location

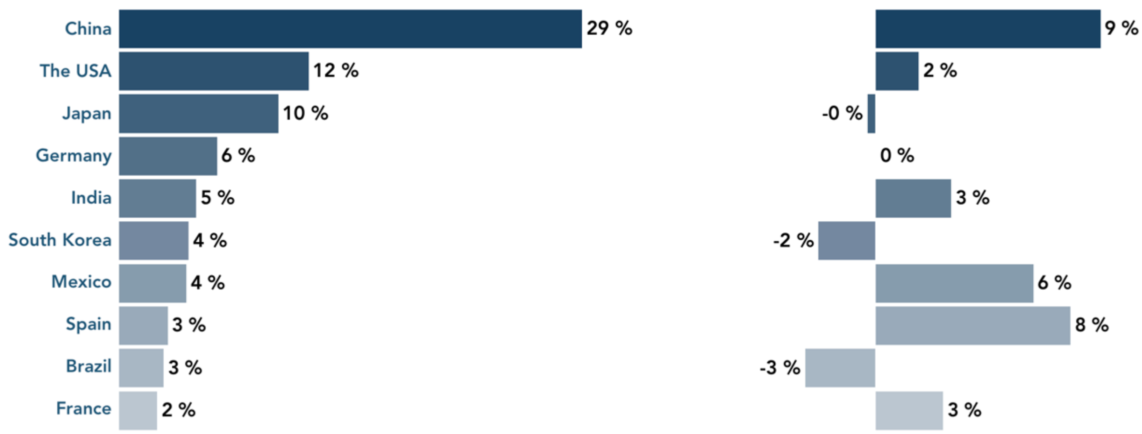
Global production

- 93 211 976 unit produced in 2017
- 3% Compound Annual Growth Rate (CAGR) 2012-2017

2017 - Number of automotive assembled (% total) Compound Annual Growth Rate (CAGR) 2012-2017



2017 - Number of automotive assembled (% total) Compound Annual Growth Rate (CAGR) 2012-2017



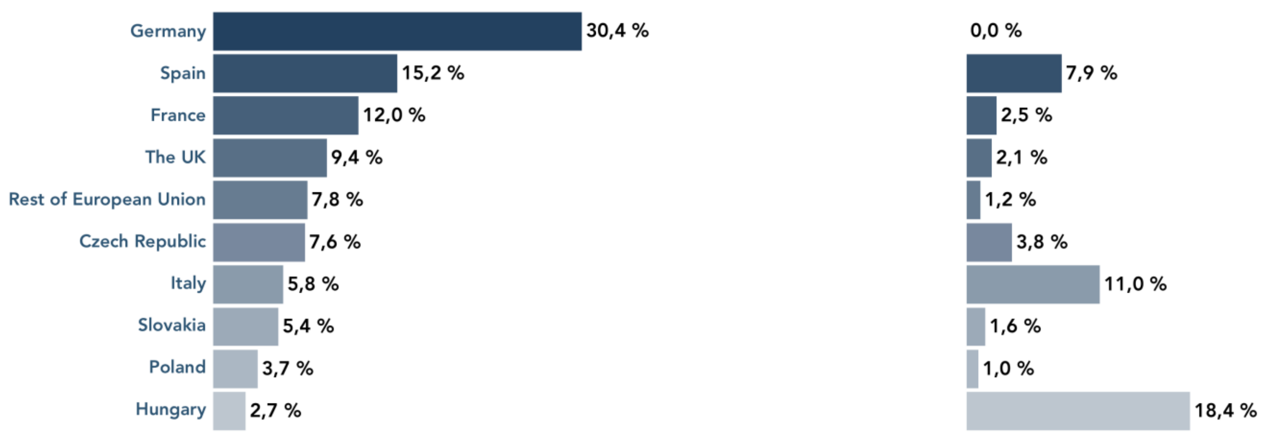
Source: IOMVM, DECISION Etudes & Conseil

Remark: Heavy trucks, buses and coaches are excluded

EU production

- 18 580 539 units produced in 2017 (20% of the world production)
- 3% Compound Annual Growth Rate (CAGR) 2012-2017

2017 - Number of automotive assembled (% total EU) Compound Annual Growth Rate (CAGR) 2012-2017



Source: IOMVM, DECISION Etudes & Conseil

Remark: Heavy trucks, buses and coaches are excluded

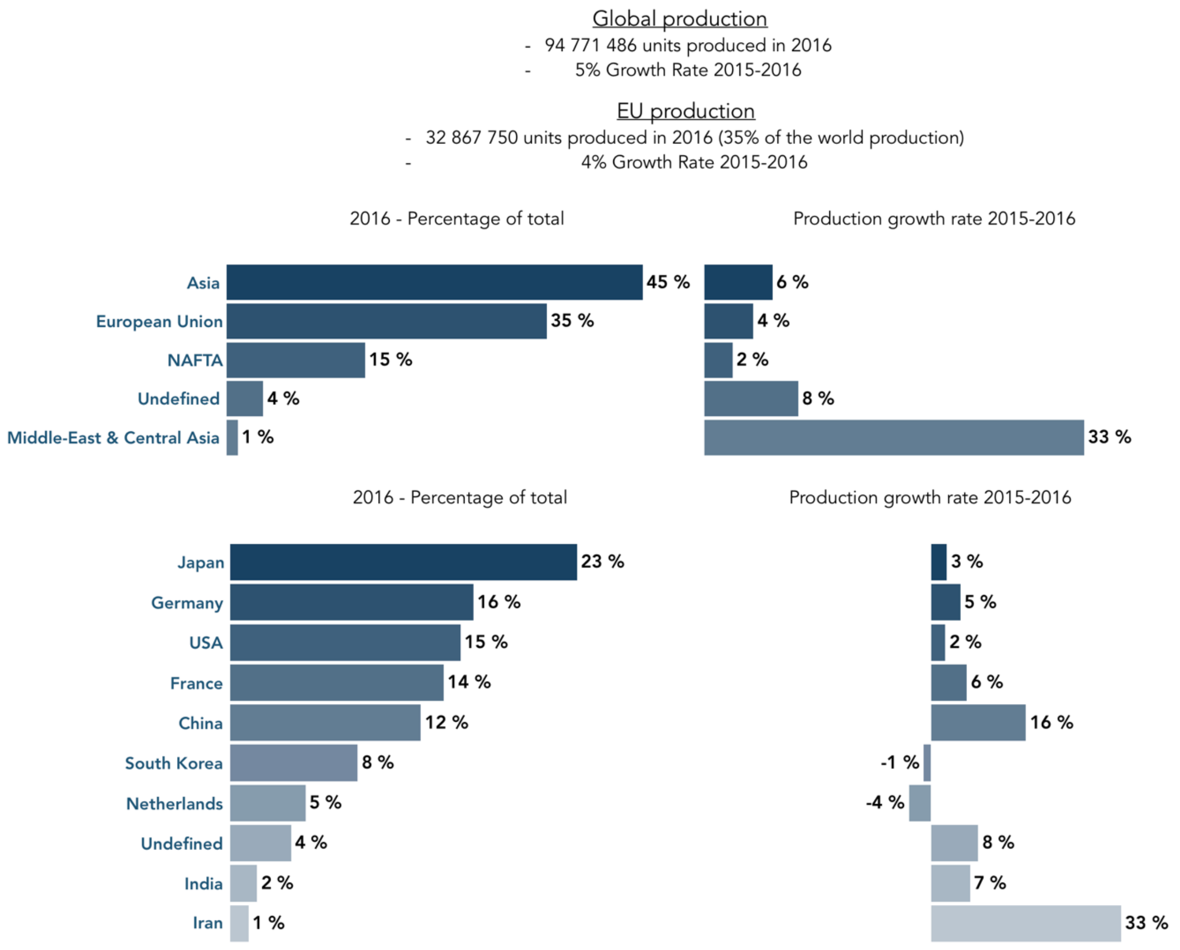
C. Regional Trends – Carmakers ownership

In 2016, 35% of the motors produced globally were made by firms whose principal shareholders were headquartered in an EU Member state, which makes the European Union the second region at the global scale regarding that criterion after Asia.

Yet, recent events lowered the representativeness of EU shareholders in terms of shares of EU owned carmakers:

- Since 2009, Qatar Investment Authority (QIA) steadily buys Volkswagen AG's shares and now holds 16% of the total shares.
- Since 2017, Dongfeng motor corporation (China) is the principal shareholder of PSA with 13% of the total shares. The Peugeot family and the French state both owns 12.9% of the total shares.
- In terms of shares, the Renault-Nissan-Mitsubishi group is leaded by the Renault group. The French State is the principal shareholder of Renault with 15% of its capital and 21.93% of the voting rights. Renault controls 43.4% of Nissan, which is the principal shareholder of Mitsubishi (34% of shares). Nissan holds 15% of Renault but without voting rights. Yet, in early 2018, the French State announced its willingness to sell part of its shares.

Number of motors of cars, buses and trucks produced by nationality of majority owners



Source: IOMVM correspondants survey, DECISION Etudes & Conseil

Table – World motor vehicle production – Unit produced

Country Ranking	Ownership nationality	Group	Group Ranking	2015	2016	Market Share 2016
1	Japan	TOYOTA	1	10 083 831	10 213 486	11 %
		HONDA	7	4 543 838	4 999 266	5 %
		SUZUKI	11	3 034 081	2 945 295	3 %
		MAZDA	16	1 540 576	1 586 013	2 %
		FUJI	23	938 553	1 024 604	1 %
		ISUZU	27	669 284	614 798	1 %
2	Germany	VOLKSWAGEN	2	9 872 424	10 126 281	11 %
		DAIMLER AG	13	2 134 645	2 526 450	3 %
		B.M.W.	14	2 279 503	2 359 756	2 %
3	USA	G.M.	4	7 484 452	7 793 066	8 %
		FORD	5	6 393 305	6 429 485	7 %
4	France	NISSAN	6	5 170 074	5 556 241	6 %
		RENAULT	9	3 032 652	3 373 278	4 %
		PSA	10	2 982 035	3 152 787	3 %
		MITSUBISHI	21	1 218 853	1 091 500	1 %
5	China	SAIC	12	2 260 579	2 566 793	3 %
		CHANGAN	15	1 540 133	1 715 871	2 %
		BAIC	17	1 169 894	1 391 643	1 %
		DONGFENG MOTOR	18	1 211 355	1 315 490	1 %
		GEELY	19	999 802	1 266 456	1 %
		GREAT WALL	20	869 592	1 094 360	1 %
		CHERY	24	525 922	695 617	1 %
		ANHUI JAC AUTOMOTIVE	25	584 038	651 291	1 %
		FAW	29	496 703	557 174	1 %
		BYD	31	446 778	510 572	1 %
6	South Korea	HYUNDAI	3	7 988 479	7 889 538	8 %
7	Netherlands	FIAT	8	4 865 233	4 681 457	5 %
8	India	TATA	22	1 010 239	1 084 678	1 %
		MAHINDRA	28	571 895	604 466	1 %
9	Iran	IRAN KHODRO	26	509 204	636 000	1 %
		SAIPA	30	368 778	531 000	1 %
		Rest		3 501 006	3 786 774	4 %
		World		90 297 736	94 771 486	
					94 771 486	

Remarks
- Qatar Investment Authority (QIA) holds 16% of Volkswagen AG's shares
- Dongfeng motor corporation (China) holds 13% of PSA's shares

Source: IOMVM correspondents survey, DECISION Études & Conseil

D. Regional Trends – Automotive potential markets

The following diagrams provide a visualization of the countries with the highest potential automotive markets at the global scale thanks to the crossing of three criteria:

- **2030 Projected population**. Countries with the highest 2030 projected population are the countries with the highest potential market.
- **2015 – Equipment rate**. Countries with the lowest equipment rate in 2015 are the countries with the highest potential market. Equipment rate is defined as car/inhabitant. Considering the population under 18 years old, which do not drive cars and account on average for 25% of the country populations, countries with an equipment rate close to 70% or more can be considered as mature and will not generate high growth anymore.
- **2015 – GDP per capita**. Potential growth coming from high projected population and low equipment rate cannot materialize without sufficient GDP per capita. Indeed, inhabitants with too low GDP per capita cannot afford to buy cars. As we can see on the diagrams, countries considered as high-income economies[14] (with more than $12,476 per inhabitant), usually already have mature or almost mature automotive markets (the European Union, Canada, the USA, Oceania countries such as Australia, etc.). Therefore, countries with maximum potential markets by 2030 are countries with GDP per capita between 5 000 and 12 000 dollars per capita, that is middle-income fast-growing economies (China, Brazil, Turkey, Mexico, Argentina, Russia, Thailand, Vietnam, etc.).

By 2030, China is clearly the country with the highest automotive growth potential: Chinese will account for 17% of the global population by 2030, China's equipment rate is only at 12% and China's GDP per capita is 8 069 $, that is to say enough to afford one car per adult and to tend to a 70% equipment rate on the long run. 700 Million cars are needed today to equip every Chinese adult with a car. By comparison, the global car stock in 2015 was of 1 282 Million cars (Passenger cars and Light Commercial Cars only).

On a longer run, the two highest potential automotive markets are Africa and India. Yet, their average GDP per capita (of respectively $ 2 003 and $ 1 596 in 2015) remain too low to launch the transition process towards mature markets.

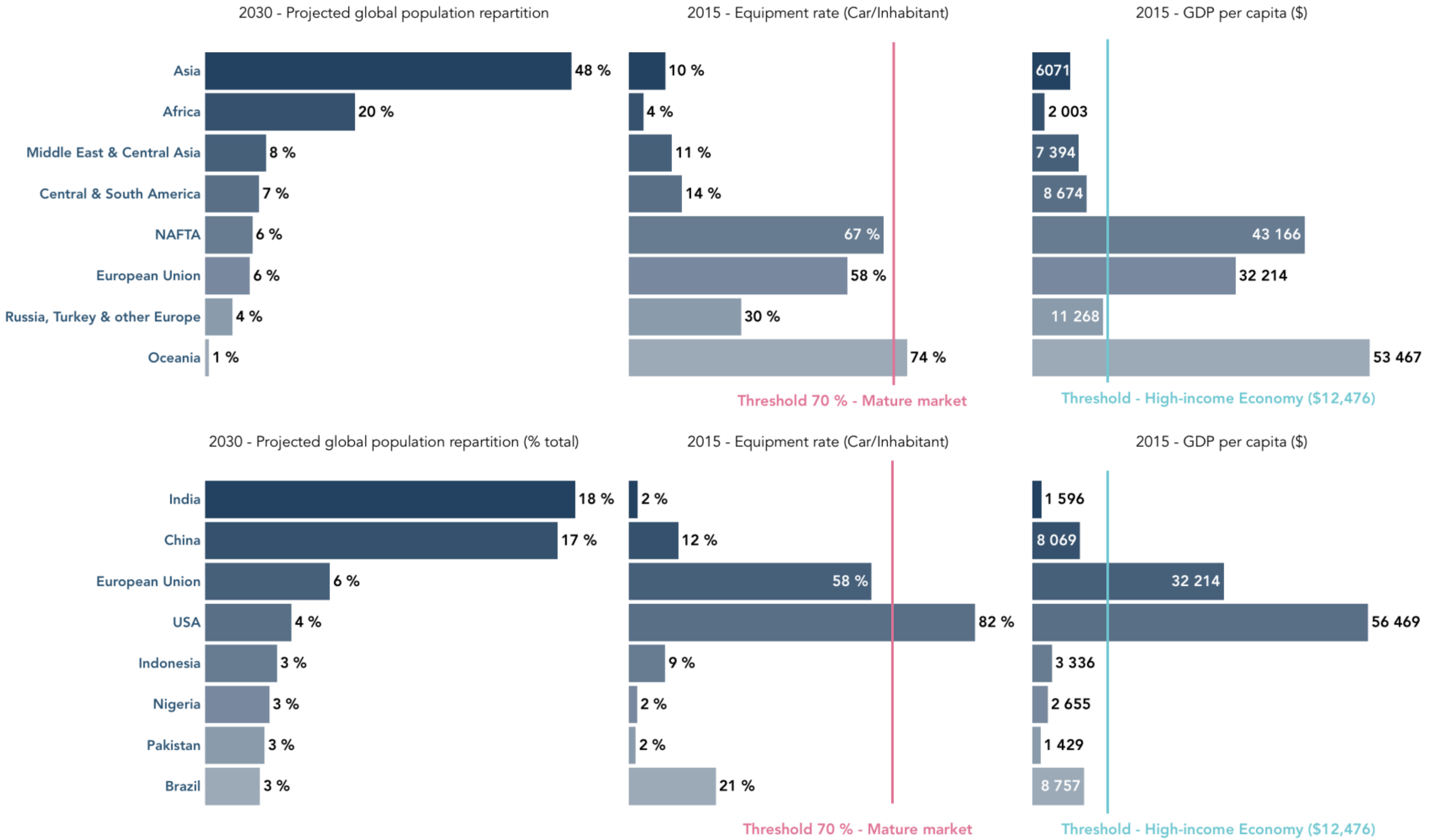
Finally, the average EU equipment rate of 58% in 2015 hides significative discrepancies between West and East Europa. West European countries have equipment rates close to 70% while East European Union countries (Poland, Romania, Bulgaria, etc.), still have a lower equipment rate, which leads to higher automotive potential growth in those countries.

[14] Countries with a GNI per capita of $12,476 or more according to the World Bank

Automotive potential markets

Global population
- 7 128 369 754 inhabitants in 2015
- 10,5% Compound Annual Growth Rate (CAGR) 2015-2030

EU population
- 509 670 169 units produced in 2015 (7% of the world population)
- 3% Compound Annual Growth Rate (CAGR) 2015-2030



Sources: DECISION Etudes & Conseil, World Bank, International Organization of Motor Vehicle Manufacturers, United Nations: Department of Economic and Social Affairs - Population Division (2018), Eurostat

Remarks: Automotive are defined in those figures as (Light Commercial Vehicles + Passenger Cars). Heavy trucks, buses and coaches are excluded.

High-Income Economy: Countries with a GNI per capita of $12,476 or more according to the World Bank

iii. The electric vehicle: the coming boom

A. Vocabulary

There is no strict frontier between petrol/diesel vehicles and electric vehicles. On the contrary, there is a continuum of types of cars leading to more or less petrol/diesel consumption and to more or less electrification of powertrains and therefore electricity consumption. Here is a list of the main motorization types by rising order of powertrains' electrification:

- **Petrol vehicles**
- **Diesel vehicles**
- **Mild hybrid vehicles**. Mild hybrid vehicles are composed of internal combustion engines equipped with an electric battery that is powerful enough to provide an assistance to the engine in specific driving phases. Mild hybrid vehicles employ batteries with higher voltage than traditional petrol/diesel vehicles (12 V), but with lower voltage than full hybrid vehicles, PHEV and BEV (> 60 V). Finally, mild hybrid vehicles do not have an exclusive electric-only mode of propulsion.
- **Full hybrid vehicles**. Full hybrid vehicles are hybrid vehicles designed with an exclusive electric-only mode of propulsion
- **Plug-In Hybrid electric Vehicles (PHEV)**. PHEV are full hybrid vehicles that can be plugged to recharge the electric battery
- **Battery Electric Vehicles (BEV)**. BEV are vehicles that are only powered with electric batteries
- **Fuel-Cell Electric Vehicles (FCEV)**. FCEV are vehicles that are only powered with hydrogen

B. Current situation

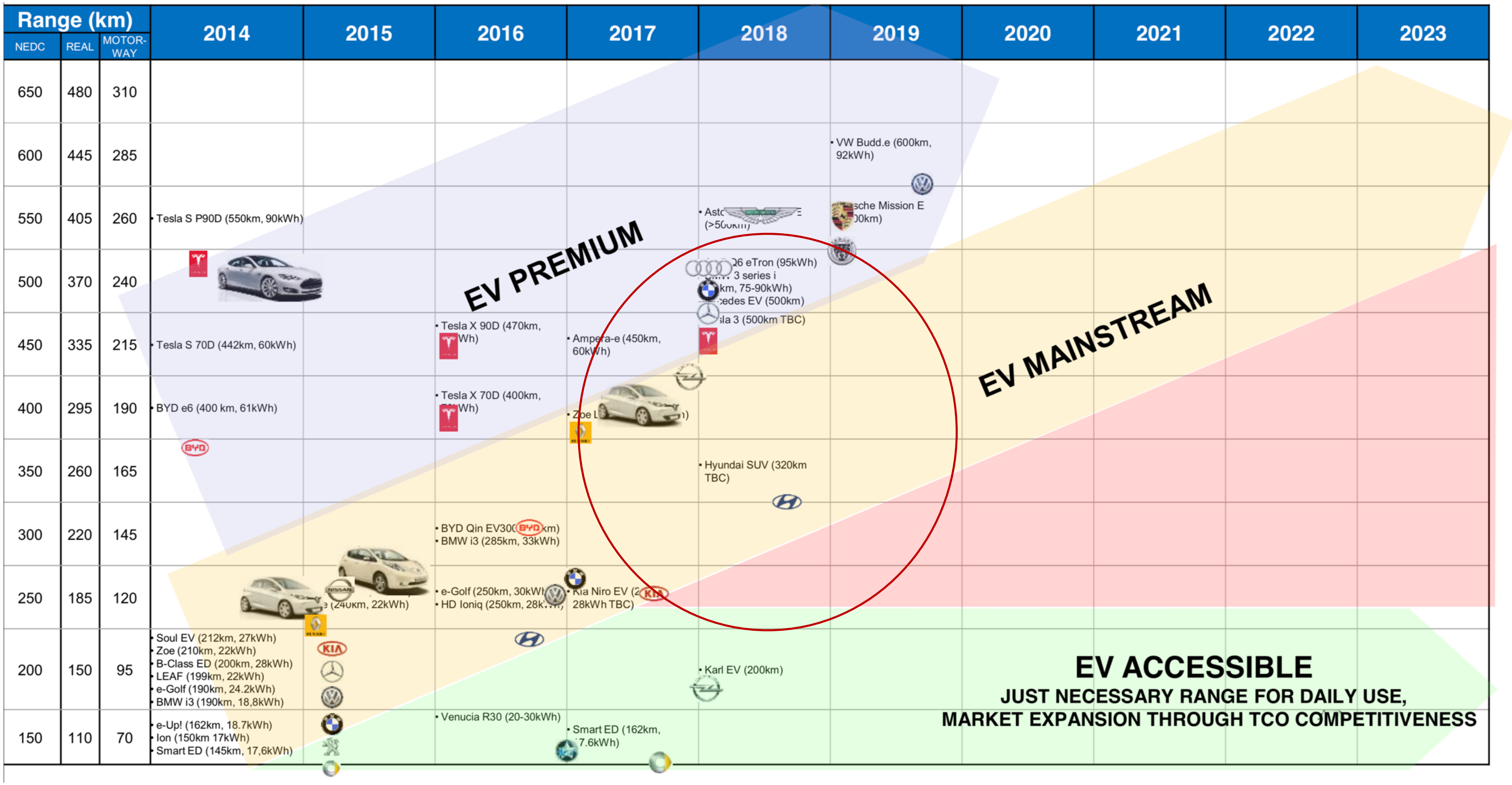
a. Impressive growth rate

In 2017 and for the first time, more than 1 Million electric vehicles[15] (BEV) where produced at the global scale (1.2 Million precisely). For nearly a decade, electric vehicles production rise at very high rates (more than 20%/year). The production of BEV should exceed 2% of the world production by 2022[16].

Furthermore, the global automotive electric vehicles production is reaching in 2018 a critical development stage. Indeed, for the first-time electric vehicles are produced by carmakers with both ranges (300 km and more in real conditions), and prices that are competitive with petrol/diesel cars. This period is represented by the red circle in the following table and can be summarized as the emergence of “EV Mainstream” market. This offers very favorable perspectives for the EV market, especially because as the cost of electricity is lower than the cost of petrol/diesel, the cost of using an EV is lower than the cost of using a petrol/diesel car.

[15] Battery Electric Vehicles and Plug-In Hybrid Electric Vehicles.
[16] Source: Scenario green constraint BIPE / PFA

Table – The emergence of an EV mainstream market: price and range-competitive with diesel/petrol cars



Source: Renault, DECISION Études & Conseil

Tax incentives and innovation support

China's announcement in September 2017 to schedule the banishment of petrol/diesel vehicles commercialization by 2030-2040 sent a decisive signal echoed in most Western countries. Since then, Germany and the Netherlands have planned the prohibition of petrol/diesel vehicles ales by 2025. In France, in July 2017, the French Minister of Transport has set the same goal by 2040. In India, the government does not want "a single petrol/diesel car" to be market after 2030. Japan's Minister for Economy announced that every new car sold in Japan would be electric or hybrid by 2050. In 2017, the executives of a dozen metropolises, such as Paris, Los Angeles, Auckland and Le Cape Town, committed to acquiring only zero-emission buses by 2025 and to ban carbon dioxide emissions in significant areas of their cities by 2030.

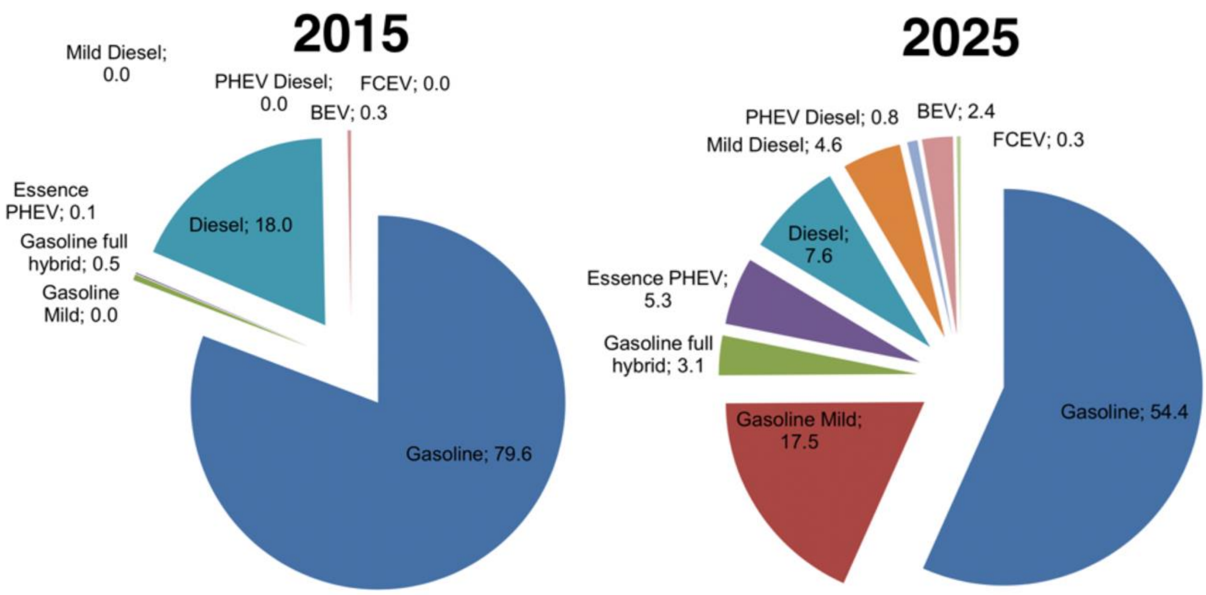
Electrification of powertrains

Yet, a critical obstacle to the development of a global BEV mass market has not yet been overcome. This obstacle is the absence of a recharging network throughout territories. The BEV market is unlikely to reach significant proportions before the set-up of such a network.

As a consequence, the most-likely scenario within the coming decades at the large scale is the development of petrol and diesel vehicles with more restrictive pollution standards, then the development mild hybrid and then only the emergence of significant PHEV / BEV markets (the diagram below illustrates these forecasts). This scenario can be resumed as the "electrification of powertrains" trend: In 2015, 2% of the vehicles sold were using other propulsion technologies than petrol and diesel and were therefore using more electrified powertrains. In 2025, such vehicles are expected to account for 37% of the global vehicles sales.

In China, every car sold in urban centers already needs to have a minim 50 km electric range. That requires at least full hybrid propulsions. BEV sells will therefore drastically rise in Chinese cities. Yet, BEV are not expected to replace petrol/diesel vehicle in Chinese sub-urbans and rural regions because the required ranges remain too high.

Table – Global repartition of vehicles by motorization types



Source: Scenario green constraint BIPE / PFA

b. China to take the lead on electric vehicle production

No other state has devised such an ambitious strategy in electromobility as China regarding electric vehicles production and conception[17].

1. In 2015, the "Made in China 2025" plan made electric car batteries an industrial priority.

2. In addition, the country benefits from its huge domestic market, which promotes economies of scale and allows Chinese companies to become more competitive.

3. Beijing can count on its production of rare earth (79% of the global production in 2017). In the 1990s, strict environmental regulations forced Western mining companies and refiners to shut down or transfer their rare earth production activities. China took that opportunity to gain the corresponding market shares. In other words, by relocating the mining pollution, the Occident has also conceded to a rival the monopoly of several strategic matters for the electric mobility: China produces 94% of the magnesium, 69% of the natural graphite and 84% of the tungsten consumed in the world. The proportions reach even 95% for some rare earths.

   China uses this position by selling some resources up to 20% more expensive to its foreign customers. To the extent that the USA filed a complaint in 2016 before the World Trade Organization (WTO), accusing China of "disadvantaging US producers". In addition, since the early 2000s, Beijing has reduced exports of various materials, such as molybdenum, fluorine, magnesium or yellow phosphorus. According to the European Commission, a myriad of metals contained in electric vehicles have already become "critical", that is to say that there is a risk of supply disruption[18].

   These maneuvers place Western manufacturers in a dilemma: should the production tools be maintained permanently in their current locations, with the associated risk of shortages coming from China? Or is it necessary to relocate to China in order to benefit from unlimited access to raw materials? Cheap labor from inland areas, the low cost of capital - driven in part by a policy of devaluation of the yuan - and the strong potential of the Chinese market have already convinced many of them to relocate to China.

4. Since 1994, foreign group moving to China have had to form joint ventures in which they cannot hold more than 50% of the shares. This legal structure allowed their Chinese counterparts to accelerate Western technology transfers and catch up.

In line with those strategies, China managed in three decades to lead the industrialization and patents of electromagnets. Yet, electromagnets are machined thanks to neodymium (a rare earth) and are indispensable for the manufacture of most electric motors. As a result, while at the end of the 1990s Japan, the United States and Europe shared 90% of the electromagnet market, China now controls three quarters of the production. The magnets are made in Baotou, an agglomeration of Inner Mongolia.

[17] "Voiture électrique, une aubaine pour la Chine", Guillaume Pitron, Le Monde diplomatique, Août 2018

[18] Communication of the European Commission on the 2017 list of Critical Raw Materials for the EU, Brussels, 13.9.2017

China has reproduced this scenario with the batteries. China accounts for only a small share of global cobalt production, an essential mineral for the manufacture of lithium-ion batteries, for which the DRC accounts for about 60% of the global production. The price of cobalt has more than tripled since 2016, forcing BMW and Volkswagen to engage in direct negotiations with mining groups in recent months to secure their supplies. However, Jingmen Gem, the Chinese specialist in the industrialization of battery materials, has formalized in early 2018 a three-year contract for the purchase of one third of the cobalt produced each year in the DRC by the British-Swiss trading group Glencore. As a consequence, in 2018, the Chinese battery manufacturers (Wanxiang, BYD Auto, Contemporary Amperex Technology Co. Limited (CATL), etc.), account for 80% of the consumption Congolese cobalt.

China is expected to produce 80% of commercial batteries sold in the world by 2020. Furthermore, the aim of China is not only to sell batteries to the world but to produce batteries in China and sell electric cars to the world. Among the 10 first world producers of battery electric vehicles (BEV), 6 are Chinese: BYD, Shanghai Automotive Industry Corporation (SAIC), Dongfeng Motor Corporation, Geely, FAW Group and Beijing Automotive Industry Holding Co. Brussels announced October 11, 2017 the creation of a European Battery Alliance to counter the Chinese lead.

c. Smart power grids challenge

Smart power grids and smart roads will be required in order to enable a significant development of the electric car market. If the whole European automotive base were at once to become electricity powered, it would lead at least to a 15% increase in electricity consumption. More realistically, projections anticipate that by 2020 electric vehicles will only create a 1% increase in power consumption, which will still have to be managed wisely considering the current state of the power grid. Communication between the car and the grid will be necessary in order to avoid any imbalances due to sudden additional load on the power networks (it is likely that most electric vehicles will be plugged in for a recharge at more or less the same time).

d. The electric vehicle is not the solution to build an ecologic transport network

Despite the impressive battery electric vehicles growth rates, electric vehicles production only accounted for 1,3% of the total car produced globally[19] in 2017. Besides, impressive growth rates are common in emerging market.

The absence of a recharging network throughout territories

Furthermore, a critical obstacle to the development of a global EV mass market has not yet been overcome. This obstacle is the absence of a recharging network throughout territories. The EV market is unlikely to reach significant proportions before the set-up of such a network.

Today, the only economically sustainable solution is to associate every sale of BEV with the installation of a fast-charging station at the client’s home. A fast-charging station at home combined with the already large BEV ranges (400 km or more), answer nearly all the needs of the owner of a BEV at non-prohibitive cost. Yet, this solution is absolutely not ecologically sustainable. Indeed, fast-charging stations lead to a very high electricity consumption and if all the fat-charging stations are used between 18:00 and 23:00, the electricity consumption peak is going to surge, implying a very great increase of the electricity production infrastructures (nuclear plants, coal-fired plants, etc.).

[19] Including Passenger cars and Light Commercial Vehicles, but excluding heavy trucks, buses and coaches.

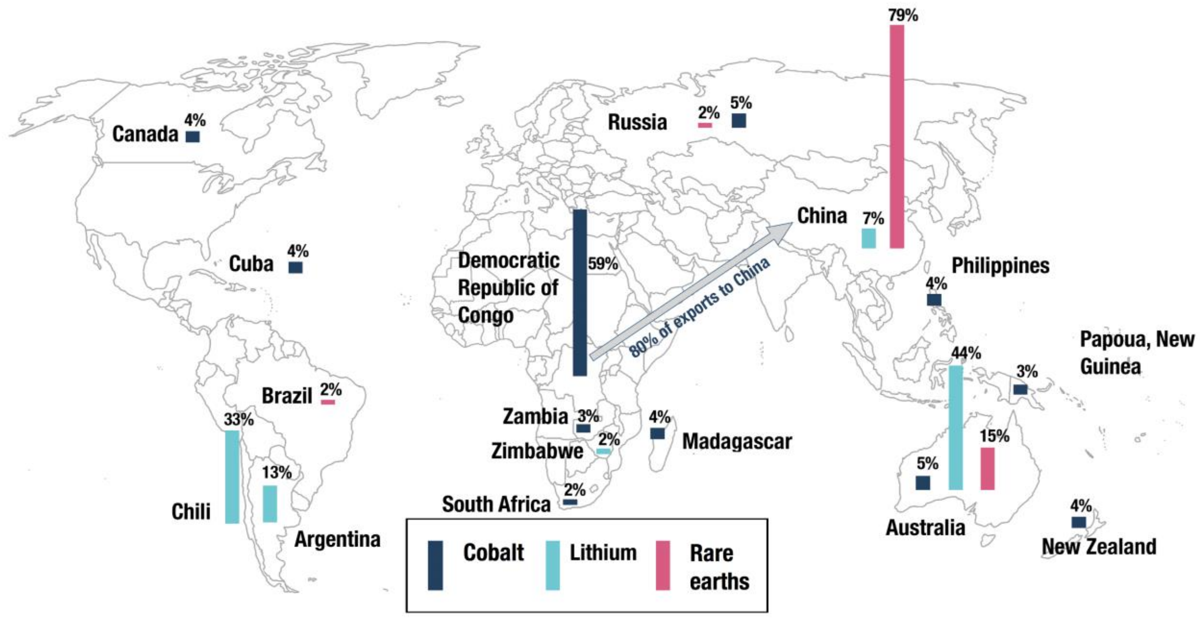
Even if the issue of "recharging network" were solved, the sustainable development of BEV would suffer from major boundaries.

Raw Materials issues

Although a BEV do not require petrol or diesel to operate, it requires electricity that is often produced through non-ecologic processes. Nuclear plants and coal-fired plants are still the two first mean of electricity production at the global scale.

Even if the electricity were sustainably produced, BEV production requires a great amount of non-ecologic raw materials: lithium, cobalt, tungsten, rare earths, etc. An automotive lithium-ion battery requires up to 3.5 kg of rare earths, 10-20 kg of cobalt and up to 60 kg of lithium to be produced. The extraction of such raw materials is very polluting and energy consuming. Inner-Mongolia, the Chinese region specialized in rare earth extraction, is one of the most polluted regions in the world. The main impact of the development of BEV is the delocalization of pollution to some emerging countries rather than the reduction of pollution.

Map – 2017 – Repartition of the global production of the three main critical resources for Battery Electric Vehicles



Sources: "Mineral Commodity summaries 2018" USGS, Le Monde Diplomatique, DECISION Études & Conseil

A threat on the long-run is the lack of lithium for Lithium-ion based electric batteries. Yet, currently 15 to 25 Million tons of Lithium are considered as extractables at the global scale, which should allow for more than a century of use, considering the automotive industry as consuming 2/3 of such reserves of lithium. Besides, investments are made to extract lithium directly from water of the oceans, which would eliminate the reserve issue. Such extractions from the oceans are for the moment very costly and very water consuming, but innovations could emerge within the course of the coming decades.

Finally, a sustainable development of BEV also requires the set-up of a costly electric battery recycling supply chain, which is already not always the case. A great proportion of lead acid batteries are "recycled" in Africa (13% in Nigeria[20]). Yet, a lead acid battery is recyclable only where a supply chain exists to do so and that is not true in Africa. Poor African citizens end-up by exploiting these old batteries until there is nothing left in it. The dead batteries then corrode and pollute the local groundwater, which is what children drink.

[20] According to Cleantech Hub

Electric battery weight[21]

Because of the current large mass of electric batteries, the rolling mass of a BEV is about 10 to 20% greater than the rolling mass of a thermal vehicle at equal habitability. Besides, a greater rolling mass leads to heavier braking system and running gear to support battery's weight. Yet, running a seventy-kilogram driver in a two-tons Tesla might look like a nonsense. The electric-assisted bicycle does not suffer from this ratio between the mass to be transported and the total mass displaced.

e. Solutions for an ecologic transport network

In this scenario, the EU develops an ambitious, proactive and independent public policy in order to shift European and, if possible, global private actors towards another growth model that is more effective in terms of social, ecologic and economic development.

In this scenario, rather than to follow the global trend towards individual battery electric vehicles with autonomous level 5, the EU chose to develop:

1. <u>For journeys between 100 km and 2000-3000 km</u>

- **Developing rail transportation for goods and people**. That is to say prohibiting vehicles for any types of long transportation (ending any type of highway investments) and set up rail network both for the transportation of people and goods.

    - First, the artificial intelligence required to the functioning of autonomous trains is already fully operational. Indeed, trains are not used in open environments but in controlled and constrained environments with no possible other obstacles than other trains. As a consequence, the two required steps to reach autonomous vehicles level 5[22] are not required to the functioning of autonomous trains because no obstacle is supposed to be on the rails. Furthermore, a network of several trains can be controlled directly through a single artificial intelligence that only needs to prevent the collision between two identified train;

    - Second, trains use the same energy as battery electric vehicles to function (that is electricity), but with an increased ecologic and economic performance;

    - Finally, as enlighten in the table of the previous page, autonomous trains olds all the advantages of autonomous vehicles level 5 but with a higher efficiency.

  In other words, the real ecologic transition in terms of transport do not consists in shifting from thermal vehicle to electric vehicles but consists in shifting from individual automotive towards rail transportation (that is to corresponds to the real "Mobility as a Service"). All the expected advantages of an individual battery electric vehicle with an autonomous level 5 used through "Mobility as a Service" are maximized with autonomous trains.

[21] "Un Bilan Litigieux", Guillaume Pitron, Le Monde diplomatique, August 2018.
[22] Second step: Understanding the situation perceived and the potential willingness of the different obstacles. Third step: Plan the trajectories of the obstacles.

2. For journeys between 0 km and 100 km

- **Developing a network of small autonomous vehicles level 4 in controlled and constrained environments**. Trains cannot not transport individuals directly in front of their houses and a rail network needs to be completed by another transport network. Automotive appears to remain the best option to answer this need, but in a form that is radically different form the actual one.

    - **Lower vehicles' weight**. Vehicles' weight is one of the two first consumption (and therefore pollution) factors with vehicles' speed. If long journeys are reserved to trains and if automotive are dedicated to journeys of less than 100 km, then automotives can be smaller with smaller weight without economic and social costs but with great ecologic benefits;

    - **Lower vehicles' speed**. Vehicles' speed is one of the two first consumption (and therefore pollution) factors with vehicles' weight. If long journeys are reserved to trains and if automotive are dedicated to journeys of less than 100 km, then automotives can be slower with smaller motors without economic and social costs but with great ecologic benefits;

    - **Avoid the trap of autonomous level 5 in open environment and focus on autonomous level 4 in controlled and constrained environment**. Today, a full autonomous vehicle is neither possible nor conceivable in an open environment. Yet, the artificial intelligence required to the functioning of fully autonomous vehicles on controlled and constrained environment is already fully operational. The turning point thus consist in considering the automotive network as a whole (that is automotive + road network and related infrastructures), rather than to only focus on the individual automotive itself. Although it is not possible to develop fully autonomous vehicles on our current old road network, it is already possible and desirable to develop fully autonomous vehicles on a new type of road network dedicated to autonomous vehicle. By adopting this strategy, the development of fully autonomous car networks can be envisaged without delay. Still, it must imperatively be coupled with a public policy of valorization of rail transport over long distances (both in freight and passenger transport) and the development of hubs intended to make the link between autonomous cars and trains (dense parking networks around railway stations in suburban areas). Finally, the development of such a new automotive network should be coupled with the new technology developments in terms of automotive infrastructures, such as wireless dynamic charging solutions for battery electric vehicles.

Both the development of rail transportation and autonomous level 4 in controlled and constrained environment requires large public infrastructure investments to succeed. This is why such a strategy can only be successful if it is leaded by ambitious, proactive and independent public policies with direct public investments to reshape the European transport infrastructure network. A start could be to set up pilot regions.

All the countries of the world will focus their public and private investments in the car itself to make it intrinsically fully autonomous, which is extremely expensive and economically, ecologically and socially absurd.

The European Union therefore has the opportunity to take a considerable lead over other countries provided that it makes sufficiently strong public investments in the right direction.

This solution - the most effective if the right investments are made - is already intuitively adopted by a few automakers. For example, the Renault-Nissan alliance is currently actively working on remote control of vehicles by operators.

1.1.1 Scope and presentation of the segment and its value chain

i. Scope of the study – Automotive electronics

The elements we consider as being part “automotive electronics” are described below:

1. **Hardware**

    a. **Electronic Control Unit (ECU)**. Embedded systems or sub-systems (including calculators) that controls one or more of the electrical functions of the vehicle. These ECU include printed circuits, semiconductors (microcontrollers/microprocessors, memories, analog inputs), connectors, cabling and other non-electronic components (packaging).

Here is the list of the most common ECUs:

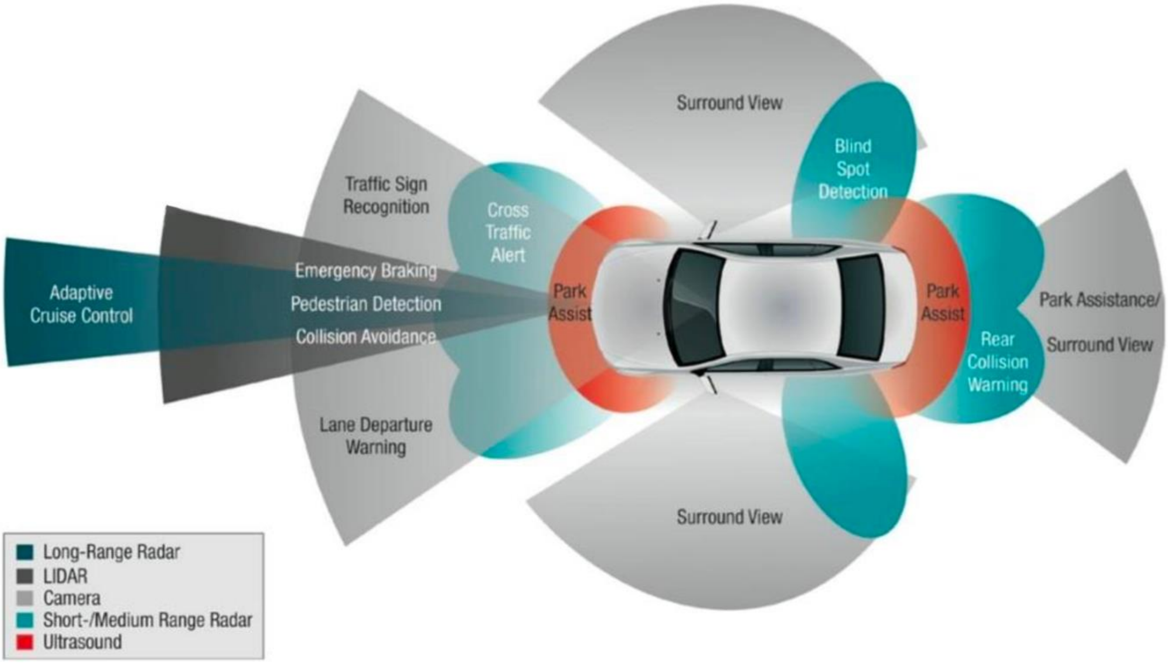
Product	Description
Electronic Control Unit	Embedded calculator or system that controls one or more of the electrical system or subsystem. It includes microcontroller, memory, analog inputs, connectics…
ECU - Engine Control Unit	Dedicated to engine control
PCM - Powertrain Control Module / TCU - Transmission Control Unit	It corresponds from time to time to a combinaison of ECU and TCU
BMS - Battery Management Systems	Dedicated to battery management
PCSU - Electric Power Steering Control Unit	Dedicated to steering control and located near the torque. ECU d’assistance de direction. Situé au niveau du convertisseur de couple (torque)
BCM - Brake Control Module	Dedicated to brake control
SCU - Speed Control Unit	Dedicated to speed control
SCU - Seat Control Unit	Dedicated to seat control
DCU - Door Control Unit	Dedicated to door control
HMI - Human-Machine Interface	Dedicated to human-machine interactions
TCU - Telematic Control Unit	It corresponds to the combination of a GPS, external interfaces for mobile communications, a micro controller and eventually a memory and/or a microprocesseur

b. **Sensors**. Embedded device that receives and responds to a signal or stimulus. Here is a segmentation of the automotive sensors by type of technology:

Types of sensors	Technology used
Camera	Optical images
Lidar - Laser Imaging Detection And Ranging	Optical laser
Radar - Radio Detection And Ranging	Echo-localization through electromagnetic waves
GNSS - Global Navigation Satellite System	Sensor that process radio signals from several artificial satellites.
IMU - Inertial Measurement Unit	Sub-system composed of accelerometers (physical sensor that measures linear accelerations), gyroscopes (physical sensor that measures rotational accelerations) and/or magnetometers (sensor that measures the change of the position of a magnetic field).
New motion sensors	Infrared sensors, ultrasounds sensors

Automotive Sensors for ADAS.

The following diagram offers a representation of automotive sensors dedicated to ADAS (Advanced Driver Assistance Systems). ADAS sensors are the sensors with the greatest growth perspective in the coming decades.



Source: Ricardo plc 2016

c. **Screens**. Principally the trip computers' screen.

2. **Embedded software.** In this study, automotive software figures are often separated from automotive electronics hardware figures. Automotive software is used by ECUs to control specific commands/applications but is also used to manage ECUs interactions with other ECUs and with external elements. Although software can be directly integrated into chips by Tier suppliers and then sold to carmakers, in most cases stand-alone software are sold to carmakers that operate the integration process.
3. **Electronic related elements** – Not considered in the figures of this study
    a. **Electric batteries**. Electric batteries are key automotive components and their importance is growing in line with battery electric vehicle development. Yet, batteries are “electric equipments” and not “electronics components and/or equipments”.
    b. **Actuators.** The great majority of the automotive actuators are electro-mechanical. In other words, they contain electronic command and/or control units, but the great majority of both their components and their added value are mechanics. Here is a list of automotive actuators: valves, flaps, radiator fans, pumps, ignition coils, etc. As global car costs are decreasing while electronic contents are rising, the necessity for carmakers to reduce marginal costs lead them to place ECUs as close as possible from actuators in order to reduce cabling costs. ECUs are therefore more and more correlated to their related actuators.

These elements -associated in various complex combinations- are used in a certain number of applications. We define 6 different applications:

- Powertrain
- Chassis
- Safety
- Security
- Comfort / Body
- Information / Entertainment

Those applications are described in the table below:

Table – Automotive electronics applications and sub-systems

Application	Potential Sub-systems
Powertrain	
Engine control	Of Cylinder Urea injector
	Of Cylinder deactivation
	Of Continuously variable valve timing
Transmission	
Stop and start system	
Electronic throttle control / Drive-by-wire, miscellaneous	
Battery	12V
	48V
	>=60V
Battery Management system	Of Regenerative braking system
	Of Sound generating system
Chassis	
ABS/ESP	
4 wheel drive	
Active roll control	
Hill-start assist	
Suspension / Active suspension	
Steering assistance	
Safety	
ADAS - Advanced Driver Assistance Systems	Camera
	Ultrasonic sensors
	Short range sensor
	Lane departure detection & warning (0)
	Collision detection & warning (0)
	Driver Alert Control / Drowsiness monitor (0)
	Blind spot detection & warning (0)
	Hands Off Detection & warning (0)
	Night vision & associated warning (0)
	Speed limiter (1)
	Cruise control (1)
	Lane correction system (2)
	Park assist (2)
	Adaptive cruise control (2)
	Automatic emergency braking system (3)
	Automatic speed adaptation from traffic signs readings (3)
	Fail operational system (3)
	DSRC (Dedicated Short Range Communications) (3)
Airbags	
Security	
Keyless entry	
Alarm	
Immobilizer	
Comfort / Body	
Body control units	
Heated seat	
Seat electronic controls	
HVAC	
Electric charger	
Active noise cancellation	
Information / Entertainment	
Screens	
Instruments	
Trip computer	
Nav. Systems	
Head-up display (HUD)	
Car audio	
Communication (GSM, etc.)	
Other entertainments systems	

 Source: DECISION Etudes & Conseil

ii. Historical evolutions of the value chain in terms of applications

Electronics experienced a slow but steady penetration into vehicle platforms, starting from the generalization of electronic ignition systems in the 1980s.

The **powertrain** is historically one of the main segments of automotive electronics in terms of value, as can be expected since electronic technologies are instrumental in increasing combustion engine performance.

After powertrain, the next big era for the deployment of electronics in the car has been **safety** and **security**. These systems have become key elements of all automobiles under the influence of regulations and consumer demand. Government safety mandates represented a major factor driving the growth of automotive electronics revenue over the period 2000-2010, in the context of public authorities' commitment to reducing casualties on the road. Traditional safety equipments such as airbags, ABS or ESP have already become natural parts of the equipment of most cars. Newer legislated systems including electronic stability control (ESC) and tire pressure monitoring systems (TPMS) have also come into play, both of which require significant electronic content.

Over the 2010-2015 period, the majority of automotive electronics' growth came from **information** (integrated GPS, live traffic information, on-board diagnostics, etc.), **comfort** (control & command systems of seats, lights, etc.), and **entertainment** applications (cabin customization, audio system customization, music and video streaming, etc.).

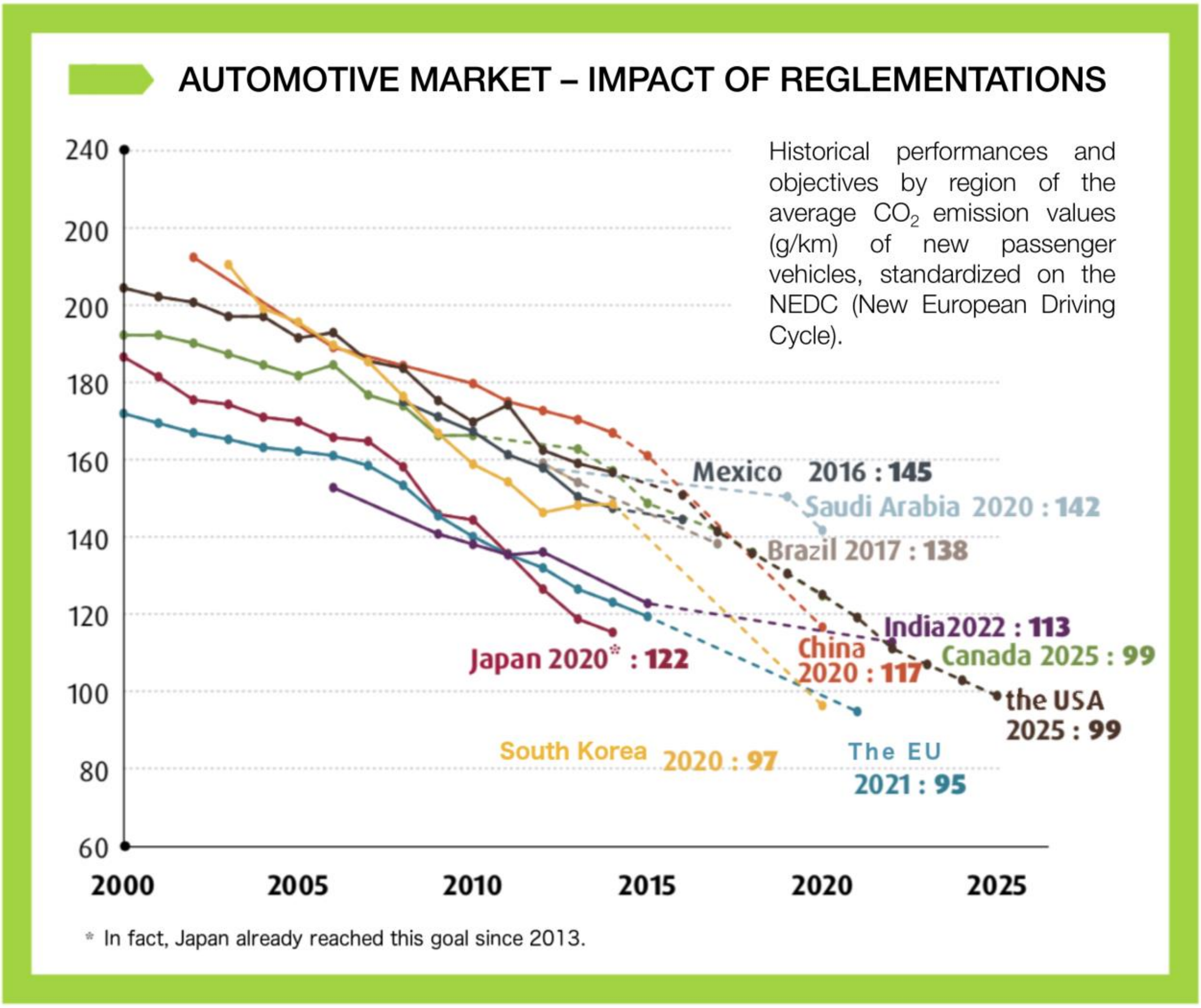
Over the 2015-2030 period, **Advanced Driving Assistance Systems (ADAS)** will definitely be the main driver of automotive electronics. First, ADAS is the application with the highest potential global leverage effect as it involves a significant number of new electronic control units, embedded software, actuators and sensors, etc. Second, ADAS development is not threatened by any potential brake (expect from a systemic global economic crisis caused by war, financial crisis, climate change, etc.), and do not require any infrastructure investment. In other words, a very significant number of electronic ADAS applications are supported by mature self-sufficient[23] technologies with sharply decreasing prices and are not integrated yet into most of the new cars globally produced. Besides, key automotive markets like Europe, Japan and North America are in the process of introducing legislation to aid the prevention of fatalities of vulnerable road users, with an emphasis on the use of vision systems, a trend that is driving the quick adoption of camera-based ADAS by car makers around the world.

Furthermore, on the short term, automakers are investing heavily in the development of engine control software and hardware (**Powertrain** and **Chassis**), in an effort to reduce the CO_2 and NOx consumption of both their petrol and diesel vehicles, so that they can continue to market them once the new European[24] and Chinese regulations will be implemented (See the graph below). As a consequence, electronics dedicated to engine control will grow on the short term (at least up to 2022). Such rise will be associated to the development of the following applications/technologies: mild hybrid (especially 48 V hybrid), injection of urea in diesel cars cylinders, cylinder deactivation systems, continuously variable valve timing, etc. However, the global demand for diesel vehicles is drastically decreasing, in line with the recent diesel emission scandals. The car manufacturers are therefore investing significant amounts to develop engine control systems dedicated to diesel vehicles when they know that in 10 years, these investments will no longer be useful because of the decline of the diesel vehicles demand.

[23] Self-sufficient means that ADAS embedded electronics, once integrated into cars, requires no infrastructure investment (in terms of roads, telecommunication networks, etc.), to operate. For instance, the development of electric cars requires the installation of a battery recharging stations network. The development of connected cars is conditioned by the development of 4G, 5G and/or long-range M2M networks… This is not the case for ADAS.

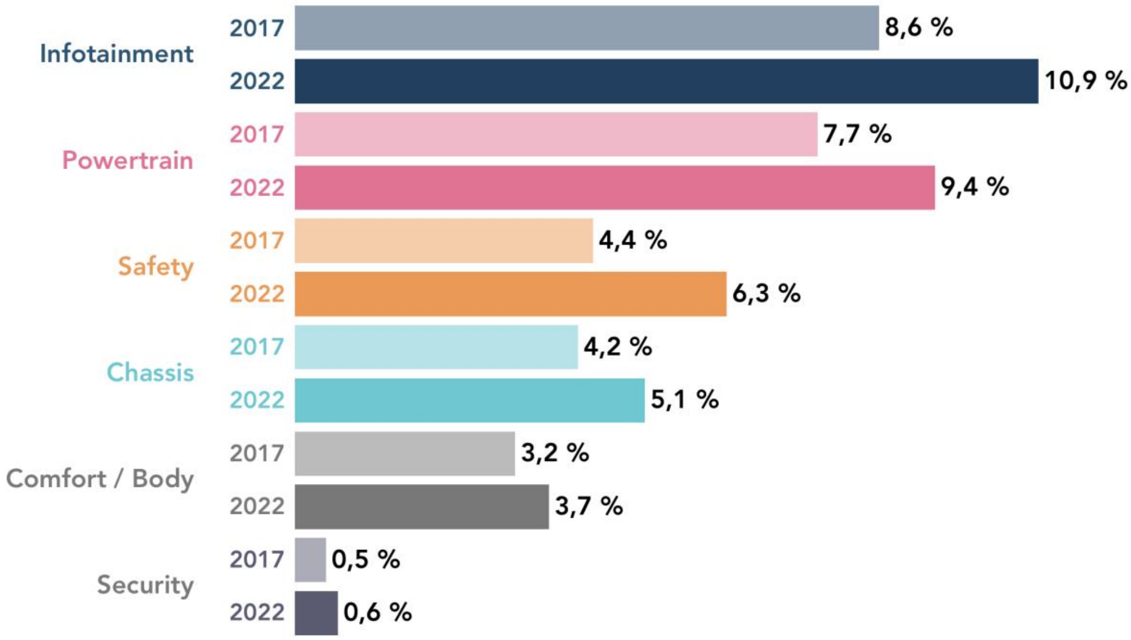
[24] The Eu regulation that will require a reduced NOx consumption to market a vehicle in the EU will enter into force on 1 January 2019.

Graph - Governments around the world are setting ambitious targets for transport vehicle CO_2 emissions



Source: International Council on Clean Transportation

Average percentage of total car cost (hardware + software)



Source: DECISION Etudes & Conseil

2017 - Automotive electronics % Average total car cost = 7%

Hardware: 21.5%

Software: 7%

2022 - Automotive electronics % Average total car cost = 36,2%

Hardware: 24.5%

Software: 11.5%

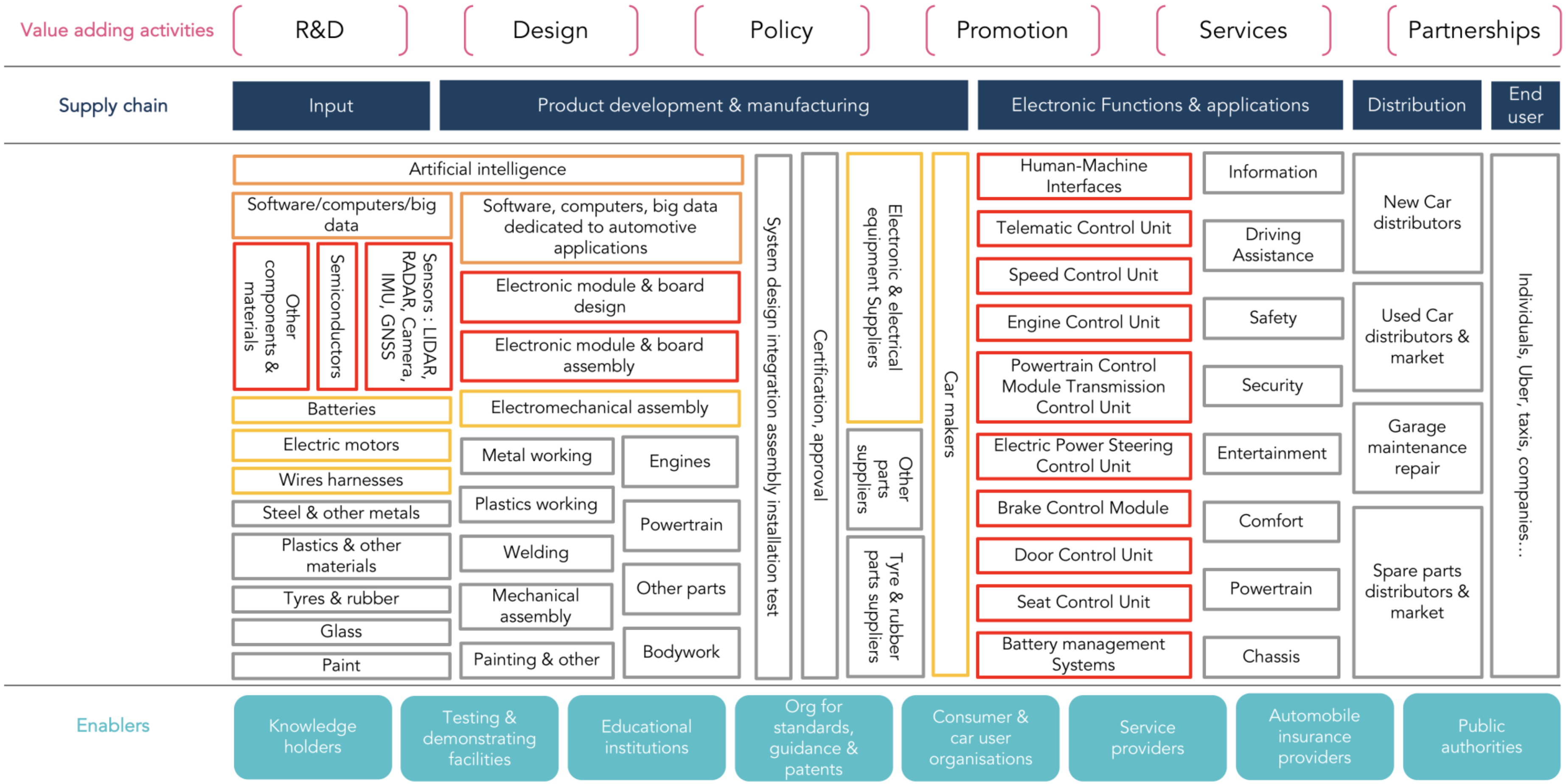
Although ADAS applications only represented 7.5% of the total value of automotive electronics in 2017, ADAS applications will contribute to 31% of automotive electronics growth during the 2017-2022 period. During the same period, Infotainment applications will contribute to 32% of automotive electronics growth. ADAS and infotainment will be the two first factors of growth during the 2017-2022 period.

Connected cars. In line with emerging new communication functions (4G, 5G, Low Power Wide Aera Networks (LPWAN), such as Sigfox and Lora), automotive extended communication functions will rise within the coming decades. Although this trend will bring more electronics contents into cars, the development of such communication networks highly depends on potential large infrastructure investments to be significant and will not be the major factor of automotive electronics contents' rise. The connected car concept will rely on increased communication capabilities between:

- Car and passenger;
- Car and car;
- Car and infrastructure networks.

Furthermore, only the most complex ADAS interactions require Vehicle-to-Vehicle (V2V) communications: Entering roundabouts, dealing with two simultaneous stops or with a priority-to-the-right rule require eye-to-eye contacts between conductors. Replacing such eye contacts requires V2V communications. As a consequence, the development of level 4 and 5 ADAS on the long run may boost the development process of connections between cars.

Here is a representation of the automotive electronics value chain:



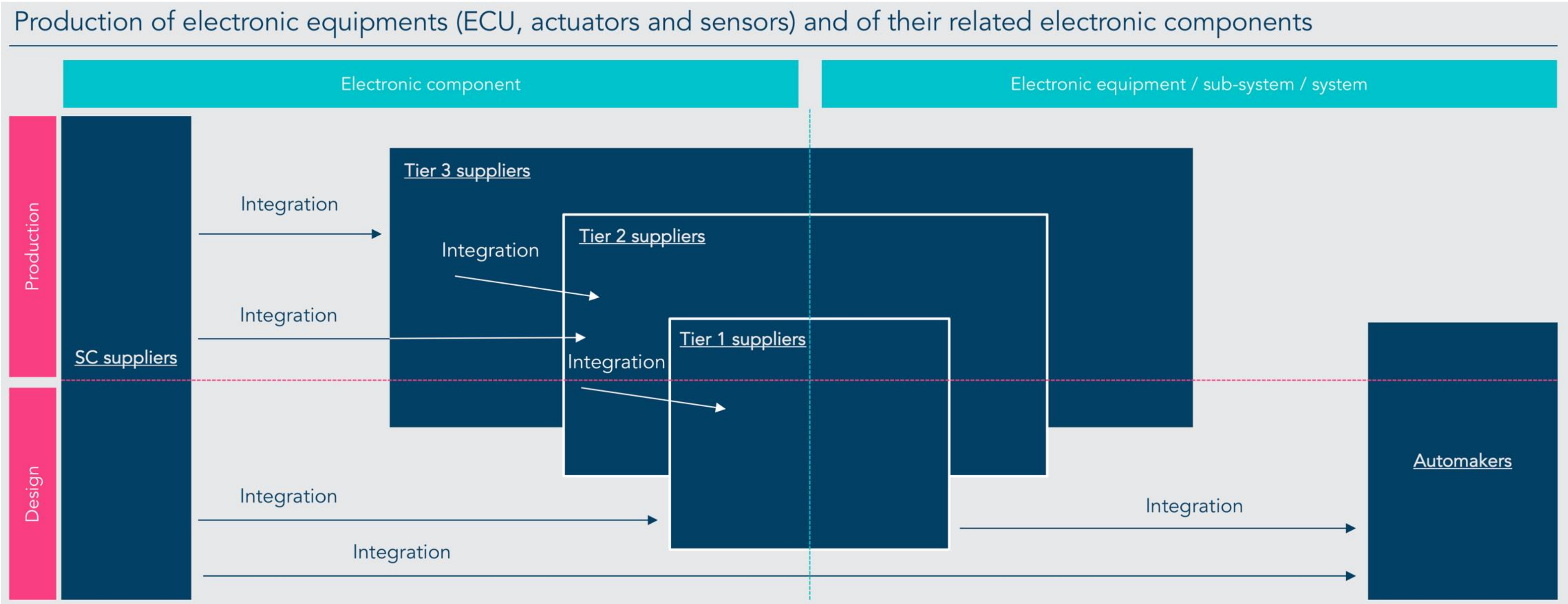
Red = Electronic components / equipments hardware

Yellow = Electric and electromechanical components / equipments

Orange = Embedded software

Grey = Other

The diagram bellow depicts the supply chain of the automotive equipments (ECU, actuators and sensors) and of their related electronic components (excluding software):



iii. The future belongs to Advanced Driving Assistance Systems (ADAS)

Today, fully-autonomous vehicles are brought to the fore by medias as one of the main drivers of automotive electronics within the next decades. Yet, there is no strict frontier between fully-autonomous vehicles and non-autonomous vehicles. Advanced Driver Assistance Systems (ADAS) are precisely the continuum of more or less complex electronics sub-systems that enable different degrees of autonomous driving. The first steps are already technically mastered by car makers and integrated to high-end, mid-range and even low-end cars. All the regions of the world are concerned as well as all the types of engines (petrol, diesel, hybrid and electric).

Advanced Driver Assistance Systems is therefore the application that will generate the largest number of new electronic devices and the greatest increase in the complexity of the interactions between these devices up to 2022.

The Society of Automotive Engineers (SAE) define 5 autonomous driving levels:

0. **Level zero – No Automation**. The driver performs all operating tasks. Driving assistance only operates through warning systems.
    - Warning systems
        - Lane departure detectors & warning systems
        - Blind spot detectors & warning systems
        - Fatigue detectors & warning systems
        - Security distance alerts (objects & events detectors, warning systems)
        - Hands off detection & warning systems
        - Night vision & associated warning systems
    - Ignition and automatic switching of the lights
1. **Level one – Driver Assistance**. Driver assistance never acts on brakes. Besides, the driver is still fully required for the monitoring of the surrounding environment. The aim of driving assistance is mainly to ease and improve the efficiency of the actions undertaken by the driver.
    - Stability control through steering assistance
    - Cruise control/limiters: Acceleration/deceleration assistance in fixed scenarios

2. **Level two – Partial Automation**. Assistance with steering and/or acceleration functions to allow the driver to disengage from some of his/her tasks. Yet, the driver must always be ready to take control of the vehicle and is still responsible for most safety-critical functions and monitoring of the environment.
    - Lane-keeping correction systems
    - Par assist
    - Adaptive cruise control: Acceleration/deceleration assistance in fixed scenarios
3. **Level three – Conditional Automation**. Complete autonomous driving modes that operate only in specific conditions/scenarios (traffic jam only, highway only, etc.). Some safety-critical functions are undertaken by the car (for instance braking), in fixed scenarios. Human attention to the road is not always required during these fixed scenarios.
    - Automatic emergency braking system
    - Automatic speed adaptation from traffic signs readings
    - Fail operational system
    - Dedicated Short Range Communications
4. **Level four – High Automation**. Complete autonomous driving, including complete assistance with monitoring of the surrounding environment. All safety-critical functions are undertaken by the car (braking, responding to any type of events, determining when to change lanes, turn, use signals, etc.). Yet, a driver is still required, the "autonomous driving mode" must be activated by the driver and a few conditions are still required (for instance, the "autonomous driving mode" may not work if the vehicle is off-road).
    - Artificial Intelligence capable of anticipating and responding to any type of event with a very low failure rate.
5. **Level five – Complete Automation**. Complete autonomous driving in any situation. No need for driver, gas pedals, brakes, steering wheel, etc.
    - Artificial Intelligence capable of anticipating and responding to any type of event with a very low failure rate.

Most automakers are currently developing vehicles at level 2. Yet, level 2 ADAS technologies already represents a huge increase in the number of electronic devices and in the degree of complexity of the interactions between these devices.

Besides, first level 3 vehicles are being commercialized since 2017 and will become significant up to 2030. In 2017, Audi launched the world's first series production L3 conditional automation system: the Audi AI traffic jam pilot, which allows the new A8 to drive in slow-moving highway traffic up to 60 km/h without any input from the driver.

Autonomous level 4 and 5 correspond to vehicles that can really be named "autonomous", because no supervision at all is required from the driver who may therefore not be hold responsible for potential accidents.

ADAS will lead to an increase of the number of electronic control units, sensors, actuators and embedded software. Yet, the prices of electronic embedded hardware and their related added value are decreasing on average. On the contrary, the price and related added value of embedded software is constantly rising.

iv. The future belongs to embedded software development

Nowadays, the added value of automotive electronics coming from software is already significant. Furthermore, embedded software is the automotive electronics segment that is currently growing at the most significant pace. The players who will most benefit from the growth of automotive electronics within the next 10 years will therefore be those who will design embedded software. Following is a description of the evolutions and associated challenges of embedded software since the beginning of automotive electronics in the 1980s.

In the 1980s, software was very difficult to alter once it was in vehicle production[25]. When they were first developed in the 1980s, electronic control units (ECUs) were housed on chips that were either erasable-programmable read-only memory (EPROM) or masked read-only memory (MROM). EPROMs were slow to program but could be erased and reused, although the process was tedious. MROMs were a better value, because they could be programmed on a large scale, but they couldn't be updated or rewritten. Wherever software was housed in these early days, this software was very difficult to alter once it was in vehicle production. Most issues were addressed via direct part replacement. Customers were notified of required changes and brought their vehicles into their dealers, where the ECUs (and the software integrated into those ECUs), were physically replaced.

In the late 1990s and early 2000s[26]. -along with engine controllers, powertrain controllers and centralized body control modules' development- **ECUs processors started using flash memory and engineers developed several paths for updates to the operating system (OS) and applications,** such as on-board diagnostics (OBD) and BDM or JTAG connection ports. During this time, designers were integrating more and more ECUs into car features and rapidly increasing their capabilities, requiring far more memory and processing power than ever before (a modern seat controller, for example, uses pulse counts and a memory switch to store a driver's preferred seat position). To meet the continually increasing demand for new features and the software to support them, the automotive industry created guidelines for three components: common library components, a common OS, and communication and diagnostics standards.

As the applications and the OSs became more sophisticated[3]**, software share in the automotive electronics added value became more and more important**. ECUs are now written in higher-level languages (such C or C++), and require more memory and processing power. Furthermore, a car today can have more than 10 million lines of code, compared to about 50,000 in the 1980s. That growth shows no signs of stopping. Software size and complexity will continue to increase as advanced driver assistance systems, autonomous vehicle mapping data and connectivity applications continue to evolve.

[25] The elements included in this paragraph are highly inspired by the intervention of John Vangelov (Manager of the embedded modem features group at Ford Motor Company), on "Software Updates in automotive Electronic Control Units" made at the workshop on "Cyber Resilience, Software update as a Mechanism for Resilience and Security" organized by the National Academies of Sciences Engineering and Medicine in Washington, DC in 2017. doi: https://doi.org/10.17226/24833.

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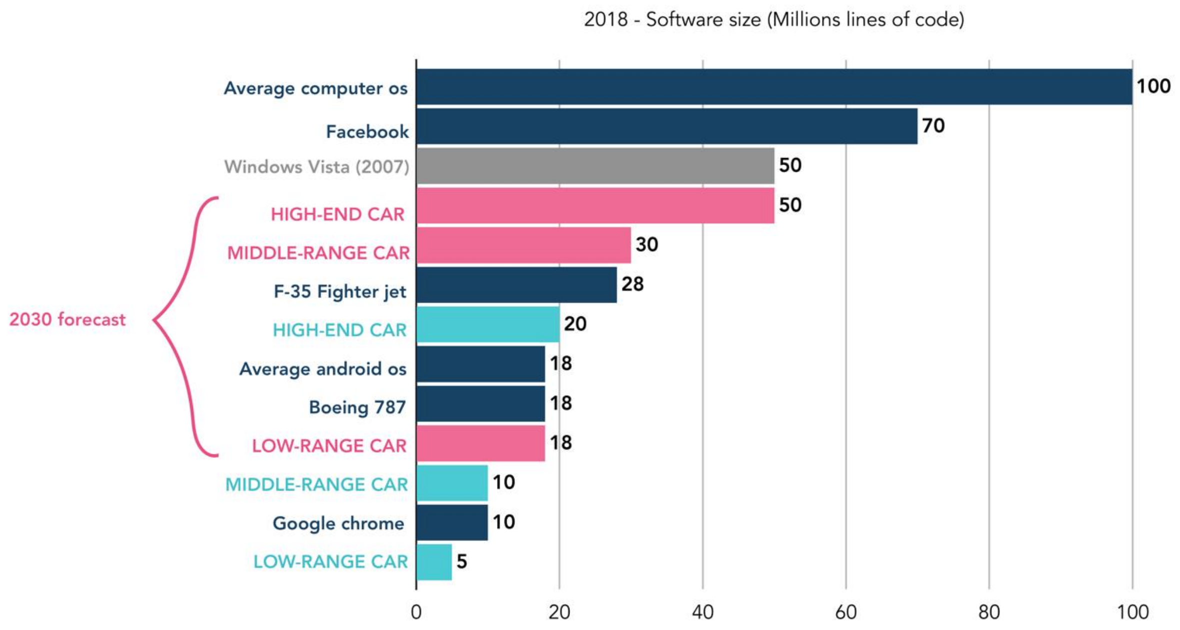
Bar chart – The rise of automotive embedded software



Source: DECISION Études et Conseil

Current main challenges for embedded software developers

Software standardization issue. The Automotive SPICE (Software Process Improvement and Capability Determination, 2004) and ISO 26262 (2011) provided first standardization elements relative to embedded software structures as well as data calibration. In 2013, Unified Diagnostic Services and ISO 15765 developed and defined diagnostic services for software update deliveries. Yet, embedded software technologies, applications and architectures drastically evolved since then and a lot of aspects of software design and integration are currently insufficiently standardized, leading to high integration costs[27]. The release of ISO26262 edition 2 is planned for late 2018 and should provide new incentives on responses to failure and potential malfunctions.

Shorten updates' time and energy consumption. As computerized as cars have become, the vast majority are powered by a lead acid battery and internal combustion engine, a power supply system that is simply not optimized for long software updates without additional charging. Very large updates could risk draining the battery, which could erase the module being updated and even deprogram some of the car's ECUs, making them inoperable. Yet, because of software integration issues, operating systems, their services and the application logic are often not optimized for software update. As a result, whenever carmakers are to update a module, they are forced to update the entire embedded system. Ideally, each specific component's software could be partitioned, but unfortunately ECUs are not written that way, and even if they were, that could create a different problem because multiple parts and subparts would all need to be individually managed and updated across a distributed system of ECUs. Therefore, the current most common solution used by automakers is to double the amount of storage to allow the car to operate the old system while the new one is being installed. This phenomenon leads to a great increase of memories integrated into cars: The automotive memory IC market is forecast to increase 73% from $ 2.9 billion in 2017 to $5.0 billion in 2021.

[27] See in particular « Deep learning in Automotive Software », Fabio Falcini, Giuseppe Lami & Alessandra Mitidieri Costanza, published by IEEE Computer Society.

Enhance remote update. Diagnostic tools are the primary method for delivering the majority of the ECUs software updates. Yet, there are several other methods, including USB (mostly for updating the “infotainment” systems), and remote methods such as Wi-Fi and cellular systems. Although Wi-Fi and cellular technologies allow for remote updates that are cheaper for automakers and more convenient for passengers, they are currently rarely used for two reasons. First, remote updates need to be designed at the stage of embedded software development and integration because it modifies embedded software’s architecture. Second, remote update ease cyber-security breaches. Indeed, in today’s cars, the infotainment ECUs network (including Wi-Fi and/or cellular interfaces) is most of the time separated from all the other ECUs in order to prevent a cyber-attack coming from Wi-Fi and/or cellular interfaces to hit powertrain & chassis actuators through their related ECUs.

Automotive electronics challenge: control the software development value chain

Most automakers subcontract all of the electronic component manufacturing. However, all of them design some of the software, so that today, the design of embedded software in cars is realized through a "distributed" value chain. In other words, software development processes are divided between automakers and their Tier 1, Tier 2 and Tier 3 suppliers.

Car manufacturers are dissatisfied with this situation for two reasons:

- On the one hand, they realize that most of the increase of added value within the next decade will come from embedded software and that it is therefore important to directly develop embedded software.

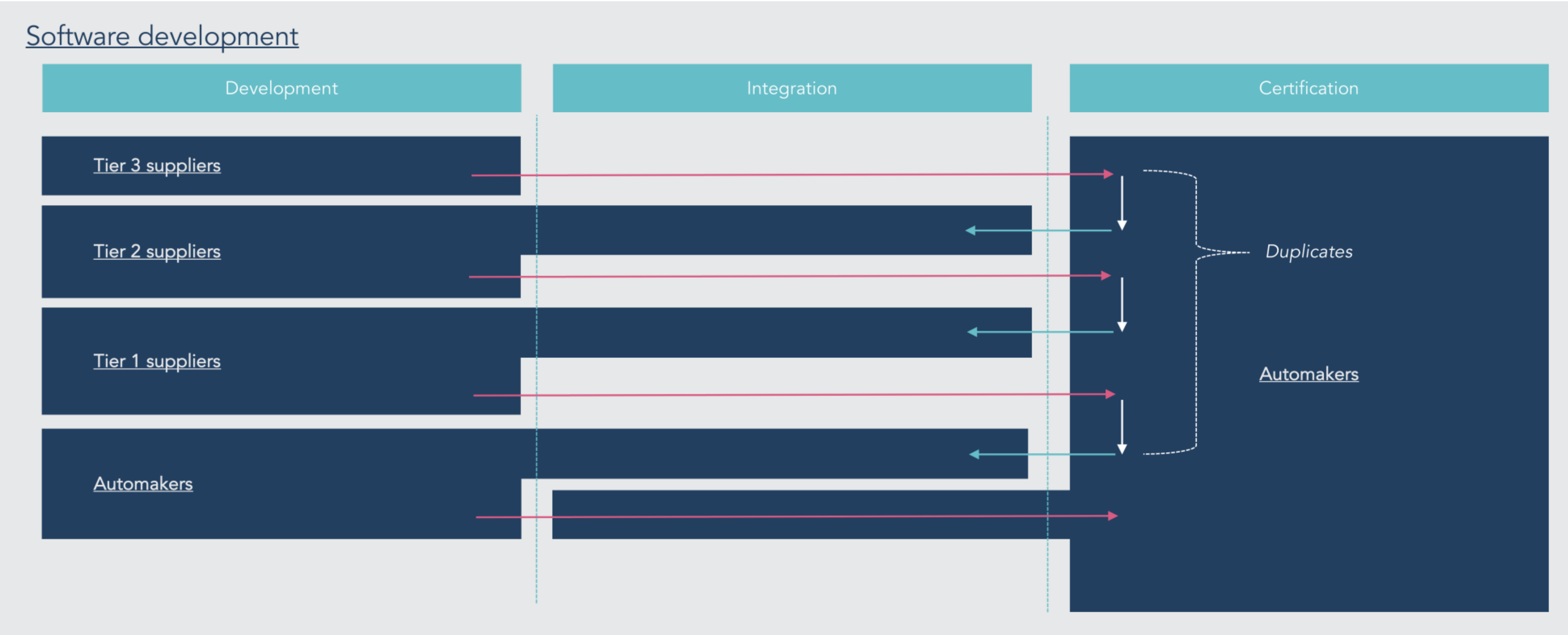
- On the other hand, they are for the moment obliged for safety reasons to certify the proper functioning of the software that each supplier sends them before sending the software back to other higher-ranking suppliers. Once they receive the new software from those higher-ranking suppliers, they have to certify for the second time the new software, etc. This creates duplicates in the certification of the work of their suppliers (see the diagram below).

Car manufacturers are therefore thriving to internalize all software development:

- By performing software development internally. For instance, this is the strategy of the Renault Group through the acquisition of 421 Intel engineers in 2017 in Toulouse and Sophia-Antipolis (France).

- By setting up Joint-Ventures and Open Innovation programs. This is for instance the strategy of the BMW Group through the development of an autonomous driving platform with Mobileye and Delphi. Mobileye, owned by Intel, is one of the leading suppliers of software that enables Advanced Driving Assistance Systems (ADAS). On its side, Delphi will leverage its expertise in automated driving and system integration. The aim of this platform is to integrate and industrialize level 3 to level 5 automated driving technology for multiple automotive OEMs.

Yet, major automotive electronic equipment suppliers, major software development companies and even the GAFA are thriving to take the lead on this embedded software value chain.


Software development
Development
Integration
Certification
Tier 3 suppliers
Tier 2 suppliers
Tier 1 suppliers
Automakers
Duplicates
Automakers

v. Impact of electric vehicles on the supply chain

The current middle term shift from diesel and petrol engine to hybrid and electric engine needs to be considered in this study and will have a significant and long-term impact on the automotive electronic supply chain.

Yet, only a few electronic embedded applications are different between a petrol/diesel car and a hybrid/electric car (2 out of 6).

- Applications impacted by the shift from diesel/petrol to hybrid/electric vehicles:
    - Powertrain;
    - Chassis;
- Applications not impacted by the shift from diesel/petrol to hybrid/electric vehicles:
    - Infotainment;
    - Comfort / Body;
    - Safety;
    - Security.

In addition:

- Electric vehicles production (Battery electric vehicles) only accounted for 1% of the world automotive production in 2017. Despite annual growth rates of 30% to 50%, the electric vehicles production is expected to represent less than 2% of the world production up to 2022[28];
- Hybrid vehicles production (Full Hybrid Electric Vehicles and Plug-in Hybrid Electric vehicles) only accounted for 2% of the world automotive production in 2017 and should not represent more than 5% of the world production up to 2022[29].

[28] Source: Scenario green constraint BIPE / PFA
[29] Source: Scenario green constraint BIPE / PFA

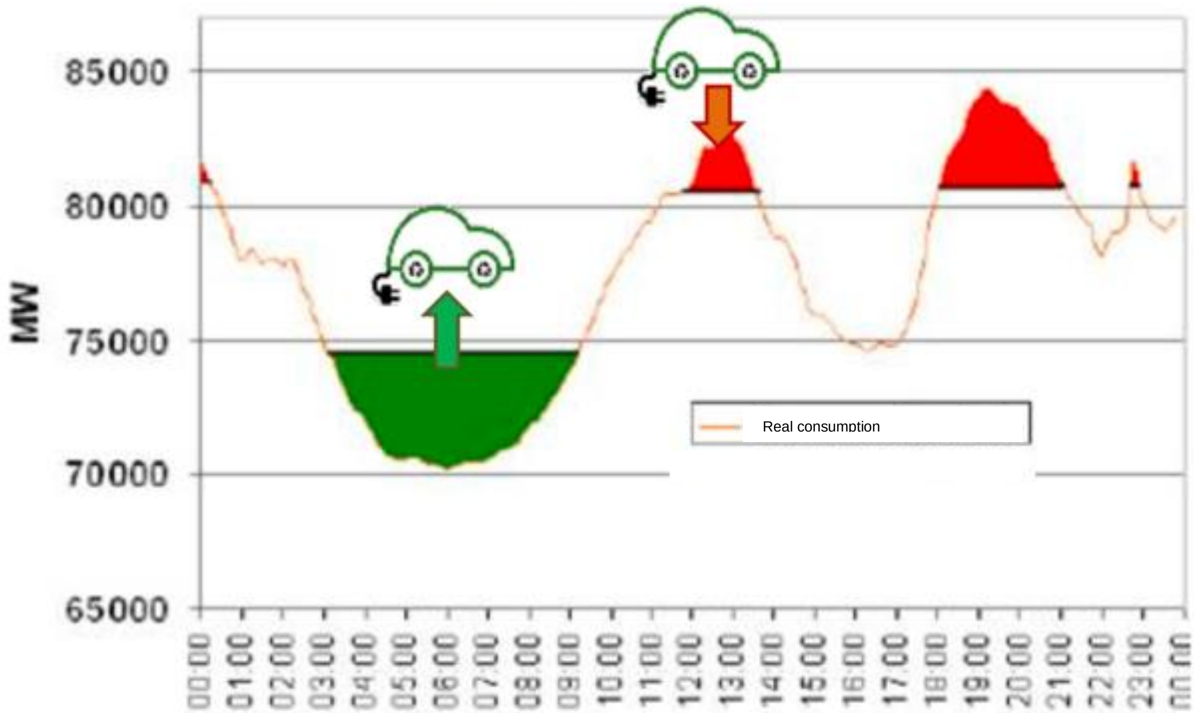
vi. Towards Mobility as a Service (MaaS)

What really is at stake with the development of ADAS and electric vehicles is not only a technical evolution, but a complete transition of the automotive industry from an energy-centered model towards a decentralized model and from a personal-cars model towards a shared-vehicles-services model.

First, once sufficient level of autonomous driving will be reached, cars will be able to park alone and to reach any destination alone. Why in such a situation having a personal parking place and a personal car? Why should the car remain in a parking while its personal owner does not need it when it could autonomously drive to another destination to transport another person from one place to another? Autonomous driving will put an end to business models centered on selling a personal car to a client for a long period of time.

The exact same phenomenon can be observed with electric vehicles which require to be often recharged. Recharging an electric vehicle is incompatible with personal car ownership. Indeed, a worker can only recharge its car between 12:00 and 14:00 or between 18:00 and 1:00, that is exactly during electricity consumption peaks (see the diagram below). No technological solution is possible to overcome that issue. Yet, moving from personal-cars models to shared-vehicles-services would directly solve it, allowing cars to recharge whenever no passenger need to be transported during the day and when electricity consumption is low.

Diagram – Electric production vs consumption (French typical day 2015)



There is thus a convergence between the development of autonomous driving and the development of electric vehicles to solve todays automotive consumption and pollution challenges.

As a consequence, new business models already emerge. In 2017, 69% of the French automotive sells were leasing with purchasing options. That depicts a first move from personal cars to shared cars.

Energy, telecom, and retail operators may be interested in developing customized and innovative services based on electric cars. Finally, transport operators, such as railway or airline operators, may also be interested in developing such type of services in order to provide end-to-end transport solutions to their customers.

1.1.2 Figures, Europe 2010-2017, world and main countries

i. Methodology notes

- The automotive figures presented in the following automotive report corresponds to a “large acceptation” of automotive electronics. Indeed:
    - The “turnover” figures correspond to the price of the electronic sub-systems sold by the automakers to the customers. Therefore, this turnover includes the turnover of automotive electronics generated by the automakers (including their margin). Contrary to the calculation methodology of the other end-user reports, it does not only correspond to the price of the automotive electronics sub-systems sold by electronics suppliers (Bosch, etc.);
    - The “employment” figures correspond to the sum of the automotive electronics employees at every step of the automotive electronics value chain (automakers + automotive electronics tier 1, 2 and 3 suppliers + automotive semiconductors suppliers). In the other end-user reports of this study, the “employment” figures (mostly measured by the Eurostat SBS industry database), correspond to the equivalent of the employees of the automotive electronics tier 1 suppliers only (excluding automakers, automotive tier 2 & 3 suppliers and automotive semiconductors suppliers).

- As a consequence, in order to be more precise in the measure of the global electronic equipment production and to ease the comparison between the different segments, the figures corresponding to “Automotive electronics” presented in the pyramids and in the overviews have been adapted to feat the methodology of Eurostat used in the other end-user segments. This is the reason why:
    - In 2017, the estimated world production of automotive electronics in this automotive report is 530 B €;
    - In 2017, the estimated world production of automotive electronics used in the pyramids and in the electronics equipments comparisons is 306 B €.

A. National statistics

National public statistics only provide a few uncompleted information regarding automotive electronics. As a consequence, an internal database has been set up to cover the entire scope of the study.

The **OECD** only provides data at the aggregate level of “Motor vehicles, trailers and semi-trailers”. Such data are therefore not relevant to study automotive electronics.

Eurostat only provides the following data:

- From the SBS industry and construction database:
  - Methodology: The SBS industry database present data from any EU company that operates 50% or more of its turnover in the related NACE 2 classification.
  - Fields covered:
    - NACE Code 2931: Manufacture of electrical and electronic equipment for motor vehicles
  - Variables available:
    - Number of employees
    - Turnover
    - Added value at factor costs
    - Net investment in tangible assets
  - Those figures cover not only the automotive electronic equipments, but also the automotive electrical equipment, which are out of scope. Furthermore, a significant number of automotive electronic equipments are classified in other segments (NACE codes) such as “Manufacture of electronic components” (NACE Code 2611). Yet, this indicator gives orders of magnitudes and trends at the European country level.

- From the Prodcom database (providing “Factory-gate” information only):
  - Methodology: Prodcom’s data present the volume of units produced by factories (only) and the related average price of every product.
  - Fields covered:
    - Vehicle speed indicators
    - Electric burglar or fire alarms and similar apparatus for motor vehicles
  - Variables available:
    - Production Value (M €)
    - Production Quantities (M units)
    - Average Selling Prices (ASP)

Regarding **the USA**, the US census only provides data automotive audio equipments (excluding speakers).

Finally, **national statistics from other countries** (Japan, Korea, China, etc.) are either not public or do not provide details for automotive electronics equipment/components.

A. DECISION's statistics

As a consequence, we have built new and dedicated hard data that allow to precisely position the European Union in the World and to depict the production of the different member states. To build such hard data, we have analyzed each annual report and other relevant documents of each leader in each segment of automotive electronics.

- We have collected hard data on the top 10 global automakers, as well as on BMW and Daimler. Altogether, those 12 automakers accounts for 73% of the world motor vehicle production (in unit).
- We have collected hard data on the top 16 global automotive electronics equipment manufacturers (Bosch, Continental, etc.), that represent 34% of the global automotive electronics equipments' production (in euros).

Thanks to those specific data, we are able to present detailed data on:

0. **Automotive electronics**. We define automotive electronics as the sum of the estimated automotive electronics activities of the Tier 1 automotive electronics suppliers in the World. We also include in automotive electronics the estimated automotive electronics activities of automakers. Apart from a very few numbers of exceptions, automakers never assemble automotive electronics equipments internally. As a consequence, automakers are negligible in terms of automotive electronics factory production. Yet, automakers' automotive electronics engineering activities represent around 1/3 of the global automotive electronics engineering.
1. **Automotive electronics – Office activities**. We provide specific figures for automotive electronics office activities. Offices activities are defined as engineering offices and headquarters only (factories, sales offices, design offices, offices dedicated to test drive as well as engineering offices specifically dedicated to motorsport are excluded from the analysis). Offices activities are carried out by skilled employees (principally by engineers). The location of offices activities is also highly correlated with the locations of the know-how and the patents.
2. **Automotive electronics – Factories activities**. We provide specific figures for automotive electronics factory activities. Factories activities are defined as the activities from factories (engineering offices, headquarters, sales offices, design offices, offices dedicated to test drive as well as engineering offices specifically dedicated to motorsport are excluded from the analysis). Factory activities represent the majority of automotive electronics activities both in terms of employment and turnover.

For every type of activity, we present the following variables:

- **Turnover (M €)**. The turnover estimated is supposed to correspond to the exact total turnover generated by the automotive electronics industry without any double-counting. Indeed, it corresponds to the sum of the final automotive electronics goods and services sold. Below is the formula used to calculate the turnover:

  Global turnover automotive electronics =

  Sum (Global turnover of automotive electronics from Tier 1 automotive electronics suppliers) +

  Sum (Global turnover of engineering offices and headquarters activities from automakers dedicated to automotive electronics)

  As we can notice in the formula above, turnovers in automotive electronics from Tier 2 and Tier 3 automotive electronics suppliers as well as turnovers of semiconductor producers dedicated to automotive are not considered in the figures presented below in this chapter. This methodology is designed to prevent any double-counting. Indeed, turnovers of automotive Tier 2 suppliers, automotive Tier 3 suppliers and of semiconductor producers are already considered into turnovers of automotive Tier 1 suppliers.

- **Number of employees (full-time or part-time but excluding internships)**. The number of employees estimated corresponds to the exact total number of employees from automotive electronics. Below is the formula used to calculate the number of employees in the figures that are presented below:

  Global number of employees in automotive electronics =

  Sum (Global number of employees in automotive electronics from Tier 1 automotive electronics suppliers) +

  Sum (Global number of employees in engineering offices and headquarters of automakers dedicated to automotive electronics) +

  Sum (Global number of employees in automotive electronics from Tier 2 and Tier 3 automotive electronics suppliers) +

  Sum (Global number of employees in automotive electronics from semiconductor producers)

Finally, for every type of activity, we present the following geographic repartition:

- The global breakdown in 8 regions:

    1. The EU (28-member states);
    2. Rest of Europe: Russia, Turkey, Switzerland, Iceland, Norway, Albania, Bosnia and Herzegovina, Liechtenstein, Moldova, Serbia and Montenegro, Ukraine, Belarus, Faroe Islands;
    3. North America: The USA, Canada and Mexico;
    4. China;
    5. Japan;
    6. Other Asia & Pacific;
    7. South America;
    8. Rest of the world: Africa (including Madagascar), Middle-east including Israel, Central Asia (Pakistan, Afghanistan, Iran, Kazakhstan, Kirghizstan, Tajikistan, Turkmenistan, Uzbekistan, Georgia, Azerbaijan, Armenia).

- The repartition of the main countries at the global scale;
- Inside the European Union, the breakdown in the 28-member states.

It is important to understand that the results of this statistical methodology from DECISION result from a broader definition of "end-user electronic value chain" than the one used in public statistics in the other end-user reports (PC & data processing for instance)[30]. This is the reason why the figures presented may seem very significant relatively to the other end-user report and this is the reason why the figures of automotive electronics have been adapted in the overview to feat the methodology used in the other end-user reports.

- **In 2017, the estimated world production of automotive electronics in this automotive report is 530 B €;**
- **In 2017, the estimated world production of automotive electronics used in the pyramids and in the electronics equipments comparisons is 306 B €.**

[30] See the explanations in the introduction of this methodology note.

i. Global automotive electronics production and growth

Market Size

Automotive electronics production represented 306 billion euros in 2017[31], that is **16% of the world electronic production**[32]. In other words, Automotive is the fourth global electronic market in 2017 **after telecommunication (€ 405 M, 21%), industrial (€ 383 M, 20%) and data processing (€ 379 M, 19%).**

Growth

Automotive electronics production registered a strong compound annual growth rate (CAGR) within the 2012-2017 period compared to the other electronics applications (Audio-Video, Home appliances, Data processing, Telecommunications, Aerospace/Defence/Security, Industrial/Medical), with a CAGR of 6%. Automotive electronics benefited from the third highest CAGR after Health & Care (10% CAGR), and the industrial segment (7.6% CAGR).

Furthermore, automotive electronics production is expected to register the highest CAGR within the **2017-2022** period compared to the other electronics applications, with an estimated **CAGR of 10%**[33].

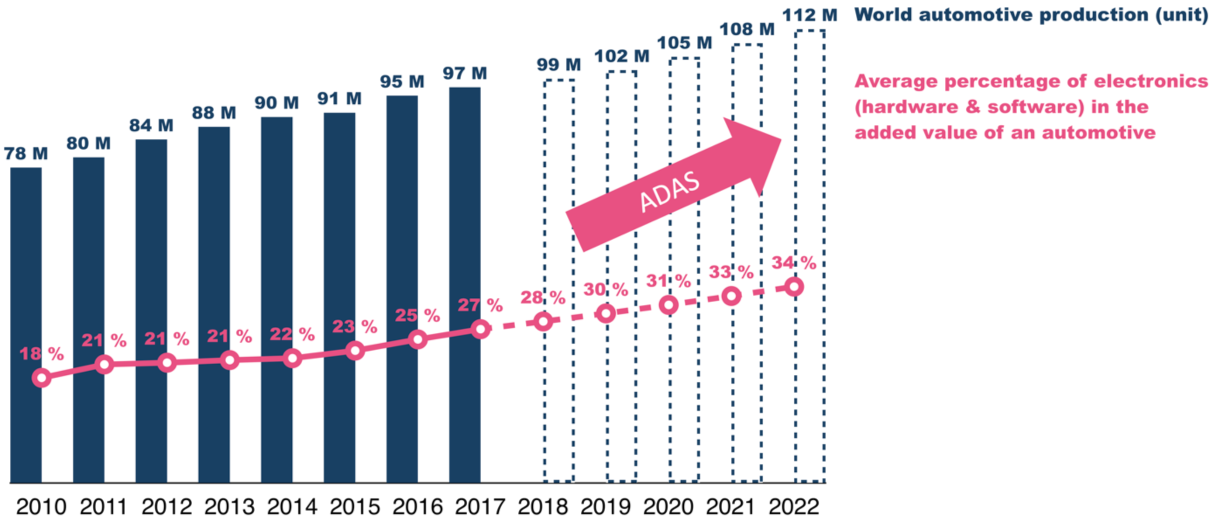
As a consequence, automotive is expected to represent € 493 B by 2022 and to outreach the telecommunication and the PC & data processing segments by 2022-2025.

The global automotive electronics production is driven by two main factors:

- The world automotive production in unit, driven by emerging markets, benefits from significant growth with an estimated average annual growth rate of more than 3% over the 2017-2022 period;
- The average percentage of electronics in the added value of an automotive will also benefits from high growth over the period 2017-2022 (5% CAGR). Its main driver will be Advanced Driving Assistance Systems (ADAS) but also Infotainment and the main beneficiaries of this growth will be embedded software developers.

[32] DECISION Études & Conseil
[33] DECISION Études & Conseil, IC Insights

Graph - The two drivers of automotive electronics production growth



Source: DECISION Études & Conseil, IOMVM, Eurostat, OECD

The average electronic cost by car is rising while the average total car cost is decreasing. Indeed, the average car production cost (in euro) slightly but steadily decreased over the 2010-2017 period with a compound annual growth rate of -1.3%. Over the same period, the average automotive electronics production costs by car rose with a compound annual growth rate of 2.2%. In other words, **the average electronic cost by car is rising while the average total car cost is decreasing**.

Table - Global Automotive growth

	Eurostat SBS industry database - 2015	DECISION - 2017
Turnover (€M)	34 400	**145 500**
Number of employees	238 408	**1 162 000**
Added value at factor costs (€M)	7 900	**38 505**
Net investment in tangible assets (€M)	1 300	**6 336**

Source: DECISION Etudes & Conseil, OECD, Eurostat, IOMVM, Industrial & Expert interviews

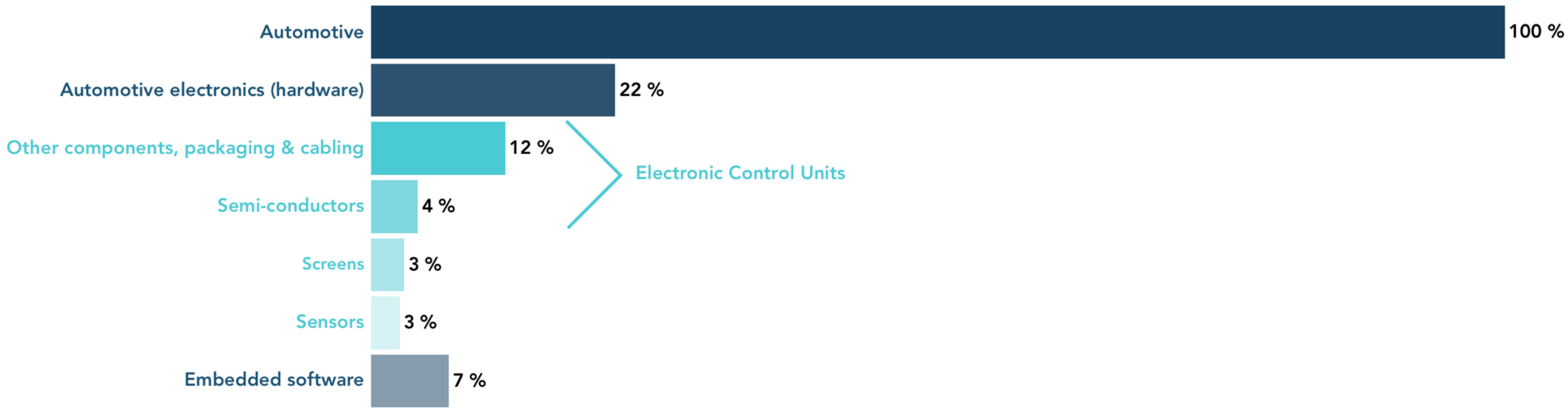
ii. Global automotive electronics production by electronic segment

The following serie of graphs provides a breakdown of the global automotive electronics production by segment of electronic equipments/components.

Automotive embedded software:

- In 2017, **automotive embedded software market** accounted for € 63 B;
- In 2017, **automotive embedded software development from automakers** (internal development), generated a global turnover of € 11 B, that is 18% of the global turnover generated by automotive embedded software development (€ 63 B). The same year, automotive embedded software development from automakers employed 21 000 high-qualified developers worldwide;
    - **The EU's position**. In 2017, automotive embedded software development from automakers in the EU generated a turnover of € 3 B (27% of the global embedded software turnover from automakers) and represented 6 500 high-skilled jobs (31% of the global number of automotive embedded software developers from automakers);
    - In other words, the EU is the first region of the world in terms of turnover generated by automotive embedded software development from automakers. Below is the regional breakdown:
        - The EU (27%), of which Germany (16%) and France (7%);
        - North America (24%) / The USA (24%);
        - Japan (19%);
        - China (13%);
        - Other Asia & Pacific (11%), of which South Korea (6%);
        - Rest of Europe (3,6%);
        - South America (1,2%);
        - Rest of the world (1,2%).
- The **automotive embedded software** market of automotive supplier therefore represented 52 B € in 2017.

Diagram: 2017 – Automotive electronics segments (hard and soft) % Automotive production value (2017)



<u>2017 - Automotive electronics % Average total car price</u> = 7%

Hardware: 21.5%

Software: 7%

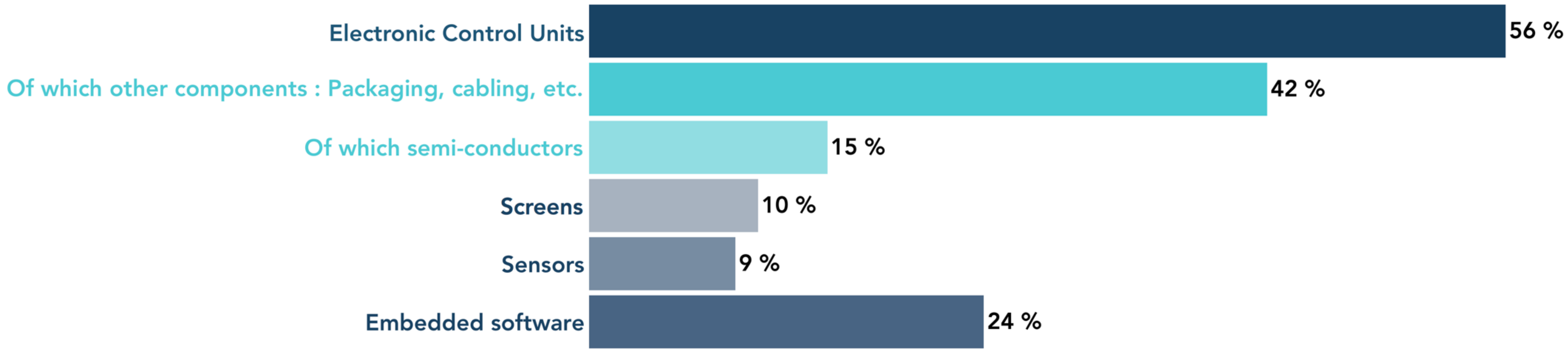
<u>2022 - Automotive electronics % Average total car price</u> = 36,2%

Hardware: 24.5%

Software: 11.5%

Source: DECISION Études et Conseil

Diagram: 2017 – Automotive electronics segments (hard and soft) % Automotive electronics production value



Source: DECISION Études et Conseil

iii. The EU's position in the World

A. Geographic repartition of automotive electronics (hardware + software) by region

a. Global repartition

The following diagrams provide detailed information on the regional repartition of automotive electronics production (hardware & software).

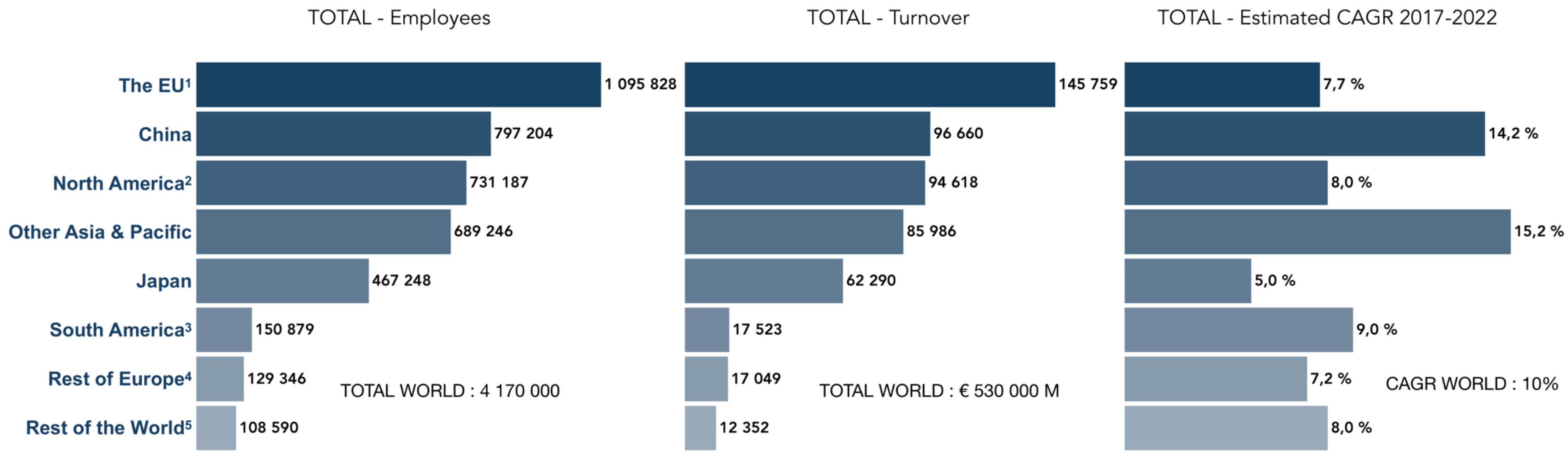
Analyses:

- In 2017, the EU automotive electronics turnover accounted for 28% of the global automotive electronics turnover. In other words, in 2017, the EU was the first region in terms of automotive electronics production (hardware and software). In line with its high automotive electronics turnover generated in the EU, 26% of the global employees in automotive electronics were located in the EU in 2017. The EU is therefore very well positioned in this huge and fast-growing end-user segment, which makes it a critical sector for the EU;

- Yet, the two first regions in terms of growth are China and South East Asia (excluding Japan), with estimated 2017-2022 CAGR of respectively 14.2% and 15.2%. As a consequence, China's production is expected to correspond to 90% of EU's production by 2022;

- Asia as a whole (that is China, Japan and rest of Asia & Pacific), represented 43% of the global production in 2012, represents 46% of the global production in 2017 and is expected to represent 50% of the global production in 2022.

Bar charts – 2017 – Automotive electronics – Regional repartition



[1] 28 member states, Germany represents 54% of the total employees and production (in euro)
[2] North America = Canada, the USA and Mexico. More than 90% of the employees are located in the USA, the rest in Canada and no employees are located in Mexico.
[3] Mainly in Brazil
[4] Mainly in Russia and Turkey
[5] Mainly in Israel and Iran

Automotive electronics: Turnover of automakers and automotive Tier 1 suppliers dedicated to automotive electronics. Employees of automakers, of automotive Tier 1, Tier 2 and Tier 3 suppliers and of semiconductor suppliers dedicated to automotive electronics.

Source: DECISION Études & Conseil

b. Office activities

The following diagrams provide detailed information on the regional repartition of automotive electronics production (hardware & software), in terms of office activities only.

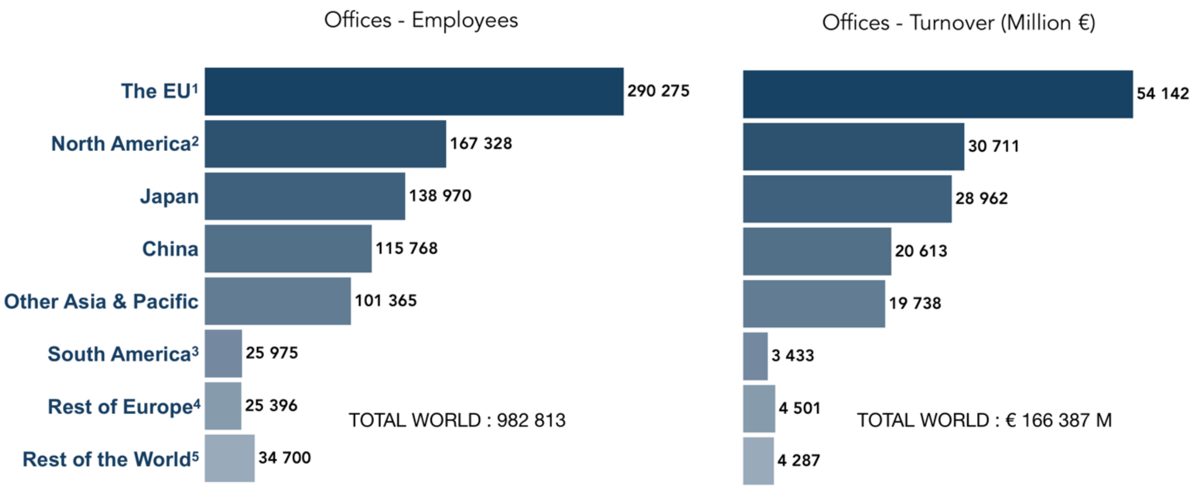
Analyses:

- In 2017, the EU automotive electronics turnover generated by office activities (engineering offices and headquarters), accounted for 33% of the global automotive electronics turnover from office activities. In other words, in 2017, the EU was the first region in terms of automotive electronics office activities (hardware and software). In line with this high automotive electronics turnover generated in the EU, 32% of the global employees in automotive electronics engineering offices and headquarters were located in the EU in 2017. The EU is therefore very well positioned in terms of skilled jobs, engineering and R&D activities in automotive electronics;

- Yet, China can already be considered as the fourth region in terms of automotive electronics skilled jobs and automotive electronics generated by engineering offices and should become the first country (ahead of Japan, the USA and Germany), by 2030;

- Asia as a whole (that is China, Japan and rest of Asia & Pacific), represents 42% of the global turnover generated by engineering offices and headquarters in automotive electronics in 2017.

Bar charts – 2017 – Automotive electronics – Regional repartition - Offices



[1] 28 member states, Germany represents 54% of the total employees and production (in euro)
[2] North America = Canada, the USA and Mexico. More than 90% of the employees are located in the USA, the rest in Canada and no employees are located in Mexico.
[3] Mainly in Brazil
[4] Mainly in Russia and Turkey
[5] Mainly in Israel and Iran

Automotive electronics office activities: Turnover of automakers and automotive Tier 1 suppliers dedicated to automotive electronics in engineering offices and headquarters. Employees of automakers, of automotive Tier 1, Tier 2 and Tier 3 suppliers and of semiconductor suppliers dedicated to automotive electronics in engineering offices and headquarters. Factories and sales offices are excluded from the analysis.

Source: DECISION Études & Conseil

a. Factories' activities

The following diagrams provide detailed information on the regional repartition of automotive electronics production (hardware & software), in terms of factories only.

<u>Analyses:</u>

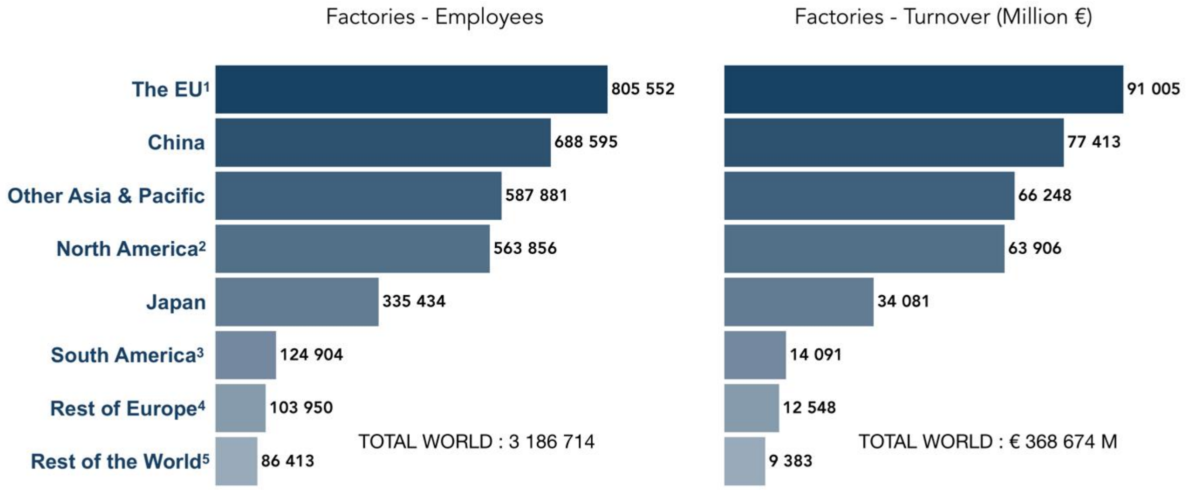
- In 2017, the EU automotive electronics turnover generated by factories, accounted for 25% of the global automotive electronics turnover. In other words, in 2017, the EU was the first region in terms of automotive electronics turnover generated by factories (hardware only). In line with this high automotive electronics turnover generated in the EU, 24% of the global employees in automotive electronics factories were located in the EU in 2017. The EU is therefore very well positioned not only in terms of skilled jobs, engineering and R&D activities in automotive electronics, but also in terms of production from factories;

- Yet, China can already be considered as the second region in terms of automotive electronics turnover generated by factories and should overtake the EU's position by 2030;

- Asia as a whole (that is China, Japan and rest of Asia & Pacific), represents 48% of the global turnover generated by factories in automotive electronics in 2017.

-

Bar charts – 2017 – Automotive electronics – Regional repartition - Factories



[1] 28 member states, Germany represents 54% of the total employees and production (in euro)
[2] North America = Canada, the USA and Mexico. More than 90% of the employees are located in the USA, the rest in Canada and no employees are located in Mexico.
[3] Mainly in Brazil
[4] Mainly in Russia and Turkey
[5] Mainly in Israel and Iran

<u>Automotive electronics factory activities:</u> Turnover of automotive Tier 1 suppliers' factories dedicated to automotive electronics. Employees of automotive Tier 1, Tier 2 and Tier 3 suppliers and of semiconductor suppliers dedicated to automotive electronics in factories. Engineering offices, headquarters, sales offices, design offices, offices dedicated to test drive as well as engineering offices specifically dedicate to motorsport are excluded from the analysis.

Source: DECISION Études & Conseil

B. Geographic repartition of automotive electronics (hardware + software) by country

The following diagrams provide detailed information on the country repartition of automotive electronics production (hardware & software): global figures, office activities only and factories' activities.

- **Global ranking**

  - In 2017 at the global scale, the automotive electronics production was clearly dominated by four countries: China, the USA, Japan, and Germany. Their cumulated turnover accounted for 53% of the global turnover in 2017;

  - The automotive electronics turnovers generated by each of these four countries are quite similar in 2017. Indeed, German's automotive electronics turnover (the fourth country) represented 56% of China's automotive electronics turnover (the first country) in 2017;

  - The other countries are quite negligible in comparison with those four leaders. Indeed, India's automotive electronics turnover (the fifth country) represented only 3,2% of the global automotive electronics turnover in 2017;

  - For already more than 10 years, China is the global leader in terms of automotive electronics. In 2017, China's turnover represented 18% of the global turnover and almost 20% of the people employed in the world in automotive electronics were located in China.

- **Office activities**

  - In 2017 at the global scale, the automotive electronics office activities (engineering offices and headquarters), were clearly dominated by four countries: China, the USA, Japan, and Germany. Their cumulated turnover from office activities accounted for 59% of the global turnover from offices activities in 2017;

  - The automotive electronics turnovers generated by each of these four countries are quite similar in 2017. Indeed, China's automotive electronics turnover from office activities (the fourth country) represented 71% of Japan's automotive electronics turnover from office activities (the first country) in 2017;

  - The other countries are quite negligible in comparison with those four leaders. Indeed, France's automotive electronics turnover from office activities (the fifth country) represented only 29% of China's automotive electronics turnover from office activities (the fourth country) and 3.6% of the global automotive electronics turnover from office activities in 2017;

  - Despite China's impressive growth for already more than 10 years, Japan, Germany and the USA remain the three world leaders in terms of engineering, R&D and supporting functions in automotive electronics;

  - Yet, China can already be considered as the fourth region in terms of automotive electronics skilled jobs and automotive electronics generated by engineering offices and should become the first country (ahead of Japan, the USA and Germany), by 2025.

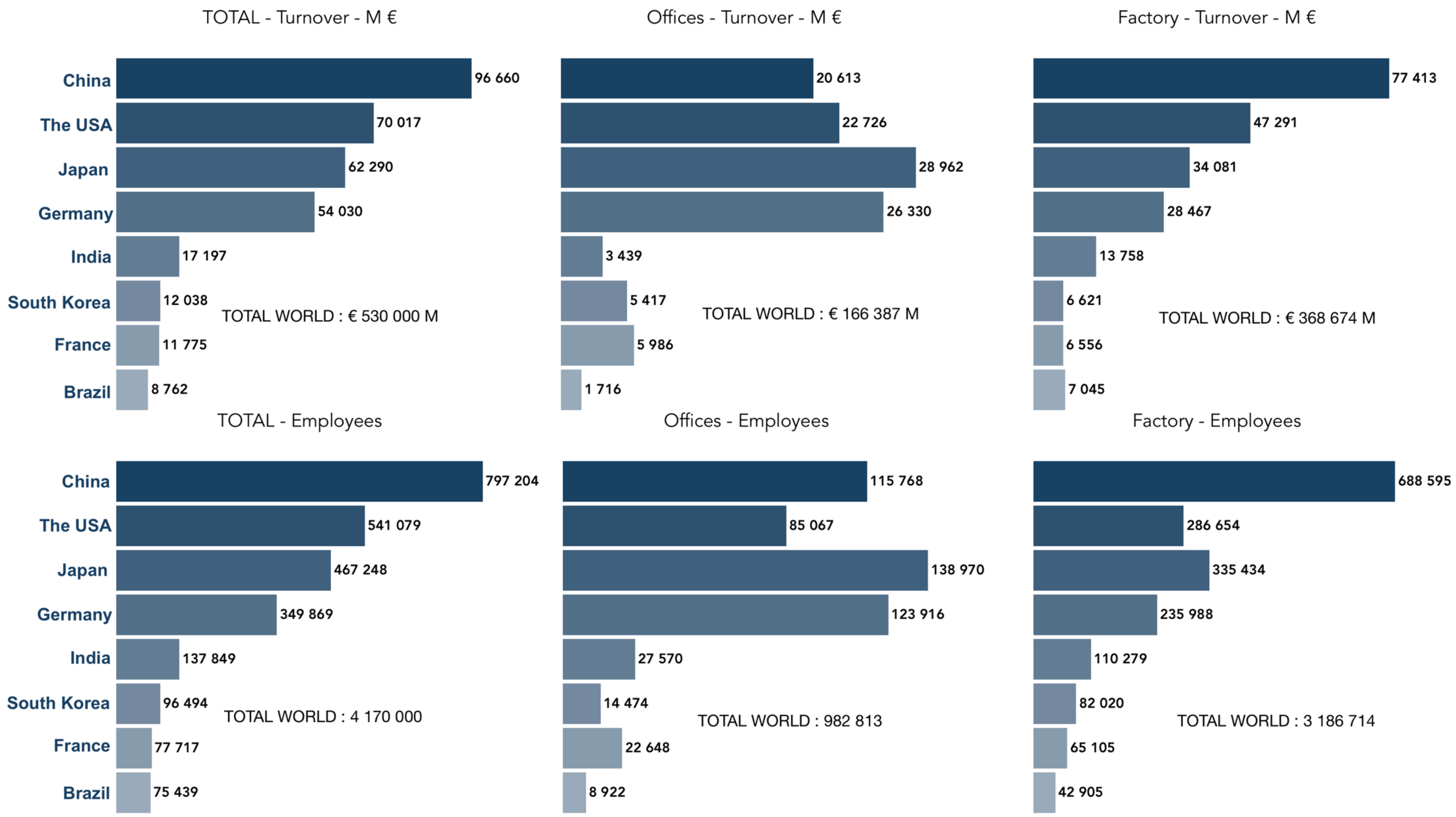
- **Factories activities**

    - For already more than 10 years, the global automotive electronics factory production is clearly dominated by one country: China. The turnover generated by Chinese factories' production accounted for 21% of the global factory production in 2017;

    - The three other main players are the USA, Japan, and Germany. Their turnover from factory production accounted respectively for 13%, 9.2% and 7.7% of the global turnover from factory production in 2017;

    - The other countries are quite negligible in comparison with those four leaders. Indeed, India's automotive electronics turnover from factory production (the fifth country) represented only 3.7% of the global automotive electronics turnover from factory production in 2017.

Bar charts – 2017 – Automotive electronics – Country repartition



Source: DECISION Études & Conseil

Automotive electronics: Turnover of automakers and automotive Tier 1 suppliers dedicated to automotive electronics. Employees of automakers, of automotive Tier 1, Tier 2 and Tier 3 suppliers and of semiconductor suppliers dedicated to automotive electronics.

Automotive electronics office activities: Turnover of automakers and automotive Tier 1 suppliers dedicated to automotive electronics in engineering offices and headquarters. Employees of automakers, of automotive Tier 1, Tier 2 and Tier 3 suppliers and of semiconductor suppliers dedicated to automotive electronics in engineering offices and headquarters. Factories and sales offices are excluded from the analysis.

Automotive electronics factory activities: Turnover of automotive Tier 1 suppliers' factories dedicated to automotive electronics. Employees of automotive Tier 1, Tier 2 and Tier 3 suppliers and of semiconductor suppliers dedicated to automotive electronics in factories. Engineering offices, headquarters, sales offices, design offices, offices dedicated to test drive as well as engineering offices specifically dedicate to motorsport are excluded from the analysis.

C. Geographic repartition of automotive electronics production (hardware only, Factory-gate figures, factories)

The following tables provide detailed information on the regional repartition of automotive electronics production (hardware only), measured in terms of Factory-gate figures[34].

Analyses:

- In 2017, the EU production (factory-fate figures, million euros), accounted for 28% of the global production. In other words, in 2017, the EU was the first region in terms of automotive electronics production (hardware only);
- Yet, the two first regions in terms of growth are China and South East Asia (excluding Japan), with estimated 2017-2022 CAGR of respectively 14% and 14.5%. As a consequence, China is expected to overtake the EU's position by 2022;
- Asia as a whole (that is China, Japan and rest of Asia & Pacific), represented 45% of the global production in 2012, represents 49% of the global production in 2017 and is expected to represent 54% of the global production in 2022.

[34] Factory-gate figures: Sum of the production costs of every automotive electronic equipment when it leaves its factory. Sales and marketing costs as well as automakers' margin are not considered in those figures.

Table (1/2) – Geographic repartition of automotive electronics production (M €) – Prodcom / US Census equivalent

Region	Product	2012	2013	2014	2015	2016	2017	CAGR 2012-2017
World	AUTOMOTIVE	**215 028**	**222 714**	**234 813**	**251 569**	**275 000**	**305 904**	***7,3 %***
	Powertrain & Chassis	96 783	100 430	106 150	114 008	125 105	139 571	*7,6 %*
	Safety & Security	37 592	39 012	41 416	44 759	49 330	55 524	*8,1 %*
	Comfort & info	80 653	83 272	87 247	92 801	100 565	110 808	*6,6 %*
Europe	AUTOMOTIVE	63 536	63 394	65 519	69 340	75 584	84 397	***5,9 %***
	Powertrain & Chassis	28 048	25 614	25 299	26 342	29 265	33 915	*4,3 %*
	Safety & Security	13 260	14 129	15 276	16 742	18 438	20 676	*9,2 %*
	Comfort & info	22 228	23 651	24 944	26 255	27 881	29 803	*5,9 %*
North America	AUTOMOTIVE	37 693	39 834	42 441	45 263	48 444	52 323	***6,8 %***
	Powertrain & Chassis	17 024	17 873	18 845	19 834	20 945	22 377	*5,6 %*
	Safety & Security	6 107	6 541	7 093	7 722	8 467	9 372	*9,0 %*
	Comfort & info	14 562	15 420	16 503	17 707	19 032	20 572	*7,2 %*
Japan	AUTOMOTIVE	25 860	26 450	27 212	28 196	29 491	31 126	***3,8 %***
	Powertrain & Chassis	11 403	11 726	12 078	12 497	13 060	13 739	*3,8 %*
	Safety & Security	4 422	4 525	4 701	4 935	5 218	5 584	*4,8 %*
	Comfort & info	10 035	10 198	10 433	10 764	11 214	11 803	*3,3 %*
China	AUTOMOTIVE	37 837	40 958	45 013	50 055	56 230	63 898	***11,1 %***
	Powertrain & Chassis	18 036	19 805	22 118	24 825	27 956	31 643	*11,9 %*
	Safety & Security	5 972	6 470	7 133	7 955	8 939	10 159	*11,2 %*
	Comfort & info	13 829	14 683	15 762	17 276	19 335	22 093	*9,9 %*
Rest of Asia and Pacific	AUTOMOTIVE	34 630	35 919	37 680	40 860	46 503	54 552	***9,6 %***
	Powertrain & Chassis	16 307	17 267	18 465	20 413	23 872	28 728	*12,1 %*
	Safety & Security	5 350	5 526	5 770	6 191	7 001	8 307	*9,3 %*
	Comfort & info	12 973	13 126	13 445	14 256	15 629	17 517	*6,3 %*
RoW	AUTOMOTIVE	15 472	16 160	16 949	17 855	18 747	19 609	***4,9 %***
	Powertrain & Chassis	7 892	8 232	8 635	9 103	9 546	9 951	*4,8 %*
	Safety & Security	1 902	1 986	2 084	2 205	2 335	2 464	*5,3 %*
	Comfort & info	5 678	5 942	6 230	6 546	6 867	7 194	*4,9 %*

Automotive electronics production = Electronic Control Units (ECUs), automotive sensors, automotive screens and embedded software.

Prodcom/US census equivalent = The values given in this table have been adapted to feat the methodology used by the Eurostat prodcom database and the US Census, in order to enable comparison with the other end-user electronic equipment reports.

Source: DECISION Etudes & Conseil

Table (2/2) – Geographic repartition of automotive electronics production (M €) – Prodcom / US Census equivalent

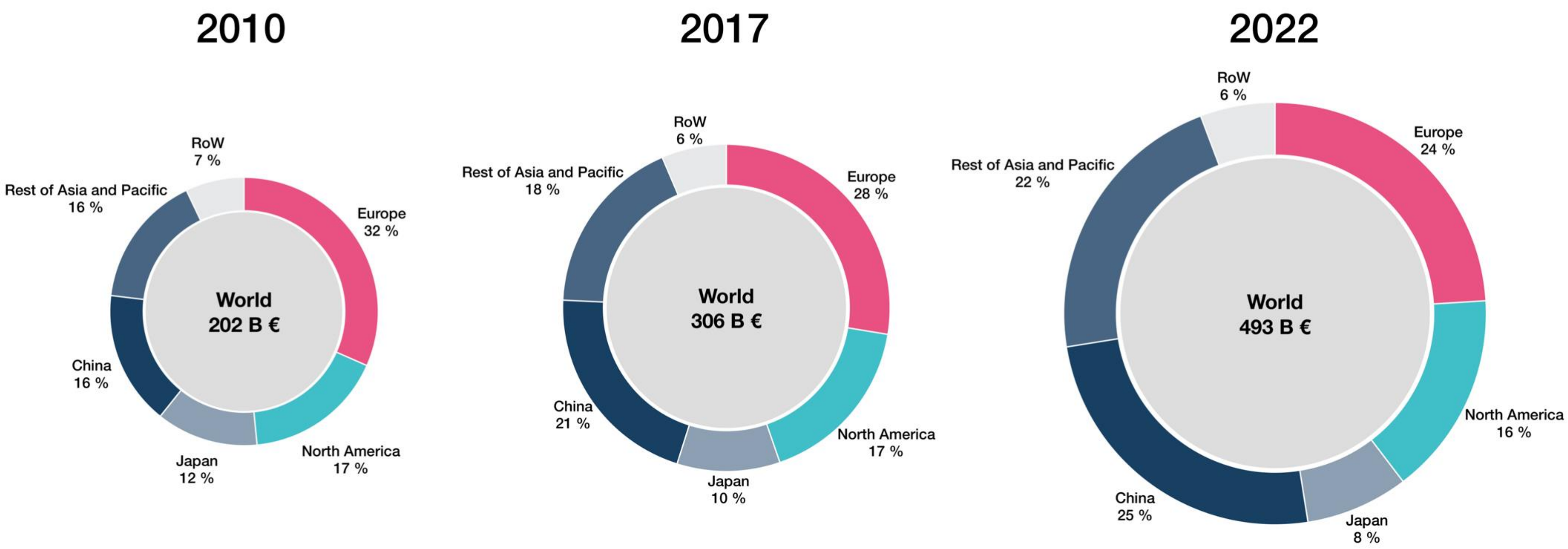
Region	Product	2017	2018	2019	2020	2021	2022	CAGR 2017-2022
World	**AUTOMOTIVE**	**305 904**	**335 188**	**365 873**	**401 904**	**443 719**	**492 506**	***10,0 %***
	Powertrain & Chassis	139 571	153 309	167 798	184 826	204 619	227 748	*10,4 %*
	Safety & Security	55 524	61 458	67 843	75 390	84 226	94 631	*11,1 %*
	Comfort & info	110 808	120 421	130 232	141 688	154 874	170 128	*9,0 %*
Europe	**AUTOMOTIVE**	84 397	91 284	96 127	102 375	109 695	118 322	***7,0 %***
	Powertrain & Chassis	33 915	37 661	40 351	43 904	48 130	53 191	*5,1 %*
	Safety & Security	20 676	22 414	23 628	25 241	27 122	29 327	*10,9 %*
	Comfort & info	29 803	31 209	32 147	33 229	34 442	35 804	*7,0 %*
North America	**AUTOMOTIVE**	52 323	56 449	60 879	65 728	71 041	76 871	***8,0 %***
	Powertrain & Chassis	22 377	23 882	25 476	27 197	29 057	31 068	*6,6 %*
	Safety & Security	9 372	10 358	11 440	12 651	14 008	15 530	*10,6 %*
	Comfort & info	20 572	22 209	23 963	25 880	27 977	30 272	*8,5 %*
Japan	**AUTOMOTIVE**	31 126	32 490	33 934	35 457	37 065	38 762	***4,5 %***
	Powertrain & Chassis	13 739	14 303	14 899	15 525	16 184	16 877	*4,5 %*
	Safety & Security	5 584	5 893	6 224	6 576	6 953	7 354	*5,7 %*
	Comfort & info	11 803	12 293	12 811	13 355	13 928	14 531	*3,9 %*
China	**AUTOMOTIVE**	63 898	72 044	81 827	93 327	106 901	122 995	***14,0 %***
	Powertrain & Chassis	31 643	35 548	40 217	45 684	52 109	59 694	*15,1 %*
	Safety & Security	10 159	11 455	13 011	14 840	16 999	19 558	*14,2 %*
	Comfort & info	22 093	25 042	28 599	32 803	37 793	43 742	*12,5 %*
Rest of Asia and Pacific	**AUTOMOTIVE**	54 552	62 153	70 727	80 874	92 940	107 362	***14,5 %***
	Powertrain & Chassis	28 728	33 404	38 759	45 191	52 951	62 361	*18,2 %*
	Safety & Security	8 307	9 546	10 948	12 612	14 594	16 968	*14,1 %*
	Comfort & info	17 517	19 203	21 019	23 071	25 394	28 033	*9,4 %*
RoW	**AUTOMOTIVE**	19 609	20 767	22 380	24 144	26 076	28 194	***7,5 %***
	Powertrain & Chassis	9 951	10 495	11 248	12 067	12 958	13 929	*7,3 %*
	Safety & Security	2 464	2 638	2 884	3 157	3 459	3 796	*8,2 %*
	Comfort & info	7 194	7 634	8 248	8 921	9 659	10 470	*7,5 %*

Automotive electronics production = Electronic Control Units (ECUs), automotive sensors, automotive screens and embedded software.

Prodcom/US census equivalent = The values given in this table have been adapted to feat the methodology used by the Eurostat prodcom database and the US Census, in order to enable comparison with the other end-user electronic equipment reports.

Source: DECISION Etudes & Conseil

Diagram - Geographic repartition of automotive electronics production (M €) – Hardware only – Factory-gate figures



Automotive electronics production = Electronic Control Units (ECUs), automotive sensors, automotive screens and embedded software.

Prodcom/US census equivalent = The values given in this table have been adapted to feat the methodology used by the Eurostat prodcom database and the US Census, in order to enable comparison with the other end-user electronic equipment reports.

Source: DECISION Etudes & Conseil

iv. EU's turnover, employment, value added and investment

Table – 2017 – Automotive Electronics – EU key indicators

	Eurostat SBS industry database - 2015	DECISION - 2017
Turnover (€M)	34 400	**145 500**
Number of employees	238 408	**1 162 000**
Added value at factor costs (€M)	7 900	**38 505**
Net investment in tangible assets (€M)	1 300	**6 336**

Source: DECISION Etudes & Conseil

v. Geographical repartition inside the EU

The prodcom database provides very few relevant hard data regarding automotive electronics. The prodcom figures can be find in the annexes of the automotive report "i. Prodcom figures".

The Eurostat SBS industry database (Structural Business Statistics, Annual detailed enterprise statistics for industry) provide data regarding the automotive electronics segment using the NACE segmentation. Yet, only one NACE segment provide information on the automotive electronics segment and this NACE segment is named "electrical and electronic equipment for motor vehicles". On the one hand, this segment includes the electrical equipments that are not part of the automotive electronics industry and on the other hand, the majority of automotive electronics equipments are excluded from this NACE segment and are considered in other NACE segments that are not specifically dedicated to automotive. As a consequence, Eurostat SBS data are presented in the annexes of the automotive report "Annexes iii. Eurostat SBS industry database figures".

The following diagrams provide detailed information on the country repartition of automotive electronics production (hardware & software) inside the European Union: global figures, office activities only and factories' activities.

A. Global intra-EU repartition

- In 2017 and for decades, the EU automotive electronics production have clearly been dominated by one country: Germany. Germany's turnover in automotive electronics accounted for 37% of the EU total turnover in 2017. Besides, 32% of the people employed in the EU automotive electronics industry in 2017 were located in Germany.

- France is the second EU country in terms of automotive electronics. Yet, France's turnover in automotive electronics only accounted for 22% of Germany's turnover and 8% of the EU total turnover in automotive electronics in 2017;

- These figures bring forwards the predominance of Germany and its hinterland (Poland, Czech Republic, Slovakia, Austria and Hungary);

    - In 2017, Germany and its hinterland accounted for 57% of EU's total automotive electronics turnover (€ 82 900 M) and for 54% of EU's total automotive electronics jobs (with 586 478 jobs).

    - Besides, according to Eurostat, in 2015 east European Union[35] represented 45% of the EU in terms of turnover, 72% of the EU in terms of employees, 41% of the EU in terms of added value and 63% of the EU in terms of investment.

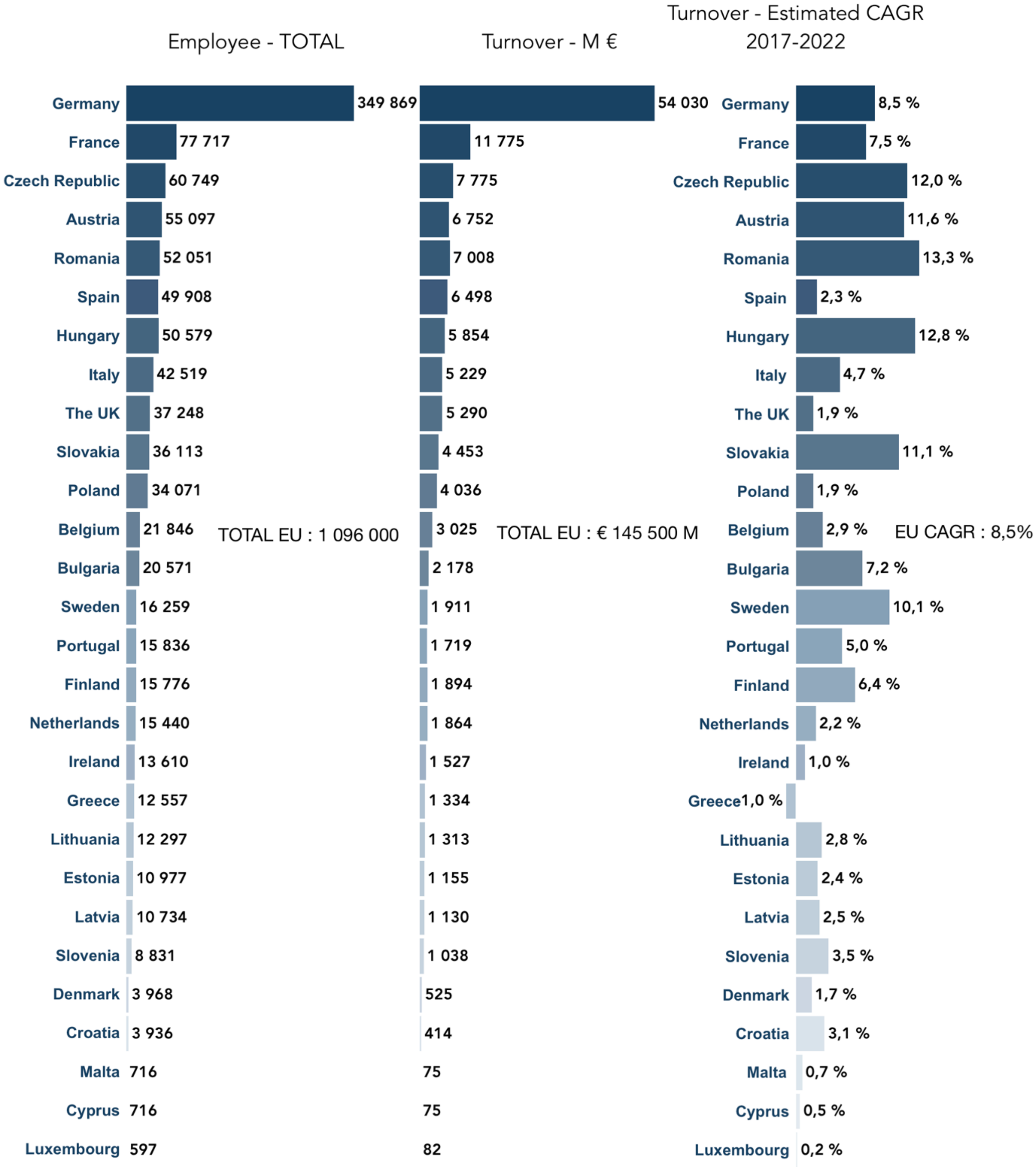
- East European Union countries are the countries with the highest growth prospects: Romania (13.3%), Hungary (12.8%), Czech Republic (12%), Austria (11.6%), Slovakia (11.1%), Bulgaria (7.2%);

- Although below the EU average growth forecast over the 2017-2022 period, Germany, France, Sweden and Portugal will benefit from very positive growth prospects with respective forecast CAGR 2017-2022 of 8.5%, 7.5%, 10.1% and 5%;

- Germany and its hinterland should benefit from an average CAGR 2017-2022 of 9.2%, above the EU average CAGR 2017-2022 of 8.5%.

[35] East European Union = Romania, Bulgaria, Slovenia, Hungary, Austria, Czech Republic, Slovakia, Poland, Lithuania (excluding Latvia and Estonia because of missing values)

Bar charts – 2017, Intra-EU repartition, Automotive electronics (hardware & software)



Automotive electronics: Turnover of automakers and automotive Tier 1 suppliers dedicated to automotive electronics. Employees of automakers, of automotive Tier 1, Tier 2 and Tier 3 suppliers and of semiconductor suppliers dedicated to automotive electronics.

Source: DECISION Études et Conseil

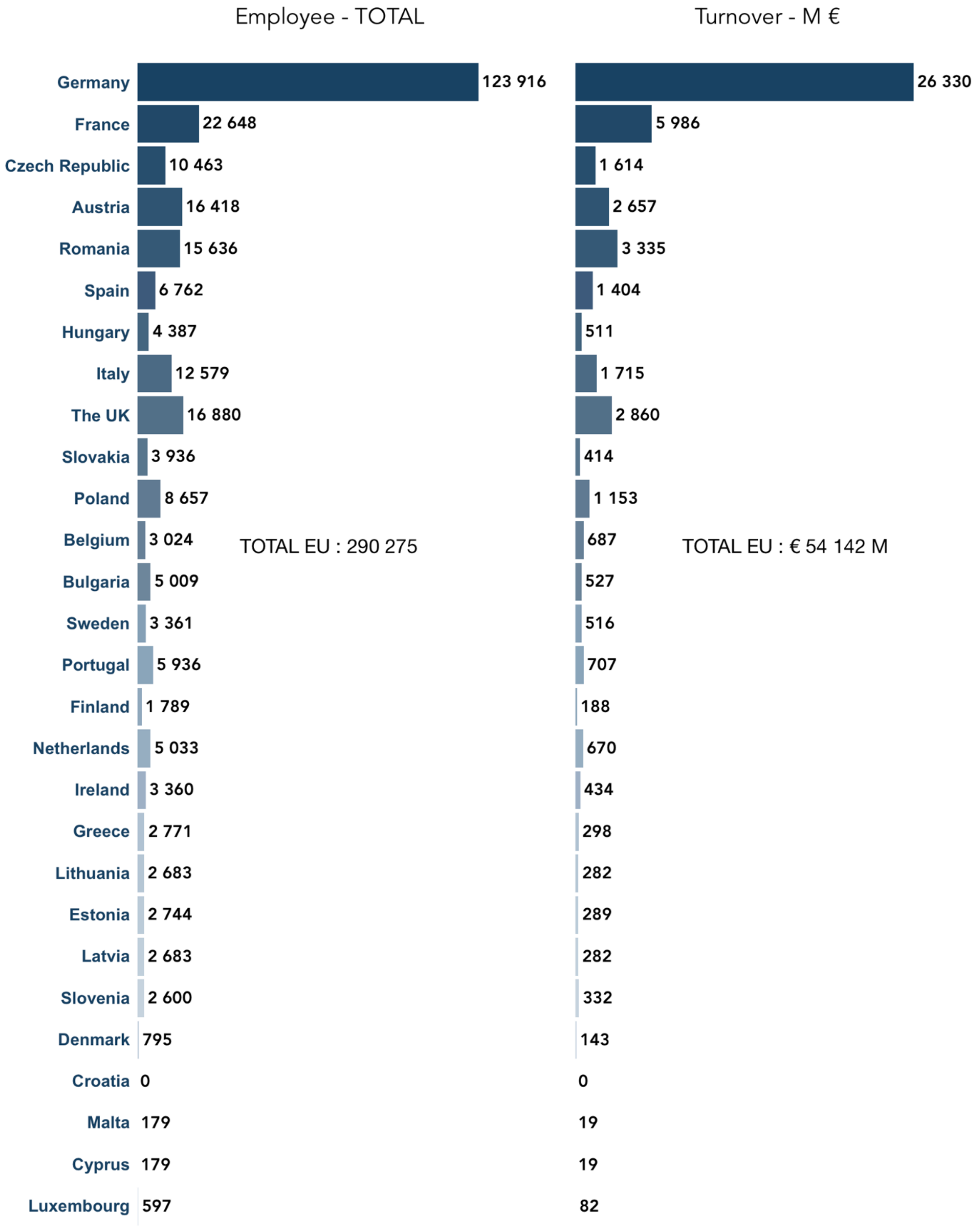
B. Intra-EU repartition – Offices activities

- In 2017 and for decades, the EU automotive electronics production in terms of engineering offices, R&D offices and supporting functions have clearly been dominated by one country: Germany. Germany's turnover in automotive electronics office activities accounted for 49% of the EU turnover from offices activities in 2017. Besides, 43% of the people employed in office activities of the EU automotive electronics industry in 2017 were located in Germany;

- France is the second EU country in terms of automotive electronics office activities. Yet, France's turnover in automotive electronics from office activities only accounted for 23% of Germany's turnover from office activities and 11% of the EU total turnover from office activities in automotive electronics in 2017;

- These figures also bring forwards the predominance of Germany and its hinterland (Poland, Czech Republic, Slovakia, Austria and Hungary). In 2017, Germany and its hinterland accounted for 60% of EU's total automotive electronics turnover from office activities (€ 32 679 M) and for 58% of EU's total automotive electronics jobs in offices activities (with 167 777 skilled jobs).

Bar charts – 2017, Intra-EU repartition, Automotive electronics (hardware & software) – Offices activities



Automotive electronics office activities: Turnover of automakers and automotive Tier 1 suppliers dedicated to automotive electronics in engineering offices and headquarters. Employees of automakers, of automotive Tier 1, Tier 2 and Tier 3 suppliers and of semiconductor suppliers dedicated to automotive electronics in engineering offices and headquarters. Factories and sales offices are excluded from the analysis.

Source: DECISION Études et Conseil

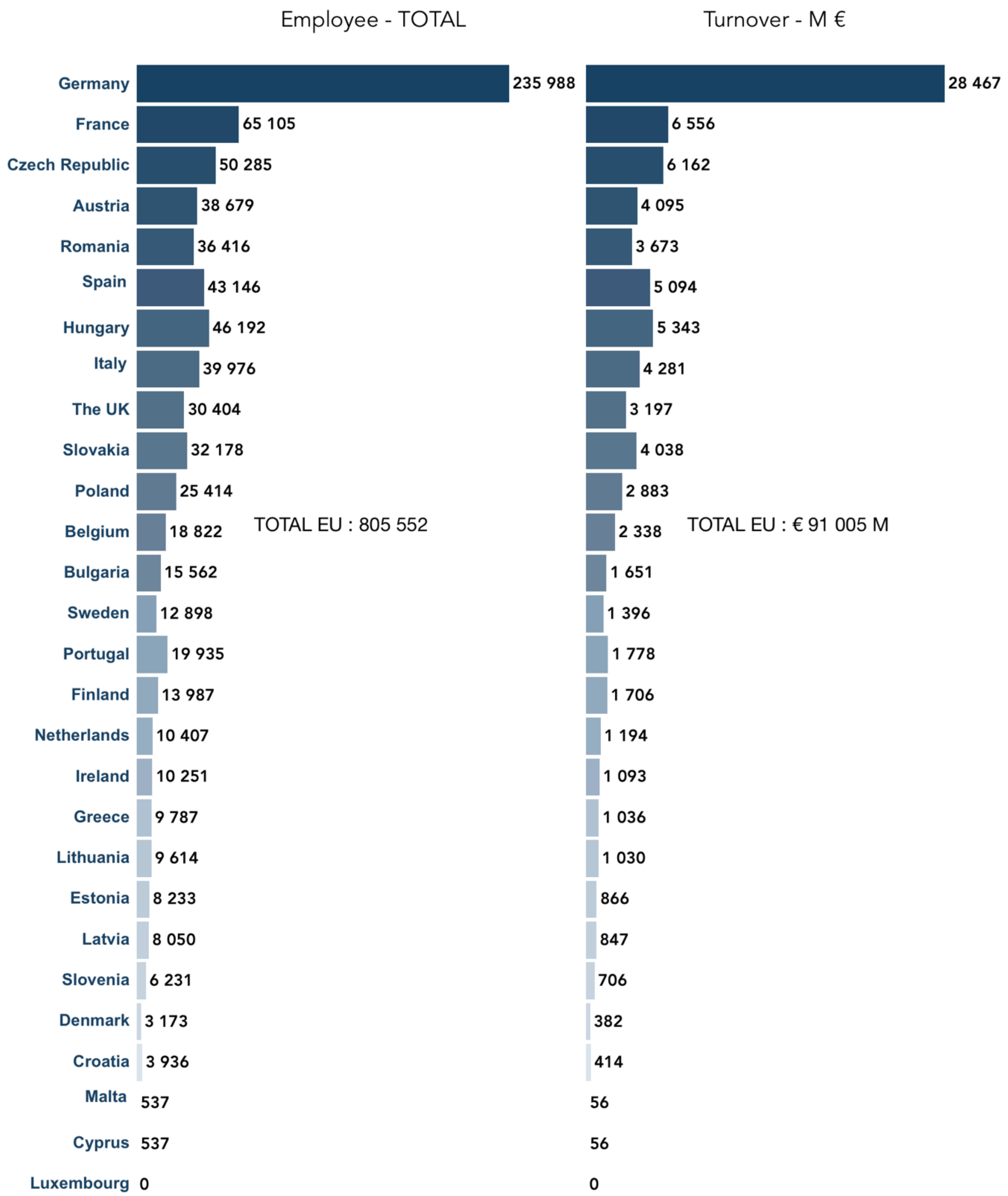
C. Intra-EU repartition – Factories

- In 2017 and for decades, the EU automotive electronics production in terms of factory production have clearly been dominated by one country: Germany. Germany's turnover in automotive electronics factory production accounted for 31% of the EU turnover from factory production in 2017. Besides, 29% of the people employed in the automotive electronics factories of the EU in 2017 were located in Germany;

- France is the second EU country in terms of automotive electronics factory production. Yet, France's turnover in automotive electronics from factory production only accounted for 23% of Germany's turnover from factory production and 7.2% of the EU total turnover from factory production in automotive electronics in 2017.

- These figures also bring forwards the predominance of Germany and its hinterland (Poland, Czech Republic, Slovakia, Austria and Hungary). In 2017, Germany and its hinterland accounted for 56% of EU's total automotive electronics turnover from factory production (€ 50 988 M) and for 53% of EU's total automotive electronics jobs in factories (with 428 736 jobs).

Bar charts – 2017, Intra-EU repartition, Automotive electronics (hardware & software) – Factories activities



Automotive electronics factory activities: Turnover of automotive Tier 1 suppliers' factories dedicated to automotive electronics. Employees of automotive Tier 1, Tier 2 and Tier 3 suppliers and of semiconductor suppliers dedicated to automotive electronics in factories. Engineering offices, headquarters, sales offices, design offices, offices dedicated to test drive as well as engineering offices specifically dedicate to motorsport are excluded from the analysis.

Source: DECISION Études et Conseil

1.1.3 Company positioning, Europe, World

The following tables provide detailed information on the TOP 20 global automotive electronics Tier 1 suppliers.

For every player, an estimation is made of its:

- Global turnover;
- Global turnover generated by its automotive activities;
- Global turnover generated by its automotive electronics activities;
- Global turnover generated by its automotive activities excluding automotive electronics activities;
- Market Share Automotive electronics. That is the ratio:

  Market Share Automotive electronics =

  Global turnover of the particular player dedicated to automotive electronics /

  Global turnover of all the Tier 1 automotive electronics suppliers dedicated to automotive electronics
- Number of employees in automotive electronics (full-time or part-time but excluding internships);
- Turnover/employee in automotive electronics;
- Growth rate 2016-2017 of automotive activities;
- Growth rate 2016-2017 of automotive electronics activities;
- Growth rate 2016-2017 of automotive activities excluding automotive electronics activities.

i. Company analyses

- The TOP 20 global automotive electronics Tier 1 suppliers account for 36% of the global automotive electronics Tier 1 suppliers' market both in terms of turnover and employees;

- The companies whose principal shareholders is headquartered in one of the 28 EU member states represents 45% of the TOP 20's total number of employees in automotive electronics and 49% of the TOP 20's total turnover in automotive electronics;

- The average growth rate in 2016-2017 of the automotive activities of the TOP 20 automotive electronics Tier 1 suppliers is very high (6,5%). This growth is driven by automotive electronics (10,2% average growth). Still, the 2016-2017 growth of the automotive non-electronics sales is also very high (4,8% average growth). Furthermore, the 2016-2017 growth is not an exception an such growth is expected to continue over the 2017-2022 period;

- The first three automotive electronics Tier 1 suppliers are the traditional three biggest German players: Bosch, Continental and ZF. Their importance needs to be outlined. These three players alone represent 13% of the global automotive electronics Tier 1 suppliers' turnover in automotive electronics and 11% of the global automotive electronics Tier 1 suppliers' number of employees in automotive electronics, that is more than all the US players and almost as much as all the north American players (The USA, Canada and Mexico). Apart from these three leaders, Germany's automotive electronics ecosystem also counts a lot of key players at the global scale: Hella, Leoni, Mahle, Draexlmaier, Webasto, Thyssenkrupp, Brose Fahrzeugteile, Vibracoustic, etc.;

- France is the second EU country in terms of automotive electronics capital ownership. France also benefits from two very strong players: Valeo and Faurecia. Yet, contrary to Germany, the French automotive electronics ecosystem does not count a lot of key players at the global scale apart from Valeo and Faurecia.

Table – 2017 – Worldwide ranking TOP 20 - Automotive electronics Tier 1 Suppliers (Hardware & Software) (1/2)

N°	Nationality principal shareholder	Company Name	Turnover (M €)	Turnover automotive (M €)	Turnover non electronic automotive (M €)	Turnover automotive electronics (M €)	Market Share Automotive electronics	Employee automotive electronics	Turnover/employee
1	Germany	Bosch	78 100	47 641	24 007	23 634	4 %	123 242	191 769
2	The UK (high presence of the USA)	Continental	44 306	25 254	6 330	18 924	4 %	94 124	201 054
3	Germany	ZF	36 444	33 528	15 453	18 075	3 %	72 486	249 358
4	Japan	Denso	33 875	32 825	18 716	14 109	3 %	62 291	226 501
5	Canada	Magna International	32 325	32 325	21 070	11 255	2 %	59 885	187 944
6	France / The USA	Valeo	18 701	18 701	8 373	10 328	2 %	61 633	167 573
7	South Korea	Hyundai Mobis	30 452	30 452	20 328	10 124	2 %	19 615	516 136
8	Japan	Sumitomo Electric Industries	20 218	10 792	2 104	8 688	2 %	81 279	106 891
9	The USA	Lear Corp	17 286	17 286	10 442	6 844	1 %	65 324	104 770
10	Japan	Panasonic (Automotive Systems)	54 951	9 802	2 993	6 809	1 %	31 906	213 408
11	The USA	Aptiv (Delphi Automotive)	10 895	10 895	4 413	6 482	1 %	58 304	111 177
12	Japan	Koito Manufacturing	6 335	5 701	0	5 701	1 %	21 211	268 776
13	China	Joyson Electronics (purchase of TKJP Corporation in June 2018)	8 781	8 781	3 453	5 328	1 %	46 683	114 131
14	Japan	Aisin Seiki	29 249	28 079	23 139	4 940	1 %	18 638	265 050
15	Germany	HELLA KGaA	6 585	5 029	281	4 748	1 %	27 203	174 540
16	The USA	Autoliv Inc.	8 787	8 787	4 613	4 174	1 %	28 461	146 657
17	Japan	Yazaki Corp	12 835	4 667	1 050	3 617	1 %	40 269	89 820
18	France	Faurecia	20 182	20 182	16 714	3 468	1 %	18 363	188 858
19	Italy	Magneti Marelli (FCA Group)	8 700	8 700	5 333	3 367	1 %	16 641	202 332
20	Germany (high presence of the USA)	Leoni AG	4 923	2 954	0	2 954	1 %	30 219	97 742
		WORLD Tier 1 automotive electronics suppliers				**477 780**	**100 %**	**2 736 427**	
		Market Shares - TOP 20					**36 %**	**36 %**	
		TOP 20 - % EU players					**49 %**	**45 %**	

Source: DECISION Etudes & Conseil

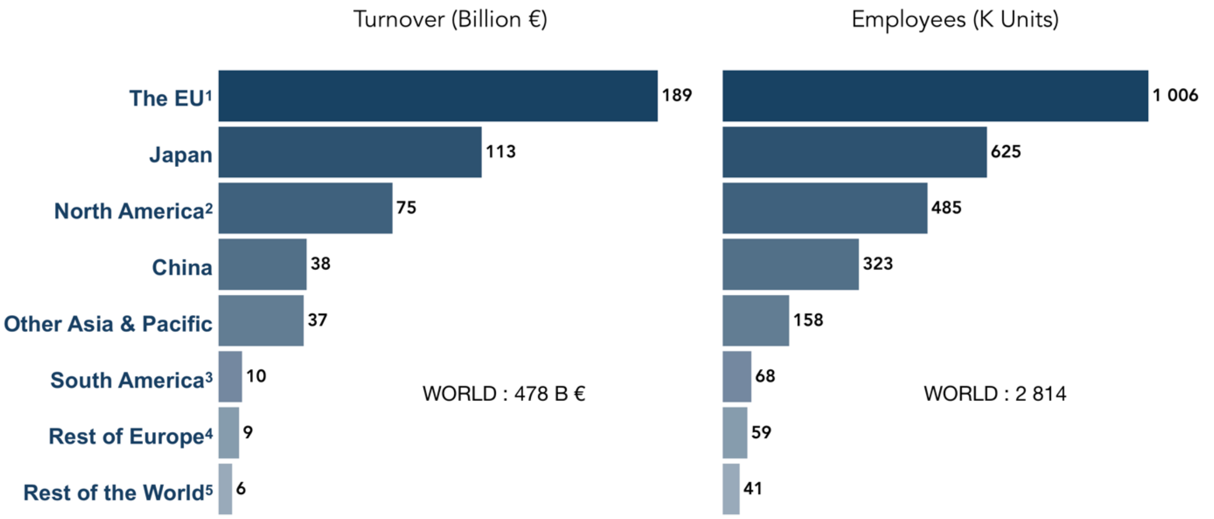
Bar charts – 2017 – Worldwide ranking TOP 20 - Automotive electronics Tier 1 Suppliers (Hardware & Software) (2/2)

N°	Nationality principal shareholder	Company Name	Growth automotive sales 2016-2017*	Growth automotive non electronics sales 2016-2017*	Growth automotive electronics sales 2016-2017*
1	Germany	Bosch	8 %	3 %	13 %
2	The UK (high presence of the USA)	Continental	8 %	2 %	10 %
3	Germany	ZF	4 %	1 %	6 %
4	Japan	Denso	6 %	3 %	11 %
5	Canada	Magna International	7 %	3 %	14 %
6	France / The USA	Valeo	12 %	7 %	16 %
7	South Korea	Hyundai Mobis	3 %	1 %	6 %
8	Japan	Sumitomo Electric Industries	-2 %	-1 %	-2 %
9	The USA	Lear Corp	10 %	4 %	19 %
10	Japan	Panasonic (Automotive Systems)	6 %	2 %	8 %
11	The USA	Aptiv (Delphi Automotive)	5 %	2 %	7 %
12	Japan	Koito Manufacturing	3 %	0 %	3 %
13	China	Joyson Electronics (purchase of TKJP Corporation in June 2018)	0 %	0 %	0 %
14	Japan	Aisin Seiki	10 %	6 %	27 %
15	Germany	HELLA KGaA	4 %	1 %	4 %
16	The USA	Autoliv Inc.	3 %	2 %	5 %
17	Japan	Yazaki Corp	0 %	0 %	0 %
18	France	Faurecia	7 %	4 %	19 %
19	Italy	Magneti Marelli (FCA Group)	0 %	0 %	0 %
20	Germany (high presence of the USA)	Leoni AG	11 %	0 %	11 %
		WORLD - Tier 1 automotive electronics suppliers	**6,5 %**	**4,8 %**	**10,2 %**
		TOP 20 - EU players only	**6,9 %**	**3,1 %**	**10,3 %**

Source: DECISION Etudes & Conseil

ii. Geographic repartition of automotive electronics from Tier 1 suppliers by nationality of principal shareholders

Bar charts – 2017, Automotive electronics production (Hardware & Software) from automotive Tier 1 suppliers - Global Repartition by nationality of principal shareholder – By region



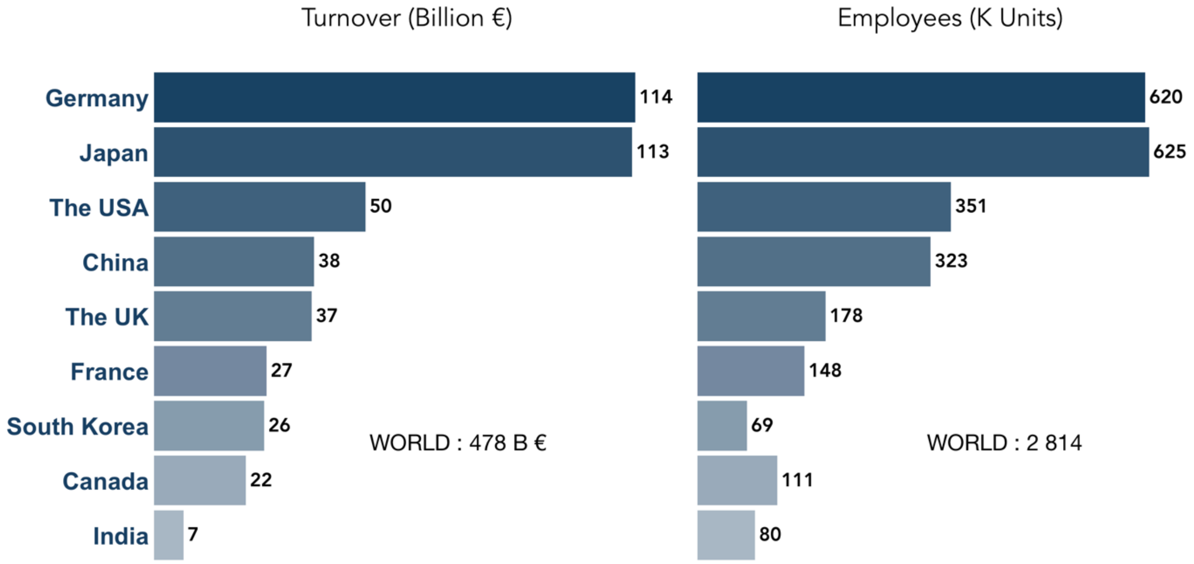
[1] 28 member states, Germany represents 60% of the EU production and 57% of the EU employees
[2] North America = Canada, the USA and Mexico.
[3] Mainly in Brazil
[4] Mainly in Russia and Turkey
[5] Mainly in Israel and Iran

Methodology : 50% of the global figures directly from annual reports of top companies and 50% of the global figures estimated.

Source: DECISION Etudes & Conseil

- The EU is by far the first region of the world in terms of capital ownership of automotive electronics Tier 1 suppliers;
- Together, China and the other countries of Asia & Pacific (excluding Japan), own companies that produced € 75 B of automotive electronics in 2017, that is as much as North America.

Bar charts – 2017 – Automotive electronics production (Hardware & Software) from automotive Tier 1 suppliers - Global Repartition by nationality of principal shareholder – Country ranking



This TOP 9 represents 87% of the global turnover and 90% of the global number of employees.

Methodology : 50% of the global figures directly from annual reports of top companies and 50% of the global figures estimated.

Source: DECISION Etudes & Conseil

- In terms of capital ownership, automotive electronics from Tier 1 suppliers is clearly dominated by two leaders: Germany and Japan. They account for 47% of the global turnover and 46% of the global employees;
- Although North America ranks third in terms of nationality of « principal shareholder », a strong presence of American shareholders in the capital of EU-owned firms needs to be noticed: Continental, Leoni AG, Infineon, etc. This strong presence has become more and more pregnant within the past years. The real influence of the USA (and accordingly North America), in terms of capital ownership is therefore more important than this bar chart tends to suggest;
- The importance of China in terms of capital ownership is growing at very fast pace since the Chinese legislation from 1994 that force any foreign group moving to China to form a joint venture in which it cannot hold more than 50% of the shares, the rest being hold by Chinese shareholders. China is already the fourth country in terms of capital ownership.

1.1.4 Technological and market development

In the following paragraphs, 19 current and future technological developments are identified their impacts on the European automotive electronic industrial base are analyzed.

i. Results summary

The three following tables provide a global technological roadmap of automotive electronics in terms of

Figure 1 – Technological maturity. At the global scale, each technology is defined at three different stages of maturity.

- R&D and tests: Signify that no carmaker has yet launched the industrial production of a car using that technology (excluding concept cars).
- Industrial production: Signify that at least one carmaker launched the industrial production of a car using that technology (excluding concept cars).
- Massive production: Signify that car production integrating the technology has already reached steps that enable significant scale economies.

Figure 2 – Impact on the global automotive value chain in terms of competitive advantage and perspective of volumes of production.

Important remark. Quick drop type system and wireless dynamic charging for automotive electric batteries are considered as having no significant impact because they require high infrastructures investments to be set up at large scales. Such infrastructure investments can only be made by states but in case they are made, such technologies could turn out to be critic.

Figure 3 – European actors positioned on each technology.

Preliminary remark. Carmakers expect automotive components to last for hundreds of thousands of kilometers over bumpy roads and a wide range of temperatures. Therefore, innovative physical components, equipments or materials must feat specific restrictive physical conditions to be industrially integrated into automotives.

Table (1/3) – Technology Roadmap – Automotive – Maturity of the technology at the global scale

	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Embedded software																					
Environment recognition software	Industrial integration									Massive integration											
Machine learning / Deep learning	R&D and tests					Industrial integration								Massive integration							
Biometry	R&D and tests					Industrial integration								Massive integration							
Blockchain	R&D and tests											Industrial integration									
Electronic components/equipments																					
Leds	Industrial integration						Massive integration														
Ultrasonic sensors	R&D and tests			Industrial integration								Massive integration									
LIDAR	Industrial integration													Massive integration							
Electronics related to connected cars	Industrial integration													Massive integration							
Lithium-ion batteries	Industrial integration													Massive integration							
Infrared sensors	R&D and tests							Industrial integration						Massive integration							
Graphene : Sensors/Battery	R&D and tests																	Industrial integration			
Lithium-sulphur batteries	R&D and tests																	Industrial integration			
Lithium-air batteries	R&D and tests																				
Others																					
3D printing	R&D and tests			Industrial integration								Massive integration									
Drones & automotive synergies	R&D and tests					Industrial integration								Massive integration							
Big data in automotive supply chain	R&D and tests					Industrial integration								Massive integration							
Hydrogen vehicles	R&D and tests					Industrial production															
Quick drop type system/ Wireless dynamic charging for electric batteries	R&D and tests					Industrial production															
Graphene : body parts	R&D and tests													Industrial integration							

Source: DECISION Études et Conseil

Table (2/3) – Technology Roadmap – Automotive – Impact on the global automotive value chain in terms of competitive advantage and perspective of volumes of production

	Short run impact (2017-2022)	Long run impact (2022-2030)
Embedded software		
Environment recognition software	Critic impact	Critic impact
Machine learning / Deep learning	Significant impact	Critic impact
Biometry	Significant impact	Significant impact
Blockchain	No significant impact	No significant impact
Electronic components/equipments		
Lithium-ion batteries	Critic impact	Critic impact
Leds	Critic impact	Critic impact
Ultrasonic sensors	Significant impact	Critic impact
LIDAR	No significant impact	Critic impact
Graphene : Sensors/Battery	No significant impact	Significant impact
Electronics related to connected cars	No significant impact	Significant impact
Lithium-sulphur batteries	No significant impact	Significant impact
Lithium-air batteries	No significant impact	Significant impact
Infrared sensors	No significant impact	No significant impact
Others		
Graphene : physical structure	No significant impact	Significant impact
3D printing	No significant impact	Significant impact
Hydrogen vehicles	No significant impact	No significant impact
Drones & automotive synergies	No significant impact	No significant impact
Big data in automotive supply chain	No significant impact	No significant impact
Quick drop type system/ Wireless dynamic charging for electric batteries	No significant impact	No significant impact

Source: DECISION Études et Conseil

Table (3/3) – Technology Roadmap – European Actors

	Indicative list of significant European Actors	Indicative list of other significant players
Embedded software		
Environment recognition software	Valeo (France), Bosch electronics (Germany), Continental (Germany)	Intel/Mobileye (USA/Israel), Delphi (USA), Hitachi (Japan)
Machine learning / Deep learning	Infineon (France)	Intel/Mobileye (USA/Israel), Delphi (USA), Nvidia (USA), Altera (USA)
Biometry	Gemalto (France)	Infosys (India), VocalZoom (Israel), Iritech (USA), Kakao (South Korea)
Blockchain	-	-
Electronic components/equipments		
Lithium-ion batteries		LG Chem (Korea), Panasonic (USA), Samsung (Korea), BYD (China), Toyota (Japan), NEC (Japan), Wanxiang (China), Lishen (China), GS Yuasa (Japan)
Leds	STMicroelectronics (France), OSRAM (Germany), Philips (Netherlands)	Cree (USA), LG Innotek (South Korea)
Ultrasonic sensors	STMicroelectronics (France), Bosch (Germany), AMS (Austria), NXP (Netherlands)	Murata (Japan)
LIDAR	Infineon (France), Continental (Germany), Bosch (Germany)	Luminar (USA), Innoviz (Israel), Quanergy (USA)
Graphene : Sensors/Battery	-	-
Electronics related to connected cars	Bosch (Germany), Continental (Germany)	LG Innotek (South Korea), Dense (Japan), Huawei (China)
Lithium-sulphur batteries	-	-
Lithium-air batteries	-	-
Infrared sensors		Murata (Japan)
Others		
Graphene : body parts	-	-
3D printing	SLM Solutions Group AG (Germany), Voxeljet (Germany)	Stratasys (USA), 3D Systems (USA)
Hydrogen vehicles	PSA (France), Valeo (France), Faurecia (France), Symbio FCell (France), Audi/Mercedes (Germany), BMW (Germany)	Toyota (Japan), Honda (Japan), GM (USA), Nikola Motors (USA), Hyundai (South Korea)
Drones & automotive synergies	Parrot (France), Faurecia (France)	Amazon (USA)
Big data in automotive supply chain	-	-
Quick drop type system	Renault (France)	-
Wireless dynamic charging for electric batteries	Renault (France), Vedecom (France)	Qualcomm (USA), KAIST (Korea Advanced Institue of Science and Technology)

Source: DECISION Études et Conseil

ii. Embedded software

A. Environment recognition software

Definition: Embedded software directly related to the treatment and the analysis of images, videos, ultrasound and/or data coming from radars. Such software can be segmented in three specific functions:

1. Identification and classification of any type of potential obstacle (car, tree, truck, leaf, etc.)
2. Calculation of relative speeds, scenario categorization and trajectory previsions. Such software can use machine learning tools.
3. Development of HD virtual maps. Those maps are then compared to sensing data to precisely geo-localize ADAS level 3 (or more) vehicles and to distinguish permanent physical obstacles from moving objects. Indeed, moving objects will be defined as objects non-identified by the 3D virtual map but identified by sensors.

Mature applications:

ADAS. Such software are essential to level 2 and more ADAS (Advanced driver-assistance systems) and are therefore being more and more integrated to high-range but also middle-range vehicles.

Here is a list of specific ADAS applications which require sensor processing software:

- Emergency brake launch from pedestrian and car detection;
- Lane departure correction system;
- Safe distance keeping system;
- Intelligent high beam control;
- Speed limit indication through traffic signs reading.

Future applications:

Applications in line with ADAS level 3, 4 and 5.

Actors:

Here is an indicative list of leading actors and related products:

- **Mobileye/Intel (The USA)** (Mobileye is an Israeli company owned by Intel). Mobileye is currently the market leader at the global scale
- **Valeo (France)**
- **Bosch electronics (Germany)**
- **Continental (Germany)**
- **Delphi (The USA)**
- **Hitachi (Japan)**

B. Machine learning / Deep learning

Considering artificial intelligence to be a broad concept with a diversity of definitions, we chose to focus on machine learning software, that are part of artificial intelligence but with a clear and standardized definition.

Definitions:

Machine learning. Software set up to be able to learn -that is to design and launch updates- without human intervention.

Deep learning. Branch of machine learning based on artificial neural networks (ANNs) that model high-level abstractions in input data by using a graph representation comprising multiple processing layers (properties: nonlinear connections, adaptability, fault tolerance). Those ANNs can combine alternatively data-driven development and learning-algorithm development.

Mature applications:

ADAS. Such software is already integrated into new generations of Advanced Driver Assistance Systems commercialized by automakers and operates two functions:

- Detection, recognition and classification of multiple objects;
- Prediction of actions.

Such functions will be essential to level 3 and more ADAS vehicles and are already integrated into some level 2 ADAS vehicles. The competitiveness of level 3 to 5 ADAS will highly depend on the well-functioning of such machine learning software. As a consequence, the integration of machine learning software dedicated to ADAS applications will be constantly rising at high rates up to 2030 and should reach most of middle-range vehicles during the 2022-2028 period.

Future applications:

Other machine learning applications are currently at the stage of R&D and tests and have smaller potential impacts than ADAS applications.

- **Cybersecurity diagnostic.** Machine learning can be used to operate automatic cybersecurity diagnostic.
- **Engine management diagnostic.** Machine learning can be used to operate automatic engine electronic network diagnostic.
- **Driver's level of alert analysis.** Machine learning can be used to operate automatic diagnostics of driver's level of alert thanks to biometrics data-bases processing and biosensors.

Standardization issue: The Automotive SPICE (Software Process Improvement and Capability Determination) and ISO 26262 are addressing software structures as well as data calibration but are far from addressing the entire scope of automotive deep learning. As a consequence, there is still a standardization gap that could accelerate the market penetration of such solutions if it were filled.

Actors:

Here is an indicative list of leading actors and related products:

- **Mobileye/Intel (USA)** (Mobileye is an Israeli company owned by Intel).
  - The EyeQ5 chip processes the more time-critical data from the stereo front camera and driver monitoring camera, required for L3 automated driving.
- **Delphi (USA)**
- **Nvidia (USA)**
  - The Tegra K1 chip is dedicated to processing data from the four cameras to create a 360-degree surround view of the vehicle when maneuvering in tight spaces.
- **Altera (USA)**
  - The Cyclone V chip is used for most of the sensor data fusion, using an integrated ARM processor.
- **Infineon (France)**
  - The Tricore chip is responsible for making and executing decisions such as planning the vehicle's trajectory and speed.

C. Biometry

Definition: Software dedicated to the measurement and statistical analysis of people's unique physical and behavioral characteristics.

Mature applications:

Those biometric software are for the most part already mature. Yet, biometric applications remain costly and are not necessary for any current major automotive use. As a consequence, biometrics applications are mostly integrated in high-range cars and that trend should last at least up to 2022.

- **Car access control & security**. Biometric features recognition (face, iris, etc.) associated to steering wheels and doors automatic immobilization actuators;
- **Safety**. Face recognition and attention control dedicated to ADAS (Advanced Driver Assistance Systems);
- **Comfort**. Driver health monitoring (heart rate, blood pressure, body heat, breathing rate, blood-alcohol concentration, dashboard glucometers, etc.), voice commands and automatic body control actuation (doors, seats, etc.).

Future applications:

-

Actors:

Here is an indicative list of leading actors and related products:

- **Infosys (India):** Toyota's Driver Awareness Research Vehicle (DARV 1.5) uses Microsoft Surface and Kinect with biometric software by Infosys to create a system that eliminates distractions for drivers.
- **VocalZoom (Israel):** Honda is working with VocalZoom's Human to Machine optical sensors to provide better voice-control performance on their cars.
- **Kakao (South Korea):** Hyundai and Kia cars are using the Kakao AI platform to bring speech recognition technology to its cars.
- **Iritech (USA)**
- **Gemalto (France)**

Here is an indicative list of carmakers integrating such solutions:

- **Volkswagen:** The Volkswagen concept car Sport Coupé Concept GTE makes driving route decision based on vital signs of the driver.
- **General Motors:** GM's smart cruise control system allows drivers to take their hands off the driving wheel. But it uses facial recognition technology to keep track if the driver is paying attention to the road or not.
- **Ford:** Ford has developed ECG car seats and dashboard glucose monitors. Future cars will have more advanced cameras and sensors that will be able to perform full-body scans.

D. Blockchain

Embedded blockchain applications are currently being developed but are not yet integrated into commercialized cars. In the coming decade, they should be integrated for **remote payments safety purpose in the context of connected cars**. Indeed, cars will start to integrate remote payments applications for tolls and fuel purchase within the context of the development of IoT networks in the coming years. Two factors argue for very low impact of blockchain on automotive electronic value chain:

1. Development of such blockchain application require the existence of complete IoT infrastructure networks on territories (notably on toll stations and petrol stations). Such networks should not be set up at large scale before years.
2. Even if such networks existed and if remote payments systems were integrated into automotive at large scale, blockchain software would remain a very small part of the global value of embedded software.

Blockchain applications in automotive are therefore negligible.

iii. Electronic components/equipments

A. Leds

Leds is already mature technology that is steadily replacing the other automotive lighting components. Leds prices are still higher than conventional bulbs but lead to lower energy consumptions. As a consequence, Leds already replace conventional bulbs in most new car lighting applications that requires high energy consumption (position light, stop light, etc.). Yet, for most low-range and mid-range vehicles, conventional bulbs remain the best cost-effective option for low-consumption lighting applications (flashers, main beam, fog lamp, etc.).

Besides, the automotive industry is already the main market outlet for Leds and allow for large scale economies. As a consequence, and in line with automotive industry growth, Leds average price should significantly decrease within the coming years, leading to a constantly higher integration of Leds into cars.

Mature applications:

Here is a list of Leds automotive applications:

- **Comfort.** Interior ambient lighting, adaptive exterior lighting both in term of distance and direction in order to prevent pedestrian blindness.
- **Infotainment.** Dashboard lights.

Future applications:

-

Actors:

Here is an indicative list of leading Leds suppliers:

- **STMicroelectronics (France)**
- **Philips (Netherlands)**
- **OSRAM (Germany)**
- **Cree (The USA)**
- **LG Innotek (South Korea)**

B. Ultrasonic sensors

Ultrasonic sensors use already mature technologies with continuously decreasing prices and miniaturization.

Ultrasonic sensors are the best-suited sensors (low-price and high-quality) for position sensing at very low distances (up to 2 meters). Therefore, ultrasonic sensors are associated to park assist functions (one of the many ADAS functions).

Yet, park assist functions (from collision warning to automatic parking) are one of the functions with the higher expected penetration rate into high-range and middle-range vehicles at the global scale within the coming years. Therefore, the automotive industry is already a critic outlet market for ultrasonic sensors and will generate very high growth within the coming years.

Mature applications:

Here is the list of ultrasonic sensors' automotive applications:

- **ADAS**. Short-range ADAS applications (mostly park assist functions).

Future applications:

Other short-range ADAS applications required for ADAS level 3, 4 and 5.

Actors:

Here is an indicative list of leading ultrasonic sensors providers:

- **STMicroelectronics (France)**
- **Bosch electronics (Germany)**
- **AMS (Austria)**
- **NXP (Netherlands)**
- **Murata (Japan)**

C. LIDAR

Definition: Light Detection and Ranging (LIDAR) are sensors using light in the form of an optical pulsed laser to measure ranges (variable distances).

Current situation:

Today, automotive LIDAR sensors costs thousands of euros per unit. This price is prohibitive for a massive integration of LIDAR into automotive.

Yet, LIDARs' prices are constantly decreasing. In late 2017, Velodyne -the world leading LIDAR developer- announced an order from Ford with targeted prices of less than $500 per unit. Furthermore, by 2030, the average cost of LIDAR sensors is expected to tend to less than 100$ per unit[36] in line with the rise of production volumes enabling scale economies.

The current only LIDAR technology integrated into commercialized vehicles is the Velodyne's mechanical design, using a laser that physically spins around 360 degrees several times per second. Emerging alternative technologies are being developed that use a solid-state design with few if any moving parts. Such technologies could make the units simpler, cheaper and much easier to mass-produce[37]. Such solid-state LIDARs are currently at the stage of R&D and/or development but did not reach the commercialization step. Here is a list of the three main alternative technologies:

- **MEMS LIDARs**, using a tiny mirror -millimeters across- to steer a fixed laser beam in different directions. Such a tiny mirror has a low moment of inertia, allowing it to move very quickly -quickly enough to trace out a two-dimensional scanning pattern in a fraction of a second. Two leading startups working on MEMS lidar sensors are Luminar and Innoviz. Another lidar company, Infineon, recently acquired Innoluce, a start-up with MEMS expertise. One advantage of the MEMS approach is that a lidar sensor can dynamically adjust its scan pattern to focus on objects of particular interest, directing more fine-grained laser pulses in the direction of a small or distant object to better identify it—something that's not possible with a conventional mechanical laser scanner.

- **Phased arrays**, using a row of emitters that can change the direction of a laser beam by adjusting the relative phase of the signal from one emitter to the next. At this point, phased-array lidars are mostly still in laboratories. Quanergy is an American start-up working on this technology.

- **Flash lidar**. A laser beam is diffused so it illuminates an entire scene in a single flash. Then a grid of tiny sensors captures the light as it bounces back from various directions. One big advantage of this approach is that it captures the entire scene in a single instant, avoiding the complexities that occur when an object—or the lidar unit itself—moves while a scan is in progress. Yet, flash lidar isn't well suited for long-range detection. And that's significant ADAS level 3, 4 and 5 will need lidars capable of detecting objects 200 to 300 meters away.

Mature applications:

-

[36] According to Alex Lidow, CEO of Efficient Power Conversion, a company that makes integrated circuits that are incorporated in a number of lidar products.

[37] See « Why experts believe cheaper, better lidar is right around the corner », Ars technica, 01/01/2018.

Future applications:

ADAS. LIDARs are necessary to most ADAS (Advanced Driver-Assistance Systems) level 3 or more functions. Such vehicles are not currently commercialized. LIDAR production dedicated to automotive is therefore very low. Yet, Audi announced the commercialization of the world first ADAS level 3 vehicle in 2019. Thus, starting from 2019, the rise of ADAS level 3 vehicles production should lead to a significant rise of LIDAR production for the automotive industry. This rise of the demand from the automotive industry during the 2020-2030 period is expected to be concomitant with the emerging of alternative LIDAR technologies leading to even lower prices.

As a consequence, LIDARs production dedicated to the automotive industry is expected to significantly rise until 2022, and to skyrocket during the 2022-2030 period in line with the development of ADAS level 3 vehicles.

Actors:

Here is an indicative list of leading LIDAR suppliers:

- **Velodyne (The USA)**
- **Infineon (France)**
- **Continental (Germany)**
- **Bosch Automotive (Germany)**
- **Luminar (The USA)**
- **Innoviz (Israel)**
- **Quanergy (The USA)**

D. Electronics related to connected cars

Definition: ECUs related to connected cars (also named telematic control units), sensors and software dedicated to vehicles' communication with their environments.

Current situation:

The current innovations in terms of network infrastructures (4G, 5G and long-range M2M networks such as Sigfox, LoRa or Neul) will rise the possibilities of interactions between vehicles and their environment (V2V communications for safety reasons, vehicles interactions with infrastructures such as tolls and petrol station, etc.). The number and the value of embedded telematic control units should thus rise within the coming decade, in line with the development of communication networks infrastructures at the global scale.

Mature applications

- **Software remote diagnostic and update**

Future applications:

Here is a list of automotive applications using new generation communication infrastructure networks:

- **Remote payments**: tolls, petrol stations, etc.
- **ADAS**. Live vehicle-to-vehicle communications to avoid car accidents.

Actors:

Here is an indicative list of leading telematic control unit providers:

- **Continental (Germany)**
- **Bosch Automotive (Germany)**
- **Huawei (China)**
- **LG Innotek (South Korea)**
- **Denso (Japan)**

E. Electric batteries: Lithium-ion/Lithium-air/Lithium-Sulphur

Definitions:

Lithium-ion battery. It is currently the most common electric battery technology.

Lithium-air battery. Currently at the stage of R&D and test. The particularity of this technology is that it uses the oxygen contained in the air of the atmosphere to operate, which has the advantage of reducing the weight of the accumulator. This technology is very promising but should not reach mass market before 40 to 50 years[38].

Lithium-Sulphur battery. Currently at the stage of R&D and test. The particularity of this technology is its very high mass density energy, leading to better performances. Components are also cheaper and less toxic. A few prototypes already exist with densities of 350 W/h, that could reach mass market in 10 to 15 years (that is up to 2030) [39].

Current situation:

On the short run, concrete innovations on automotive electric batteries that will have an impact on mass production will only be incremental and will only concern Li-ion technologies. New technologies such as lithium-air batteries and lithium/Sulphur batteries are very promising but will definitely not reach mass market by 2022. Therefore, the main driver of battery costs decrease in the coming years will be the rise of the production leading to scale economies. Optimization of batteries' end of life is a third mean of reducing batteries average production costs, but it requires high infrastructures investments that only states could make.

Yet, such innovations are keys to electric vehicles. Indeed, electric batteries represents around 25% of battery electric vehicles' weight[40] and prices. Thus, lead battery providers are key partners of carmakers: LG Chem, Samsung HDI and Panasonic are now as unavoidable as Bosch, Valeo or Continental regarding electric vehicles. Partnerships between such providers and carmakers reflect three different strategies:

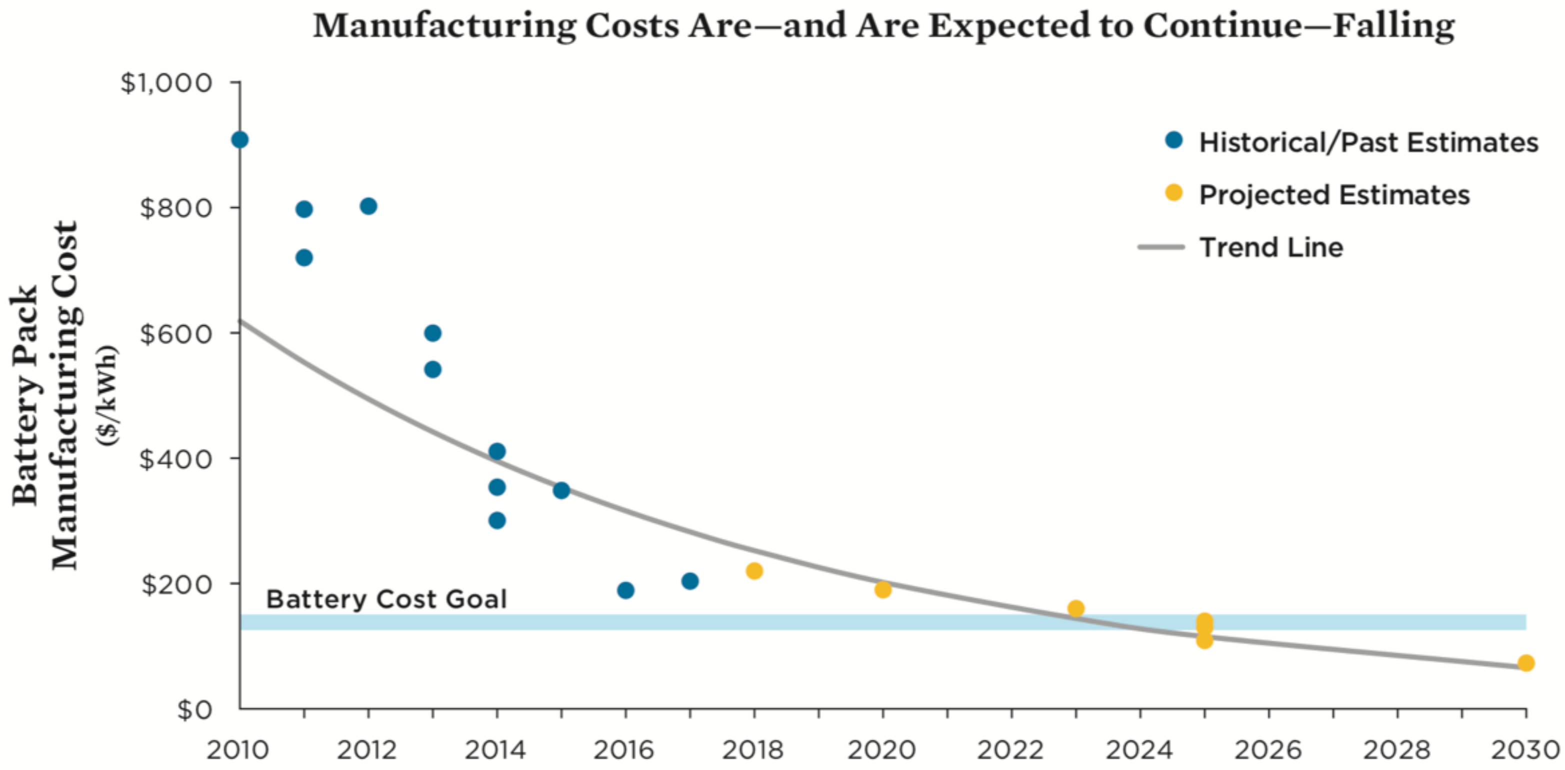
- Vertical integration. Toyota owns 80% of Primearth, its historical battery provider.
- Horizontal integration. General Motors and Renault set up co-innovations and research projects with LG Chem.
- Joint-Ventures. Nissan developed a joint-venture with NEC.

[38] Jean Marie Tarascon, professor at the Collège de France at the Chemistry of solid and energy chair and creator at the CNRS of the Electrochemical Energy Storage Research Network (RS2E)

[39] Jean Marie Tarascon, professor at the Collège de France at the Chemistry of solid and energy chair and creator at the CNRS of the Electrochemical Energy Storage Research Network (RS2E)

[40] For instance, the Chevrolet Bolt weights 1 617 kg and its battery weights 400 kg

EV Battery Pack Manufacturing Costs Predicted to Fall over Time



If battery costs continue to decline as EV production increases, within several years they will reach the $125–$150 target that makes EVs competitive with conventional gasoline vehicles.

Note: Battery cost estimates include both academic analysis and statements from automakers. Multiple data points in a given year represent estimates from multiple analyses. Trend line represents exponential best fit of battery cost data.

SOURCES: ARB 2017; SOULOPOULOS 2017; VOELCKER 2017; SLOWIK, PAVLENKO, AND LUTSEY 2016; VOELCKER 2016; NYKVIST AND NILSSON 2015.

Actors:

Here is an indicative list of leading Electric Battery providers:

- **Samsung HDI (South Korea)**
- **LG Chem (South Korea)**
- **Panasonic (USA)**
- **BYD (China)**
- **Wanxiang (China)**
- **Toyota (Japan)**
- **NEC (Japan)**
- **Lishen (China)**
- **GS Yuasa (Japan)**

F. Infrared sensors

Definition: Sensors of infrared radiation (that is electromagnetic wave emitted by objects with temperature above 0 kelvin), that enable body temperature control.

Current situation:

Infrared sensors are already mature technologies for years and infrared sensors producers are able to provide competitive infrared sensors to the automotive industry. Yet, the only existing automotive application for infrared sensors is a measure of driver and passengers' body temperature for comfort purpose (adaptive Heating, Ventilation and Air-Conditioning). This comfort application concerns high-range cars, preventing infrared sensors scale economies coming from the automotive industry. Besides, ADAS applications using infrared sensors may only be integrated into ADAS level 3 vehicles and should therefore not lead to great growth, even on the long run.

Infrared sensors applications in automotive will therefore remain negligible for a long time.

Mature Applications:

- **Comfort**. Infrared sensors enable driver health monitoring and adaptive HVAC (Heating, Ventilation and Air-Conditioning), thanks to live measurement of passengers' body temperature.

Future Applications:

- **ADAS (Advanced Driver-Assistance Systems)**. Automatic switch to autonomous driving mode in case of sudden decrease of driver's body temperature measured by infrared sensors.

Actors

Here is an indicative list of leading infrared sensors leaders that may diversify their products in the automotive industry:

- **Murata (Japan)**, is the current leading provider of infrared sensors for automotive.
- **Hoffmann-La Roche (Switzerland)**
- **Medtronic (The USA)**
- **Siemens healthcare (Germany)**

G. Graphene dedicated to sensors or electric batteries

Current situation:

Graphene is a material that have been discovered in 2004. Yet, early 2018, the MIT succeeded to develop a continuous manufacturing process that produces 3D long strips of high-quality graphene. This process can produce five centimeters of high-quality graphene per minute. This is the first 3D graphene produced at speed and costs that enable industrial production.

The potential applications of graphene in automotive could revolutionized this industry. Yet, at least 5 to 10 years will last until the first commercialization of a car incorporating graphene sensors and/or electric batteries using graphene.

Mature applications:

-

Future applications:

Automotive sensors. R&D projects are currently being conducted to develop sensors and biosensors using graphene. Graphene's conductivity characteristics are currently unequalled. Therefore, such sensors could have way higher performances than current automotive sensors and biosensors, leading to an increase of the functions and of the number of sensors integrated into cars.

Electric battery. R&D projects are currently being conducted to develop automotive electric batteries using graphene. Graphene's conductivity characteristics are currently unequalled. Therefore, such electric batteries could have way higher performances than current automotive electric batteries, leading to potential rise of the battery-electric-vehicles (BEV) market.

Actors:

Here is an indicative list of companies involved in automotive graphene sensors R&D:

- **SHD composites (UK)**
- **Applied graphene materials (UK)**

iv. Others

A. Graphene dedicated to physical structures

Current situation:

Graphene is a material that have been discovered in 2004. Yet, early 2018, the MIT succeeded to develop a continuous manufacturing process that produces 3D long strips of high-quality graphene. This process can produce five centimeters of high-quality graphene per minute. This is the first 3D graphene produced at speed and costs that enable industrial production.

The potential applications of graphene in automotive could revolutionized this industry. Yet, at least 5 to 10 years will last until the first commercialization of a car incorporating graphene sensors and/or electric batteries using graphene.

Mature applications:

-

Future applications:

Automotive physical structure. R&D projects are currently being conducted to build automotive physical structures using graphene. Graphene is very resistant and yet has a very low density. As a consequence, replacing automotive physical structures' material with graphene would lead to a huge decrease of automotives' weight for equivalent performances.

Actors:

Here is an indicative list of companies involved in synergies between graphene and automotive:

- **SHD composites (UK)**
- **Applied graphene materials (UK)**

B. 3D printing

Current situation:

3D production of specific spare parts (mostly in plastic or carbon fiber), easing stock management of spare parts. Indeed, any spare part concerned can be immediately printed by 3D printers at little marginal costs. Audi and BMW are already examples. Such 3D printing application could ease the rise of the proportion of embedded electronic equipment in reducing the cost of other physical embedded parts. Furthermore, on the long run, 3D printed sensors may replace current embedded sensors in many applications.

In the last decade, the use of high-Power LEDs led automotive lighting modules to become one of the main characteristics of vehicles' identification, offering new possibilities for car designers. To face the constraints associated to the production of automotive lights with different and very specific forms, 3D-printing offers a reduced prototyping time for automotive suppliers (during the conception phase).

Mature applications:

Production of bumpers, wind breakers, pumps, valves, cooling vents, body panels, control panels, hubcaps, tires, suspension springs, dashboards, seat frames, and all other physical elements dedicated to protecting and/or covering (battery cover, air conditioning ducting, etc.).

Future applications:

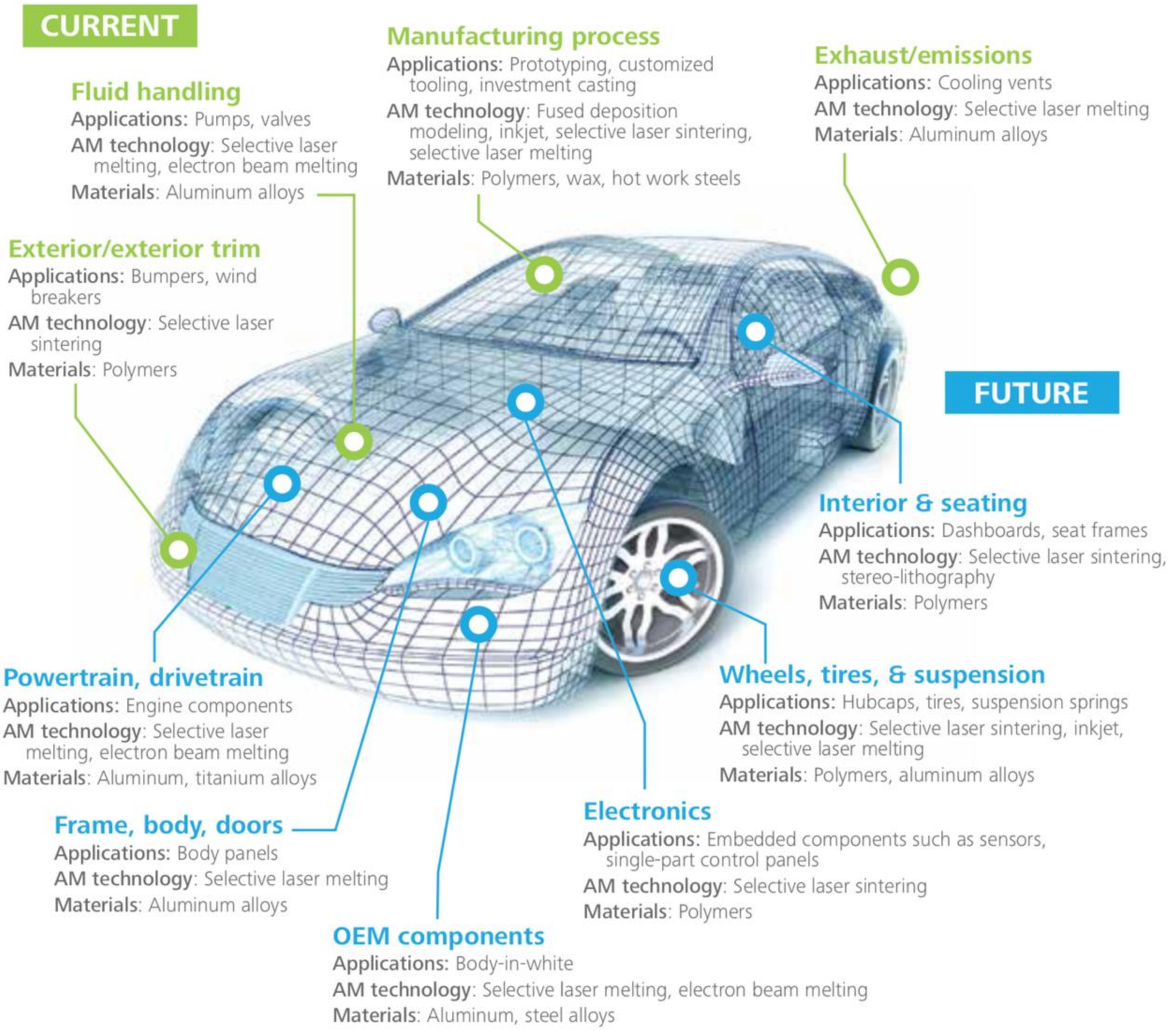
3D printing production of engine components and sensors are currently at the stage of R&D.

Actors:

Here is an indicative list of companies positioned on automotive electronic 3D printing:

- **Stratasys (USA)**
- **SLM Solutions Group AG (Germany)**
- **Voxeljet (Germany)**
- **3D Systems (USA)**

Diagram – Illustrated applications of AM in an automobile



Source: Deloitte analysis.

Graphic: Deloitte University Press | DUPress.com

AM = Additive Manufacturing

C. Hydrogen vehicles

Current situation:

Hydrogen is already a mature technology. The world's first commercially available hydrogen fuel cell vehicle is the Toyota Mirai which has been released in November 2014 and currently cost less than $60 000. Numerous automakers are nowadays able to produce hydrogen vehicles at non-prohibitive costs. The purchasing costs, which remain high, are indeed compensated by the low refuel prices. Yet, hydrogen vehicles' market remains very small with less than 50 000 vehicles sold at the global scale in 2017, which account for around 0,05% of the global automotive sales (that is the equivalent of 5% of the Iranian automotive market). Indeed, hydrogen vehicles development suffers from the competition between hydrogen cars, diesel/petrol cars and electric cars. Diesel/Petrol cars will remain top sellers at the global scale unless a major rise occurs on oil prices -which is clearly unlikely within the next 5 years in view of the remaining oil reserves and the shale gas development. Furthermore, hydrogen development is limited by two major obstacles (which are similar to electric vehicles' development obstacles but at much higher degrees): the complete absence of refueling capabilities network and the insufficiency of hydrogen production. Such elements require very high infrastructure investments that only states could make. Yet, returns on such investments are way too low for the moment. As a consequence, similarly to electric vehicles' market, the hydrogen vehicles' market will remain very small until such infrastructure investments are made but could skyrocket if those investments were made.

Besides, similarly to electric vehicles, moving from petrol/diesel vehicles to hydrogen vehicles only impacts the electronic contents of powertrain and chassis with limited consequences. Indeed, the powertrain/chassis electronic content of diesel/petrol vehicles is already high (for consumption and pollution reduction purposes).

Actors:

Here is an indicative list of leading companies which develop hydrogen vehicles:

- **PSA (France)**
- **Valeo (France)**
- **Faurecia (France)**
- **Symbio FCell (France)**
- **Audi/Mercedes (Germany)**
- **BMW (Germany)**
- **Toyota (Japan)**
- **Honda (Japan)**
- **GM (USA)**
- **Nikola Motors (USA)**
- **Hyundai (South Korea)**

D. Drones & automotive synergies

Current situation:

Every drones' applications in the automotive value chain is complementary rather than in competition with automotive electronic equipments/applications. Therefore, Drones will have either no impact on automotive electronics, or may lead to a slight improvement of automotive industry productivity and therefore to a slight increase in the potential electronic contents of cars.

Mature applications:

- Automatic periodic surveys of finished vehicle inventory in open parking lots near manufacturing plants;
- The use of drones on delivery vans to extend the reach of the vehicle. For example, delivering packages to the balcony of a higher floor apartment;

Actors:

Here is an indicative list of companies which develop synergies between drones and automotives:

- **Parrot (France)**
- **Faurecia (France)**
- **Amazon (USA)**

E. Big data in automotive supply chain

Definition: Exploitation of new datasets generated by connected objects all along the value chain thanks to dedicated software applications.

Current situation: Software dedicated to big data are already mature and will impact the automotive value chain in the exact same way it will impact all industrial value chains, that is in terms of optimization of:

- Customer behavior analytics;
- Marketing mix analytics;
- Supply chain optimization analytics;
- Predictive quality and maintenance analytics.

Such supply chain improvement could reduce the current existing discrepancies between the SC supply chain and the automotive electronic supply chain, resulting in lower costs of components. Yet, those improvements will not be specific to neither SC components nor electronic equipments and will therefore be negligible for the automotive electronics industry.

Besides, automakers are setting up new ECUs dedicated to live treatment and responses to data collected by embedded sensors (for instance to immediately decrease CO_2 emission in case of peak). Yet, those new ECUs are not directly associated to “big data”, but to applications such as ADAS, engine control for pollution reduction, etc.

F. Quick drop type system / Wireless dynamic charging for electric batteries

Two solutions are currently technically proved to reduce the electric battery autonomy issue for all car segments: Quick drop type system and wireless dynamic charging.

Definitions:

Quick drop type system. Electric vehicles chassis configuration system that allow for electric battery change in less than 5 minutes.

Wireless dynamic charging. Use of an electromagnetic field to transfer energy between the vehicle and the road through electromagnetic induction. The higher the speed of the vehicle is, the faster the charge operates.

Current situation:

Quick drop type system. Although this technology is mature, it requires a network of garages able to operate the change and a standardization of electric batteries and chassis among carmakers (or at least a standardization of the chassis part involved in the replacement of the battery). As a consequence, this technology is rarely adopted for now. The world first launched of a hundred quick drop stations was made by Renault in Israel in 2011.

Wireless dynamic charging. Although this technology is mature, it requires a complete replacement of current roads and therefore very high and unlikely infrastructures investments.

Actors:

Here is an indicative list of companies which develop quick drop type systems:

- **Renault (France).**

Here is an indicative list of companies which develop wireless dynamic charging systems:

- **Qualcomm (USA);**
- **KAIST (Korea Advanced Institute of Science and Technology);**
- **Renault (France);**
- **Vedecom (France).**

1.1.1 MNE interactions

i. Automotive IC Worldwide summary

Automotive IC global market in 2016

- The automotive IC market is the fourth IC Market (out of six) in terms of turnover in 2017, with 7.7% global market share;
- The automotive IC market represents € 27.7 billion in 2018;

Automotive IC global growth 2016-2021

- The automotive IC market is the first IC Market in terms of expected compound annual growth rate in the 2016-2021 period;
- The automotive IC market is expected to grow at a compound annual growth rate of 13.4% on the 2016-2021 period: from € 19.3 billion to €36.2 billion. The total automotive IC market jumped by 10% in 2016, a big turnaround from the 2% decline registered in 2015. Moreover, a 22% surge is forecast for this market in 2017.

Automotive IC market characteristics

- **Low volumes**: lower than consumer markets' volumes, but greater than aeronautic/defense/security and spatial volumes;

N°	End-user segment	Market size in thousand units
1	Smartphone	1 500 000
2	Computer	370 000
3	Audio/Video	280 000
4	Home appliances	200 000
5	Automotive	93 000
6	Industrial, health & care	85 000
7	Security	75 000
8	Wearables	30 000
9	Aeronautics/Defense/Spatial	30

Source: Decision Etudes & Conseil

- **Low prices**;
  - In line with the very high-quality standards and with the long product life cycle in automotive, this end-user segment is consuming for the most part old technologies (40-60 nanometers rather than 7 nanometers). These old technologies have lower prices than advanced technologies;
  - Furthermore, automakers are players with great negotiation power and on the other hand.

- **Very high-quality standards:** Higher to consumer segments and equal to aeronautics/defense and spatial segments;
- Therefore, the increase of the global automotive SC market is the result of
    - Decreasing prices;
    - Stable technologies;
    - Stable players;
    - Volumes that are skyrocketing (in line with the average content per car).

The EU's position

- The European automotive IC market represents €8.9 billion in 2018;
- Asia-Pacific first passed Europe to become the largest total automotive IC market in 2015. It is forecast to hold a 37% share in 2021, up from an expected 35% share in 2017. The Asia-Pacific automotive IC market is forecast to be 20% larger than that of Europe in 2021;
- From 2016 to 2021, although all geographic regions are forecast to enjoy strong automotive IC sales growth, Europe will experience the smallest growth with a 12.5% compound annual growth rate.

There is a dichotomy between advanced technologies (MPU / MCU), and older technologies in Europe

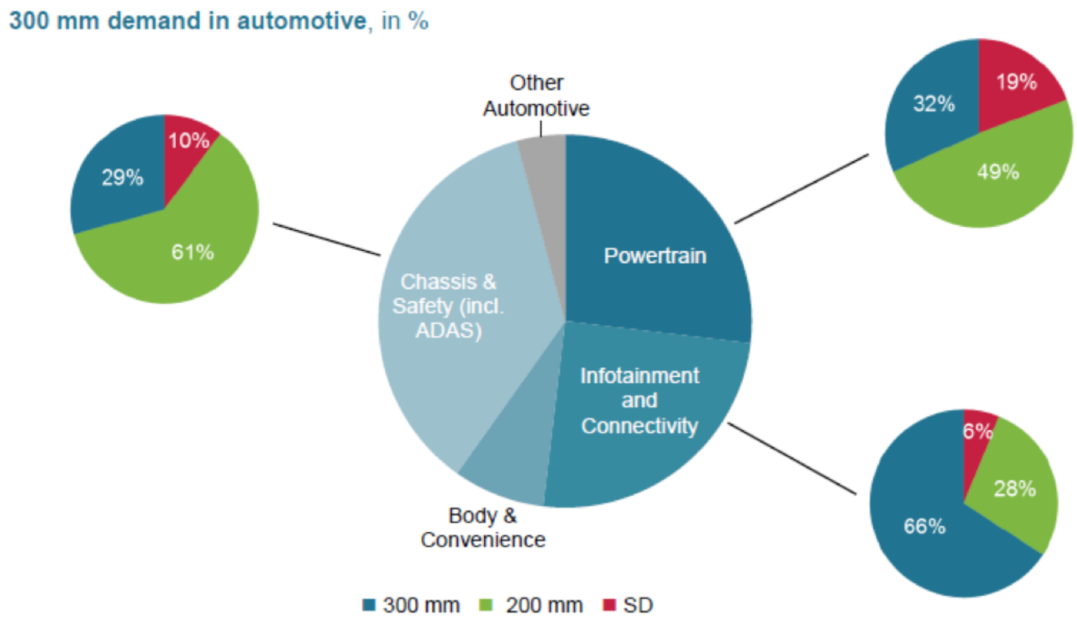
- **In terms of production of older technologies, the EU remain well positioned** in particular thanks to the size and the growth of the industrial, automotive and aeronautics/defense/security end-user segments.
- **On the contrary, advanced technologies are no longer manufactured in Europe** (except for the design and for a few very specific advanced technologies), so that Europe will soon become dependent of Asia regarding these technologies (leading to sovereign risks, climatic risks like earthquake, etc.). This dependence should impact the automotive segment within the following decade. Indeed, automotive quality standards are very high, leading to the quasi-systematic adoption of old technologies that have been proven reliable. As a consequence, it traditionally lasts a decade between the production of an IC new technology and its large-scale integration into automotives.

  The manufacture of advanced technologies is leaving the EU because of the lack of public investment to support the manufacture of such technologies compared the US and Asia (in particular China).

  Yet, in terms of capital ownership, the EU players are still well positioned on advanced technologies: Infineon, STMicroelectronics, NXP and XFab. As a consequence, the middle-term risk only concerns the production of advanced technologies in Europe but do not concerns the know-how (patents, skilled-jobs, design, etc.).

Automotive will be impacted by this phenomenon through every new application that involves advanced technologies (ADAS and infotainment in the first place). Yet, as shown in the diagram below, power electronics and ADAS do not involve a great amount of advanced technologies (300 mm) and represent a great part of automotive electronics.

Diagram - Within a car, most silicon is used for powertrain, infotainment and safety



[41] ADAS = Advanced Driver Assistance System
Source: Siltronic

Automotive IC sub-segments

- Analog ICs are by far expected to continue to represent the largest product segment within the automotive IC market throughout the forecast period;
- MPUs[42] and DSPs[43] are forecast to continue to comprise a very small share of the automotive IC market through 2021;
- The automotive memory IC market is forecast to increase 73% from €2.4 billion in 2017 to €4.2 billion in 2021, in a great measure due to the rise of embedded software and the need to operate fast live updates which requires systems to operates while the update is launched, and therefore to copy the entire system in memory.

[41] ADAS = Advanced Driver Assistance System
[42] MPU = Micro processor
[43] DSP = Digital Signal Processor

Roadmap – For every electronic system type, what is the size and growth of automotive in Europe compared to the other segments and what is the European position in automotive compared to the other regions

Source: DECISION Études et Conseil, IC Insights

AUTOMOTIVE	Analog	Logic	MOS Memory	MOS DSP	MOS MCU	MOS MPU	TOTAL ICs
European automotive market in 2017 – M €	3,869	867	293	458	1,693	38	7,218
Rank of automotive in Europe in terms of market size	**1 – Automotive** 2 – Industrial 3 – Communications 4 – Consumer 5 – Computer 6 – Gov/Military	1 – Communications 2 – Computer **3 – Automotive** 4 – Consumer 5 – Industrial 6 – Gov/Military	1 – Computer 2 – Communications 3 – Industrial **4 – Automotive** 5 – Consumer 6 – Gov/Military	**1 – Automotive** 2 – Communications 3 – Industrial 4 – Gov/Military 5 – Consumer 6 – Computer	**1 – Automotive** 2 – Industrial 3 – Consumer 4 – Communications 5 – Gov/Military 6 – Computer	1 – Computer 2 –Communications 3 – Industrial 4 – Gov/Military **5 – Automotive** 6 – Consumer	1 – Computer **2 – Automotive** 3 – Communications 4 – Industrial 5 – Consumer 6 – Gov/Military
CAGR 2017–2022 European automotive market	10%	19%	27%	12%	10%	15%	12%
Rank of automotive in Europe in terms of CAGR 2017–2022	**1 – Automotive** 2 – Computer 3 – Gov/Military 4 – Communications 5 – Industrial 6 – Consumer	**1 – Automotive** 2 – Industrial 3 – Computer 4 – Gov/Military 5 – Consumer 6 – Communications	**1 – Automotive** 2 – Consumer 3 – Industrial 4 – Computer 5 – Gov/Military 6 – Communications	**1 – Automotive** 2 – Industrial 3 – Communications 4 – Computer 5 – Consumer 6 – Gov/Military	**1 – Automotive** 2 – Computer 3 – Industrial 4 – Communications 5 – Consumer 6 – Gov/Military	1 – Consumer 2 – Industrial **3 – Automotive** 4 – Computer 5 –Communications 6 – Gov/Military	**1 – Automotive** 2 – Industrial 3 – Consumer 4 – Computer 5 – Communications 6 – Gov/Military
Share of European consumption	36%	25%	17%	42.5%	30%	9%	31%
Rank of Europe	**1 – Europe** 2 – Asia–Pacific 3 – Americas 4 – Japan	1 – Asia–Pacific **2 – Europe** 3 – Japan 4 – Americas	1 – Asia–Pacific 2 – Americas **3 – Europe** 4 – Japan	**1 – Europe** 2 – Asia–Pacific 3 – Americas 4 – Japan	**1 – Europe** 2 – Asia–Pacific 3 – Japan 4 – Americas	1 – Asia–Pacific 2 – Americas **3 – Europe** 4 – Japan	1 – Asia–Pacific **2 – Europe** 3 – Americas 4 – Japan

The table above provides for each electronic system type an overview of:

1. The size of the European automotive market compared to the other European markets;
2. The growth of the European automotive market compared to the other European markets;
3. The size of the European automotive market compared to the other regional automotive markets.

Analog

- With € 3 869 Millions in 2017, automotive is the first European end-user segment in terms of analog consumption.
- With an estimated compound annual growth rate of 10% over the 2017-2022 period, automotive is also the first European end-user segment in terms of analog consumption growth in value.
- Finally, with 36% of the global consumption, Europe is the first region of the world in terms of analog consumption dedicated to automotive.

The automotive is very consuming in terms of analog compared to the other segments, and the automotive consumption in terms of analog will increase within the coming years. Indeed, automotive electronics involves a lot of sensors, cabling and information transmission tools.

Logic

- With € 867 Millions in 2017, automotive is the third European end-user segment in terms of logic consumption.
- With an estimated compound annual growth rate of 19% over the 2017-2022 period, automotive is the first European end-user segment in terms of logic consumption growth in value.
- Finally, with 25% of the global consumption, Europe is the second region of the world in terms of logic consumption dedicated to automotive.

Automotive is not very consuming in terms of logic (apart from MCUs).

MOS Memory

- With € 293 Millions in 2017, automotive is the fourth European end-user segment in terms of MOS Memory consumption.
- With an estimated compound annual growth rate of 27% over the 2017-2022 period, automotive is the first European end-user segment in terms of MOS Memory consumption growth in value.
- Finally, with 17% of the global consumption, Europe is the third region of the world in terms of MOS Memory consumption dedicated to automotive.

Historically, automotive is not very consuming in terms of memory. Yet, for a few years, the importance of memories in automotive is rising at fast pace in line with the growing importance of embedded software[44]. Still, this growth will not last on the middle/long term and will not lead automotive to become one of the first electronic memories markets. Indeed, even if the storage capacity embedded into cars were to double, the automotive memories market would remain very low in value because the automotive market is a low-volume market (with only 93 Million automotive produced every year compared to the 1 500 Million smartphones produced every year at the global scale).

Furthermore, no more memories are produced in Europe apart from embedded memories: MCU, NAND, etc. (produced by Infineon, and STMicroelectronics).

MCU are one of the only advanced technologies with a remaining strong productive base in Europe. Indeed, the automotive and industrial segments consume a lot of MCU and Europe is specialized in Automotive and Industrial.

MOS DSP

- With € 458 Millions in 2017, automotive is the first European end-user segment in terms of MOS DSP consumption.
- With an estimated compound annual growth rate of 12% over the 2017-2022 period, automotive is also the first European end-user segment in terms of MOS DSP consumption growth in value.
- Finally, with 42,5% of the global consumption, Europe is the first region of the world in terms of MOS DSP consumption dedicated to automotive.

[44] In particular, a lot of memory is required for operating systems update’s purpose.

MOS MCU

- With € 1 693 Millions in 2017, automotive is the first European end-user segment in terms of MOS MCU consumption.
- With an estimated compound annual growth rate of 10% over the 2017-2022 period, automotive is also the first European end-user segment in terms of MOS MCU consumption growth in value.
- Finally, with 30% of the global consumption, Europe is the first region of the world in terms of MOS MCU consumption dedicated to automotive.

Historically, automotive is not very consuming in terms of memory.

Furthermore, no more memories are produced in Europe apart from embedded memories: MCU, NAND, etc. (produced by Infineon, and STMicroelectronics).

MCU are one of the only advanced technologies with a remaining strong productive base in Europe. Indeed, the automotive and industrial segments consume a lot of MCU and Europe is specialized in Automotive and Industrial.

MOS MPU

- With € 38 Millions in 2017, automotive is the fifth European end-user segment in terms of MOS MPU consumption.
- With an estimated compound annual growth rate of 15% over the 2017-2022 period, automotive is the third European end-user segment in terms of MOS MPU consumption growth in value.
- Finally, with 9% of the global consumption, Europe is the third region of the world in terms of MOS MPU consumption dedicated to automotive.

TOTAL ICs

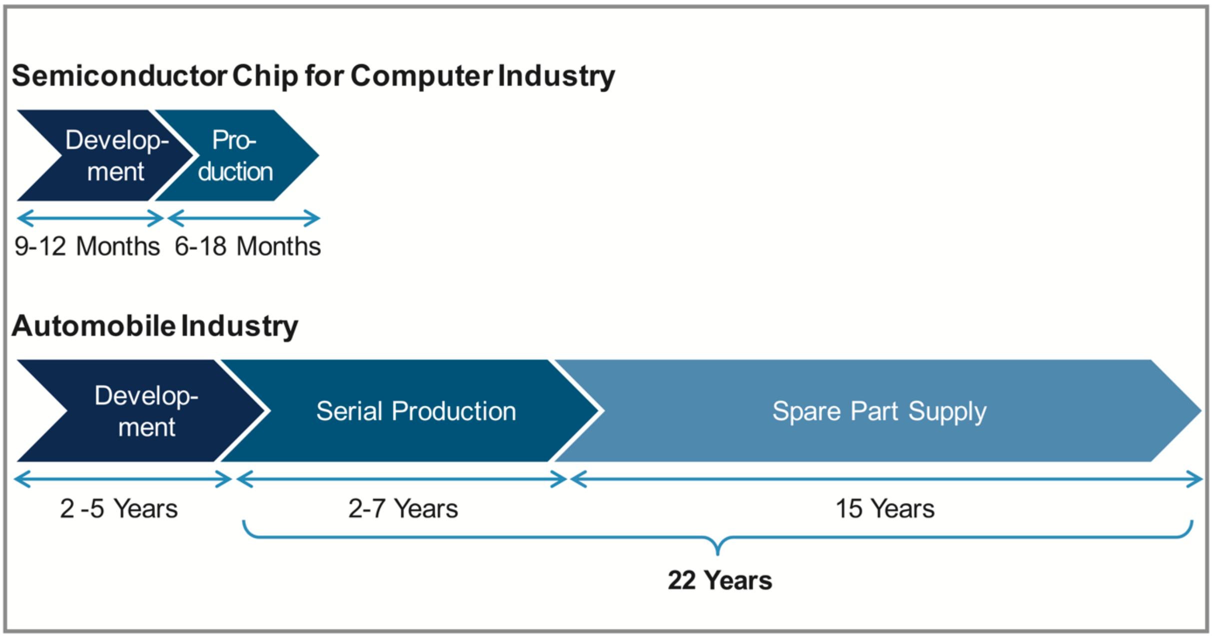
- With € 7 218 Millions in 2017, automotive is the second European end-user segment in terms of ICs consumption.
- With an estimated compound annual growth rate of 12% over the 2017-2022 period, automotive is also the first European end-user segment in terms of ICs consumption growth in value.
- Finally, with 31% of the global consumption, Europe is the second region of the world in terms of ICs consumption dedicated to automotive.

ii. Interactions between SC and Automotive supply chains

The characteristics of the Semiconductors supply chain and the automotive supply chain differ in several ways[45], leading to discrepancies:

1. **Product life cycles**.

   Most of semiconductors are integrated into products with shorter sales periods than automotives: computers, phones, home appliances, etc. (e.g. less than a year for mobiles phones against 3-7 years for a car). In other words, the semiconductor market is globally much more volatile than the automotive market. As a consequence, the development cycles of these two industries are frequently out of line.



C.Forster, M.Zapp, J.Aelker, E. Westkämper and T.Bauernhansl

This phenomenon brings the following consequences:

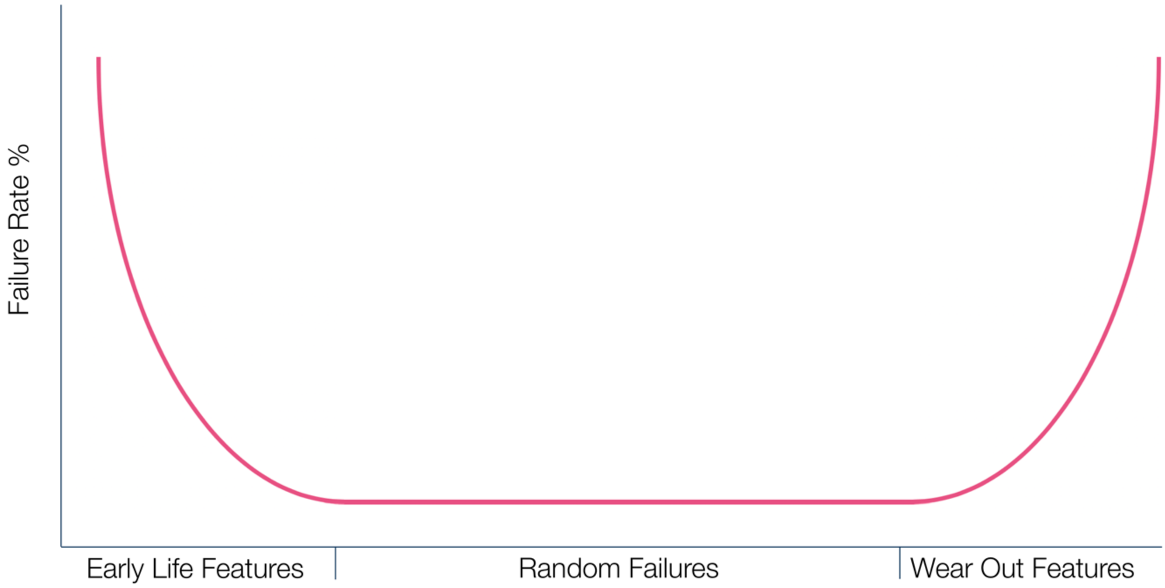
- **Spare parts supply.** Automakers needs guarantees that spare parts can be supplied in unmodified technical form for periods of 15 to 25 years. Such long-term supplies represent a challenge for semiconductor suppliers: both **maintaining production capacity for spare parts** or properly **storing semiconductors for long periods** engages **high costs**.

- **Delay in the innovation process**. Because of the shorter innovation cycles in the semiconductor industry than in the automotive industry, some semiconductors technologies are already outdated at the launch of a new car production

[45] These analyses are inspired by the article "Collaborative value chain management between automotive and semiconductor industry: an analysis of differences and improvement measures", written by C.Forster, M.Zapp, J.Aelker, E. Westkämper and T.Bauernhansl.

2. **Quality**. At the global scale, the average share of semiconductors that leaves the manufacturing process without defects (default rate) is estimated to lie around 1 ppm (1 / 1 000 000). This yield is about the same for every of semiconductors' applications (telecommunications, home appliances, etc.). Yet, the criteria to evaluate the defect rate significantly differs from an end-user segment to another. In the automotive industry and the spatial industry are the two end-user segments with the highest test criteria. Indeed, a semi-conductor integrated in a car must be able to tolerate temperatures from -40 to +150 Celsius degrees. Besides, the life of an electronic component inside a car is very short in terms of real time of use[46]. Yet, the default rate of an electronic component is very high not only at its end of life but also at its early life (see the graph below). It therefore even more difficult for SC manufacturers to meet the default rates imposed by the automotive industry.

Graph – Electronic components life cycle



Source: DECISION Études et Conseil

These high-costs certification activities lead the automotive industry to keep older semiconductor technologies (implying **delay in the innovation process**), which results in **high costs** for semiconductor suppliers.

3. **Lead times**. Lead time in the automotive industry lies between 2 and 4 weeks, while lead time in the semiconductor industry lies between 10 and 16 weeks. In other words, the average lead time in the automotive industry accounts for one fourth of the average lead time for semiconductor components.

    - **Planning horizons**. Those different production lead times lead to different planning horizons (up to six months). It is usual practice that semiconductor suppliers get reliable planning data from their automotive customers only for the next 2-3 months. This lack of planning reliability pushes some semiconductor producers to build up **large stocks** that leads to **high costs**. This issue is worsened by the complexity of the automotive supply chain through its division between automakers and Tier 1, Tier 2 and Tier 3 suppliers: OEMs pass down only part of the information given by automakers so that semiconductor suppliers tend to consult sub-party sources for their long-term planning.

[46] Although a customer can hold the same car for 20 years, this car will be in fact used only 67 full days to cover a distance of 80 000 km. As a consequence, the electronic devices inside the car will only be used 67 full days over the 20 years period.

High negotiation power form carmakers. Furthermore, among all the end-user segments, clients in the automotive industry are the SC clients that own at the same time the highest financial/commercial power and the deepest technical knowledge of the IC industry.

Indeed, most commercial relationships in the automotive industry involve 3 types of players: a car manufacturer (Renault, etc.), an automotive Tier 1 supplier (Valéo, etc.), and a semiconductor manufacturer. The automotive Tier 1 supplier is already appointed by the automaker when those two players launch the negotiations with the SC manufacturer. The manufacturer lists his needs and provide the design while the tier 1 supplier set up the technical specifications and identifies the corresponding price thanks to his good knowledge of the semiconductor industry. Automotive Tier 1 suppliers have most of the time an in-depth knowledge of the SC industry (prices, costs and returns), because a significant share of their engineers started their careers in the SC industry. A few carmakers even require a minimum percentage of employees among the engineering teams of semiconductor manufacturers in charge of customer relations to undertake several weeks trainings in order to become familiar with their practices (including quality standards).

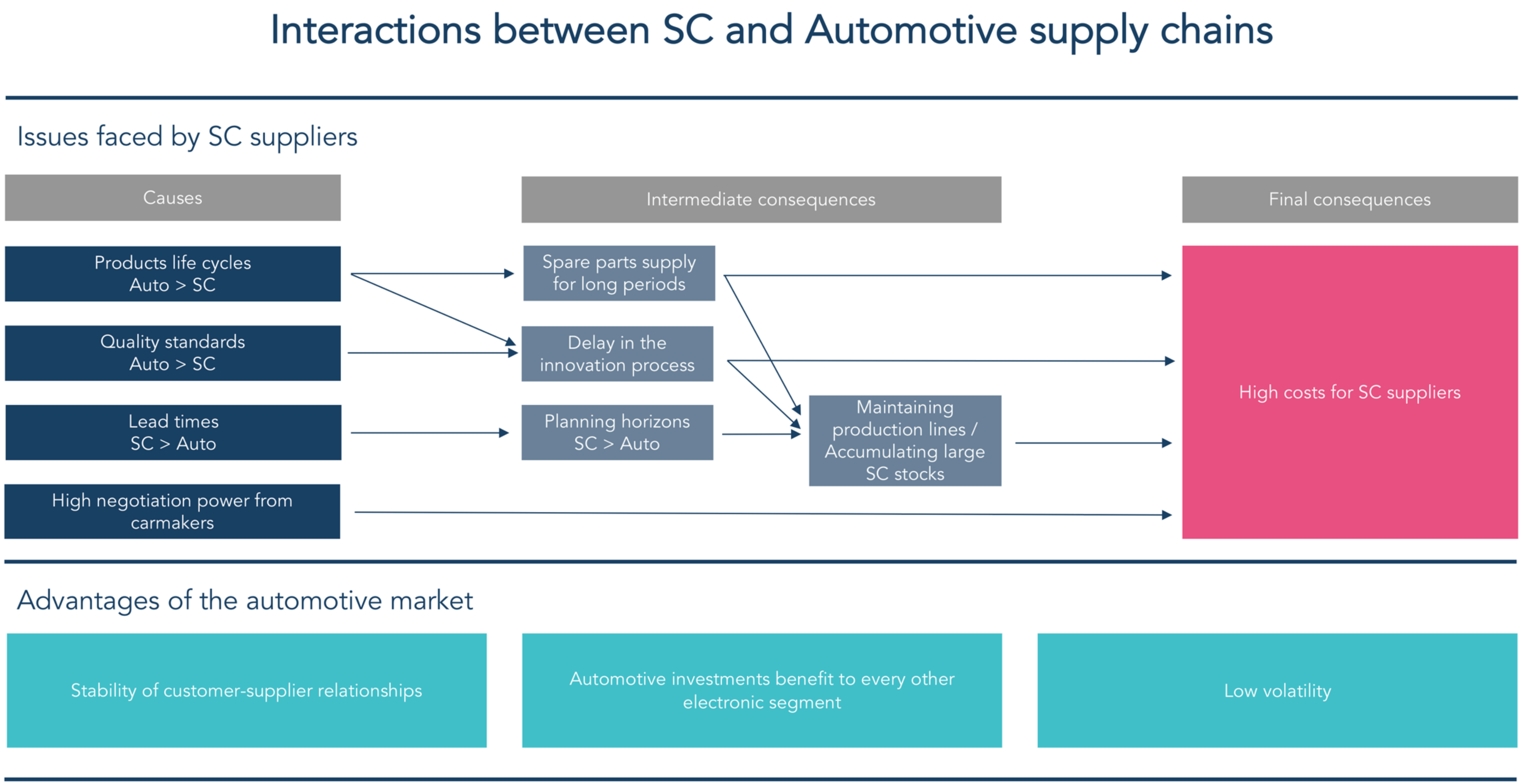
Yet, IC manufacturers also have incentives to take strong positions on the automotive market:

1. **Stability of customer-supplier relationships**. Because of the strong requirements from automakers and automotive Tier 1 suppliers, the customer-supplier relationships in the automotive segment are very stable. Yet, on the short and middle run, this stability is threatened by the will of China to control the entire automotive electronic value chain. Chinese carmakers and automotive Tier 1 suppliers are already key players at the global scale and China impose foreign automakers and Tier 1 suppliers to set up joint ventures with Chinese players in order to set up activities in China. Now that such Chinese actors gained sufficient negotiation power at the global scale, they are thriving to progressively impose Chinese SC manufacturers at the bottom of the value chain. It is very unlikely that the traditional stability of customer-supplier relationships in the automotive segment will be sufficient to protect the EU SC manufacturers' market share from the attempt of China to take the lead of the value chain. A proactive industrial policy will be required if the EU is to protect the market share of the EU producers.

2. **Low volatility.** Automotive is one of the least volatile SC end-user segments. The industrial segment and the aeronautics/defense/security segment also benefit from a very low volatility, but those two segments' sizes are much smaller than the size of the automotive segment (both in volume and in value).

3. **Automotive investments benefit to every other electronic segment**. Investments required in the automotive segment to meet standards, deadlines and yields are then applied to all the other electronic segments at no additional cost.

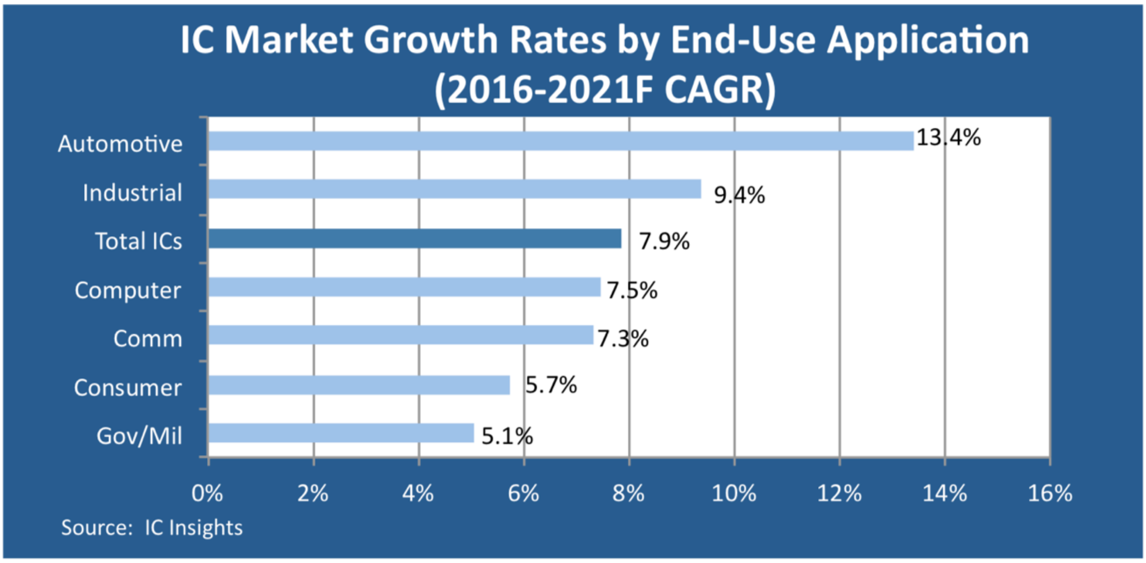
Those elements are summarized in the following diagram:



Source: DECISION Études et Conseil

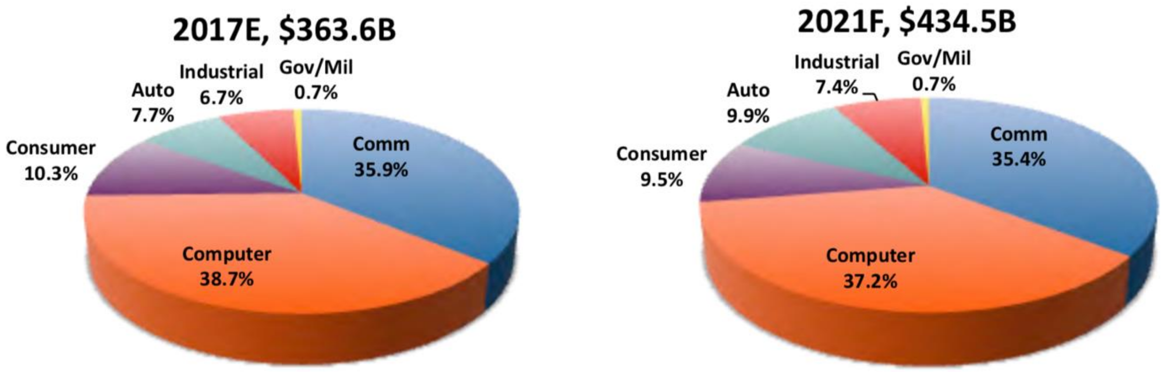
iii. Automotive IC growth (IC Insights)

Automotive IC is the end-user application that is growing the fastest with 13.4% compound annual growth rate over the period 2016-2021.



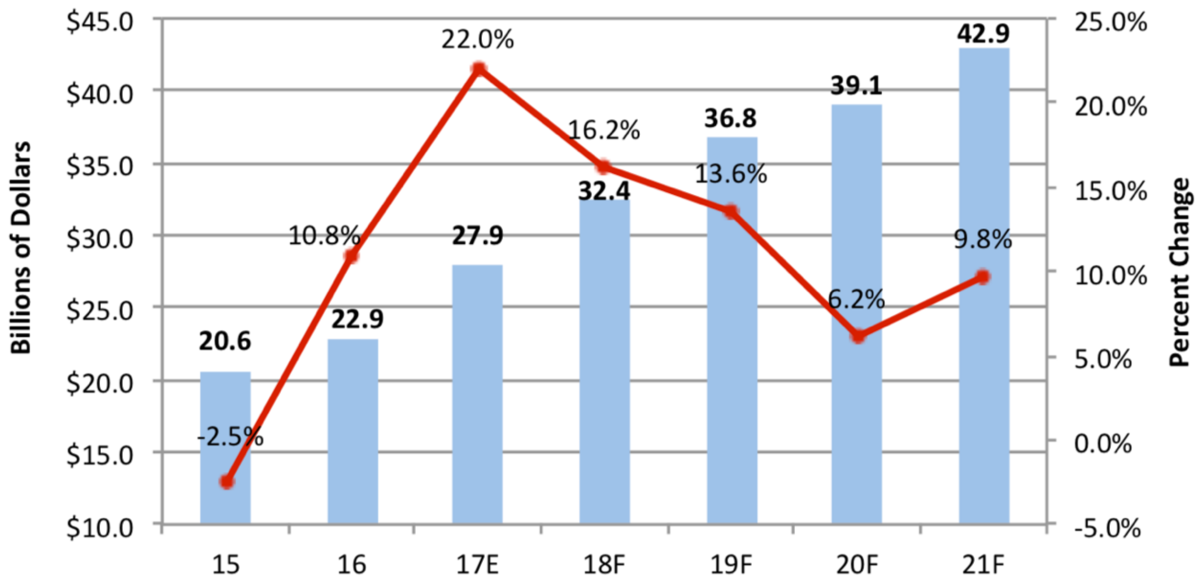
Although automotive IC sales only represent 7.7% of total IC sales in 2017 (far less than computer, communications and consumer applications), this market is expected to account for nearly 10% of total IC sales in 2021, which would make it the third-largest end-use application for ICs, slightly ahead of the consumer segment.

Pie chart – IC Market by End-Use Application



Source: IC Insights

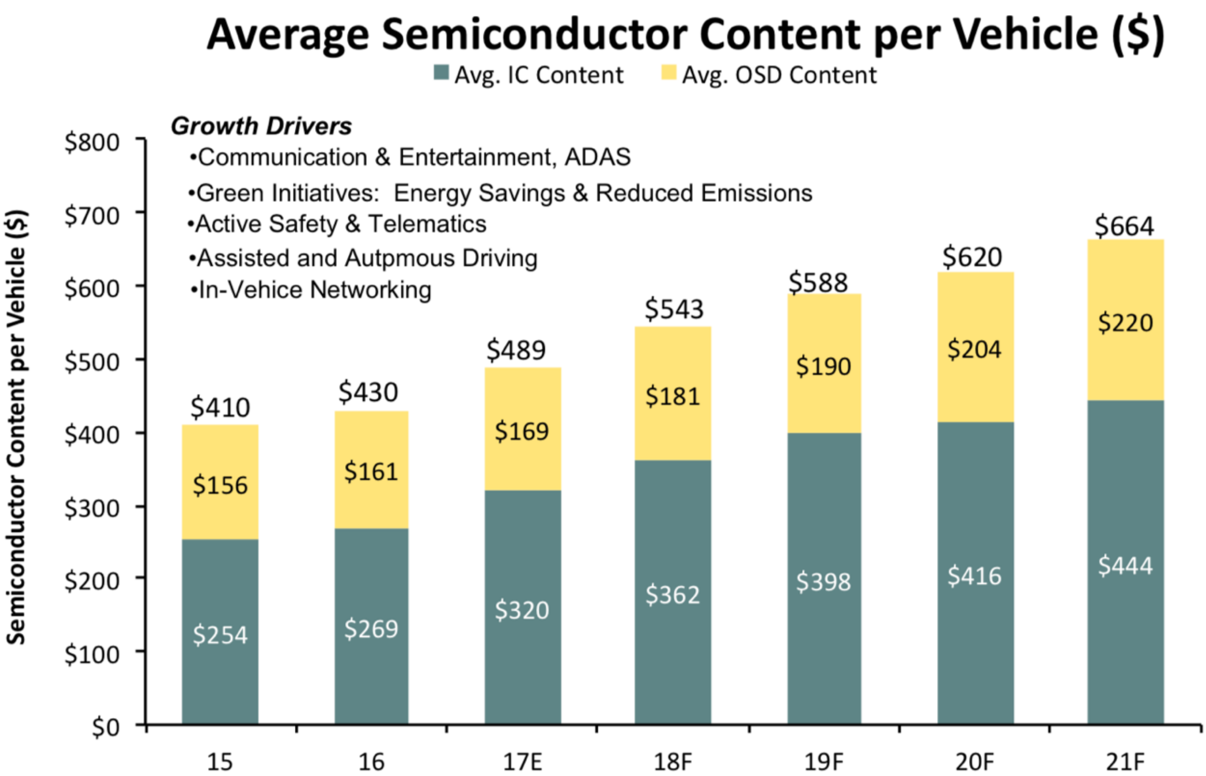
Bar chart – 2015-2021F Automotive IC Market



Source: IC Insights

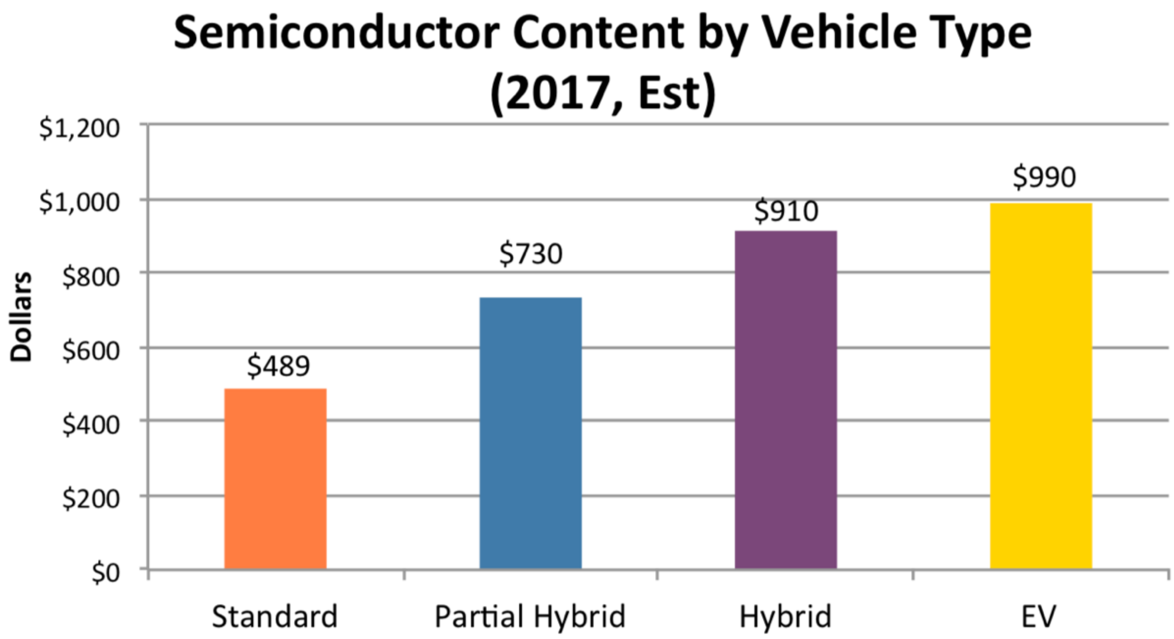
The average IC content per vehicle is also expected to rise at a compound annual growth rate of 8% over the 2017-2021 period to reach 664$ per vehicle in 2021, which would represent 6-7% of the average vehicle total cost.

Such a rise of automotive IC is in line with the global development of automotive electronics: ADAS applications, but also infotainment applications and -only on the short run- powertrain applications (see the paragraph "Historical evolutions of the supply chain in terms of applications").



Source: IC Insights

Yet, in addition of the global automotive electronics growing factors, automotive IC may specifically rise in line with electric vehicles' development. In 2017, electric vehicle[47] IC content's price is twice standard vehicle IC content's price (990$ against 489$), and that gap is expected to rise within the coming years. As a consequence, the current trend of electrification of powertrains will drastically rise automotive IC content.



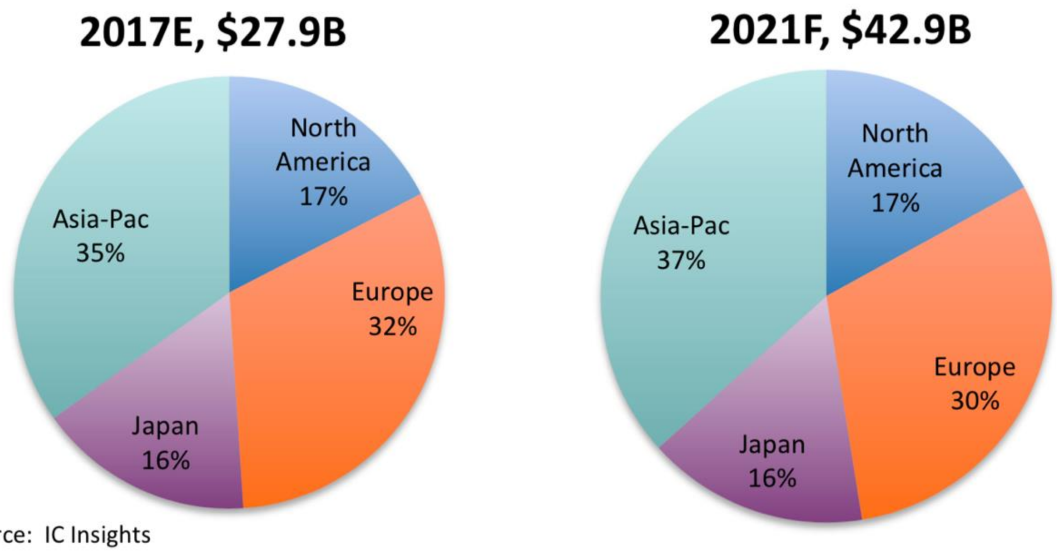
Source: IC Insights, Infineon

iv. The EU position in terms of IC consumption (IC Insights)

Finally, for many years, Europe was the largest market for automotive ICs, but that changed in 2015 when the Asia-Pacific region edged ahead of Europe. Asia-Pacific's regional market share is forecast to expand through 2021 to represent 37% of global automotive IC sales.

Pie chart - Automotive IC Market by Region

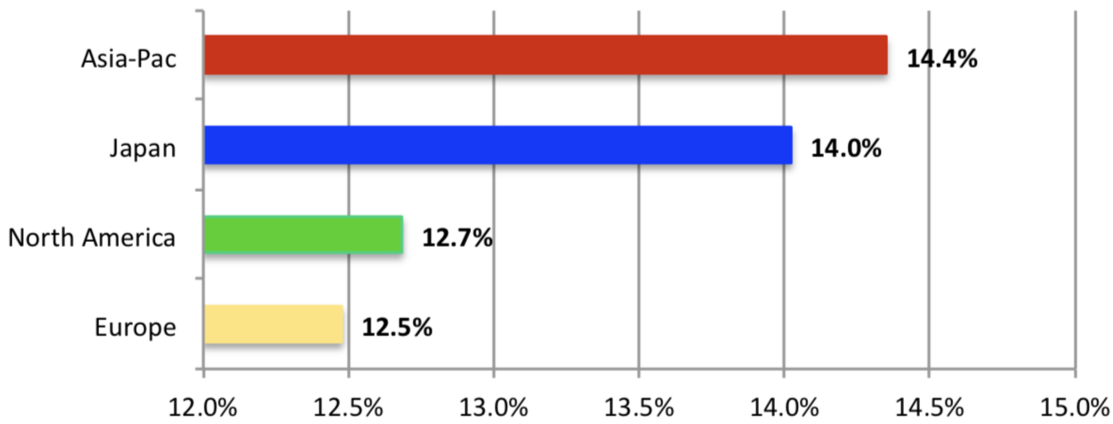
[47] Battery Electric Vehicle (BEV) and Plug-In Hybrid Electric Vehicle (PHEV)



Source: IC Insights

From 2016 to 2021, although all geographic regions are forecast to enjoy strong automotive IC sales growth, Europe will experience the smallest growth with a 12,5% compound annual growth rate. Within Asia-Pacific, China continues to be instrumental in driving automotive IC sales. China is increasing emphasis on electric vehicles, which will help boost automotive IC sales in that country.

Regional Auto IC Market Growth (2016-2021F CAGR)



Source: IC Insights

Worldwide Automotive IC Markets ($M)

MOS MPU

Region	2015	2016	2017E	2018F	2019F	2020F	2021F
Americas	120	150	185	220	260	270	280
Europe	30	38	45	55	70	75	80
Japan	17	22	27	35	40	45	50
Asia-Pac	155	195	235	285	345	375	440
Total	**322**	**405**	**492**	**595**	**715**	**765**	**850**

MOS MCU

Region	2015	2016	2017E	2018F	2019F	2020F	2021F
Americas	1,132	976	1,048	1,105	1,184	1,182	1,228
Europe	1,754	1,921	2,195	2,423	2,718	2,838	3,060
Japan	1,068	1,351	1,497	1,621	1,786	1,833	1,936
Asia-Pac	1,754	1,741	1,996	2,263	2,602	2,759	3,039
Total	**5,708**	**5,988**	**6,735**	**7,411**	**8,291**	**8,611**	**9,264**

MOS DSP

Region	2015	2016	2017E	2018F	2019F	2020F	2021F
Americas	140	209	241	260	277	279	294
Europe	357	427	575	638	698	719	772
Japan	71	83	93	101	109	110	117
Asia-Pac	243	307	360	395	428	437	468
Total	**812**	**1,027**	**1,269**	**1,393**	**1,512**	**1,544**	**1,651**

Analog

Region	2015	2016	2017E	2018F	2019F	2020F	2021F
Americas	1,504	1,780	2,070	2,363	2,667	2,895	3,196
Europe	3,620	4,054	4,576	5,140	5,715	6,054	6,530
Japan	1,316	1,483	1,852	2,127	2,413	2,632	2,848
Asia-Pac	2,774	3,510	3,976	4,785	5,334	5,725	6,183
Total	**9,214**	**10,826**	**12,474**	**14,414**	**16,128**	**17,307**	**18,757**

Logic

Region	2015	2016	2017E	2018F	2019F	2020F	2021F
Americas	405	416	553	696	852	969	1,127
Europe	567	582	1,014	1,292	1,598	1,723	1,917
Japan	405	416	737	894	1,065	1,077	1,240
Asia-Pac	1,377	1,496	1,751	2,186	2,557	2,768	3,157
Total	**2,754**	**2,909**	**4,056**	**5,067**	**6,072**	**6,537**	**7,441**

MOS Memory

Region	2015	2016	2017E	2018F	2019F	2020F	2021F
Americas	567	490	772	907	1,022	1,048	1,180
Europe	205	235	379	470	559	605	706
Japan	166	178	305	390	474	519	615
Asia-Pac	879	803	1,405	1,759	2,048	2,164	2,456
Total	**1,817**	**1,707**	**2,861**	**3,526**	**4,102**	**4,336**	**4,958**

Total Automotive ICs

Region	2015	2016	2017E	2018F	2019F	2020F	2021F
Americas	3,869	4,021	4,869	5,550	6,262	6,643	7,305
Europe	6,533	7,258	8,784	10,017	11,359	12,013	13,065
Japan	3,044	3,532	4,511	5,168	5,887	6,216	6,807
Asia-Pac	7,181	8,052	9,723	11,672	13,313	14,228	15,743
Total	**20,627**	**22,863**	**27,888**	**32,407**	**36,821**	**39,100**	**42,919**

Source: IC Insights

v. The EU position in terms of Automotive IC suppliers

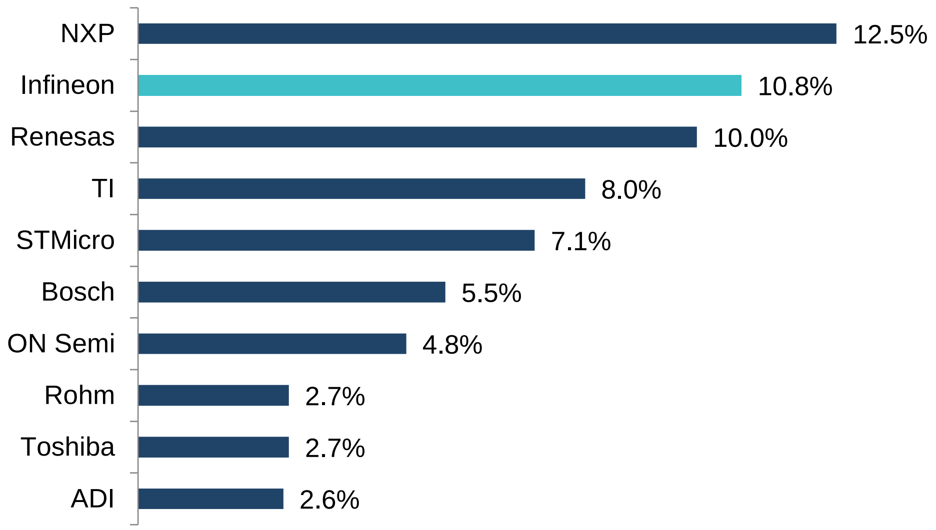
Table – 2017 – Ranking TOP European automotive electronic components manufacturers

Nationality of principal shareholder	Company name	Automotive turnover (€M)	Automotive % total turnover	Turnover (€M)	World auto SC PDM %
Germany (7,5%), The USA (10%)	Infineon	2 966	42 %	7 063	6,1 %
France (14%), Italy (14%)	STMicroelectronics	2 634	37 %	7 120	5,4 %
Belgium (48%)	XFab	221	45 %	491	-
The USA (30%)	NXP	2 363	30 %	7 875	4,9 %
The USA (21%)	AMS	170	16 %	1 064	0,3 %

Source: DECISION Etudes & Conseil

Bar chart – Automotive semiconductor – Global market shares 2017

Total market in 2017: $34.5 B



Source: Strategy Analytics

On Automotive semiconductor, NXP (n°1), Infineon (n°2), ST (n°5) and Bosch (n°6) covers 36% of a WW market of $34.5 B.

- Infineon automotive sales represented 42% of its turnover in 2017, that is € 2 989 M.

- STMicroelectronics automotive sales represented 40% of its turnover in 2017, that is € 2 848 M. Automotive is by far the first market for STMicroelectronics. In 2008, the first market of STMicroelectronics was telecommunications (Nokia), with 20% of the total turnover (€ 1 340 M). In 2008, automotive IC sales only represented 15% of STMicroelectronics total turnover, that is € 1 006 M.

- NXP became one of the world's largest automotive IC supplier in 2016 following its $ 11.8 billion acquisition of Freescale Semiconductor in December 2015. NXP automotive IC sales represented € 2 255 M in 2017 (29% of NXP's total turnover). During 2017, NXP was itself the target of an acquisition by Qualcomm, which agreed to buy the Dutch chipmaker for $ 39 billion. The completion of the transaction was delayed in 2017 by a European Commission review of the acquisition. Since then, this acquisition has been cancelled. Qualcomm was drawn to NXP for at least two automotive-related reasons. First, NXP is the largest supplier of automotive ICs. Its portfolio would have help significantly diversify Qualcomm's offering and would have provide it an entry into multiple markets outside its core mobile chipset business. Second, NXP is using its chips to gain a foothold in the emerging market for self-driving cars, a market in which Qualcomm wants to participate.

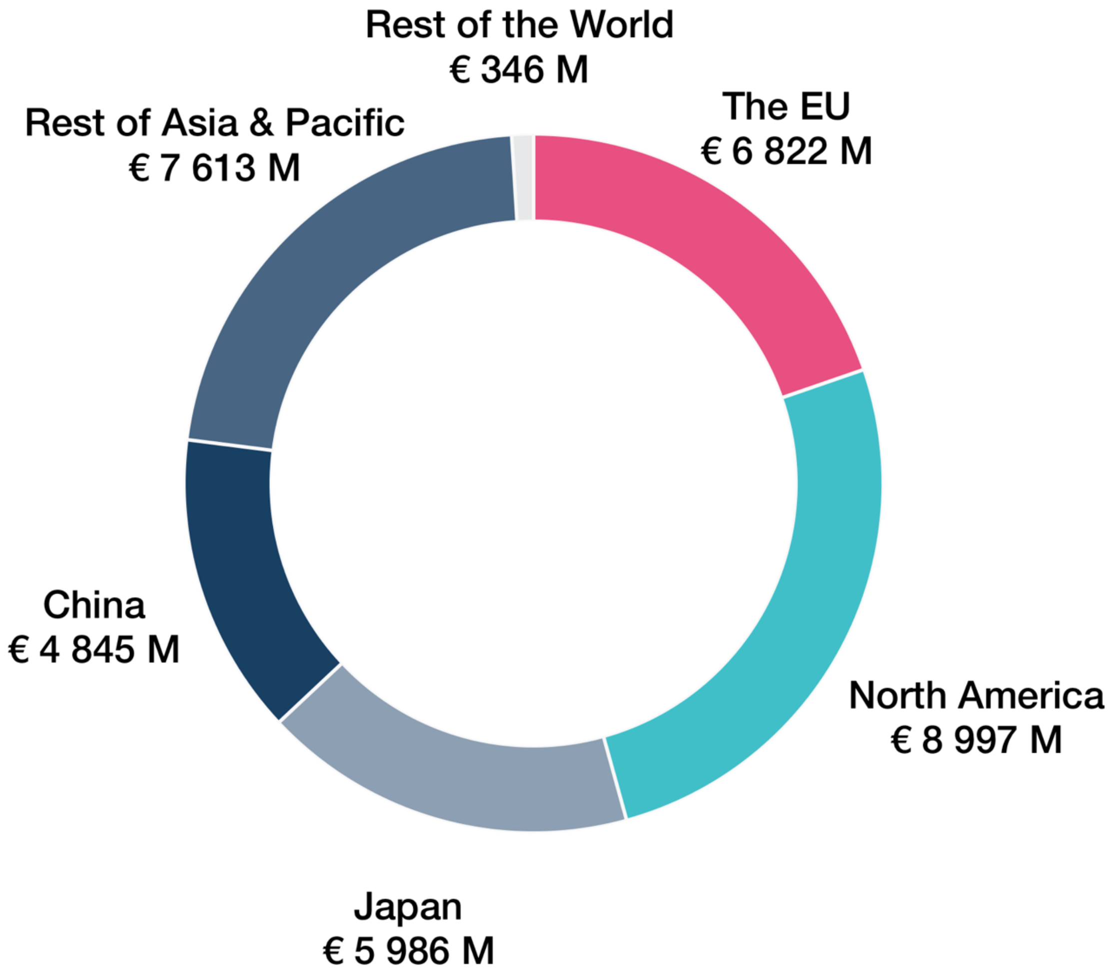
- AMS automotive sales represented 20% of its turnover in 2017, that is € 213 M.

Although interested in the related growth prospects, TSMC and the other European manufacturers do not hold significant market shares in the automotive segment and do not try to improve their market shares in this segment. It is indeed long and difficult to enter the automotive segment because of the stability of the customer-supplier relationships.

NXP and AMS are not considered as "European" in terms of capital ownership in this study. Indeed, the principal shareholders of both NXP and AMS are American (the USA).

Yet, altogether, the EU producers account for 20% of the global Automotive IC production in 2017. The EU is therefore the third region for Automotive IC production in terms of nationality of principal shareholder after North America and Other Asia & Pacific (South Korea, etc.).

Diagrams - 2017 - Global repartition - Automotive IC production in terms of nationality of principal shareholder



Appendix – Automotive report

i. Appendix 1 - Prodcom figures

The Prodcom database provide specific “factory-gate” data. Prodcom present the volume of units produced by factories (only) and the related average price of every product.

The issue regarding automotive electronics is that Prodcom only provide data on very specific sub-systems.

Therefore, those data are absolutely not representative of the global EU automotive electronic production.

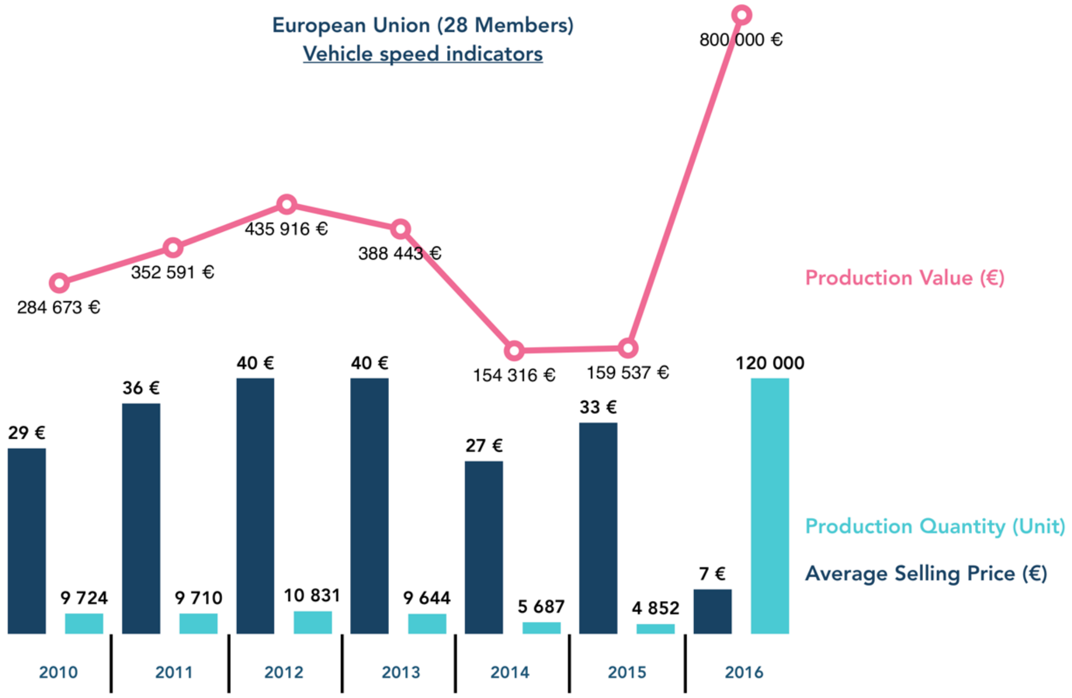
The table below present a summary of Prodcom’s data regarding automotive electronics.

Prodcom statistics

PRODCOM CODE	Subsection	Prodcom Definition	2010		2016			Compound average growth rate 2010-2016	
			Quantity (Unit)	Value (M €)	Quantity (Unit)	Value (M €)	Value growth rate 2015-2016	Quantity (Unit)	Value (M €)
29312330	Other electronic products	Electric burglar or fire alarms and similar apparatus for motor vehicles	30 000	390 000	63 645	381 201	1,6 %	13,4 %	-0,4 %
26516453		Vehicle speed indicators	9 724	284 673	120 000	800 000	402 %	52 %	18,8 %
26516620		Test benches	26 243	822 285	35 098	1 483 430	3,3 %	5 %	10,3 %

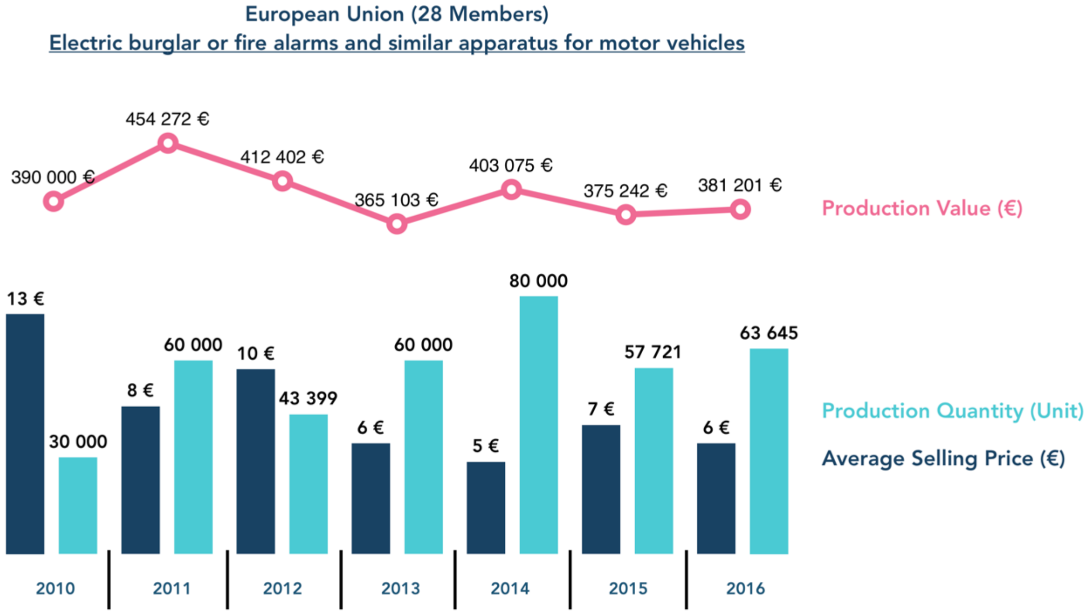
Source: Eurostat - Prodcom

In terms of vehicle speed indicators, the EU production jumped from € 285 000 in 2010 to € 800 000 in 2016, which represents a compound annual growth rate of 19% during that period.



Source: Eurostat - Prodcom

In terms of electric burglar or fire alarms and similar apparatus for motor vehicles, the EU production fell from € 390 000 in 2010 to € 381 000 in 2015, which represents a compound annual growth rate of -0,5% during that period.



Source: Eurostat - Prodcom

ii. Appendix 2 - Automotive electronics engineering activities

The following table present the global repartition of the production of value in automotive electronics from automakers engineering offices[48] (software & hardware).

The production of automotive electronics equipments by automakers is almost null.

Yet, at the global scale, engineers employed by automakers and dedicated to automotive electronics issues represent around 99 300 people and produce a turnover of € 55 B in 2017.

In other words, engineers employed by automakers and dedicated to automotive electronics issues represent 12% of the global automotive electronics number of employees in engineering offices and 25% of the global automotive electronics turnover generated by engineering offices.

Therefore, automakers are key players in terms of automotive electronics engineering.

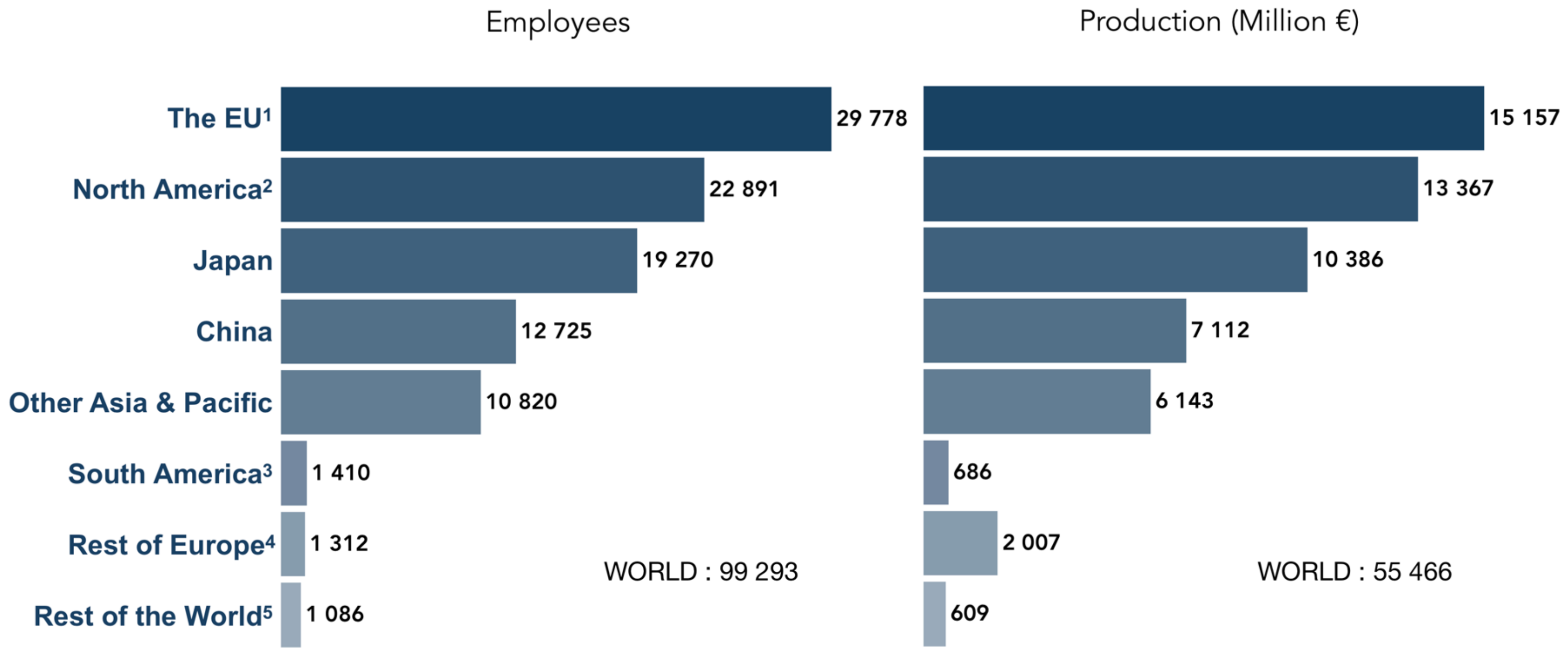
Table - 2017 - Global Repartition of value in automotive electronics from automakers engineering offices (hardware & software)

Region	Turnover Produced (M €)	Employees (Number)
The EU	**15 157**	**29 778**
Germany	7 835	16 126
France	3 178	7 567
Italy	1 588	2 484
Romania	1 458	1 700
The UK	649	1 040
Austria	402	613
Spain	146	374
Rest of the EU (Belgium, Czech Republic, Switzerland)	135	273
Rest of Europe (Russia, Turkey)	**2 007**	**1 312**
Japan	**10 386**	**19 270**
China	**7 112**	**12 725**
Other Asia & Pacific	**6 143**	**10 820**
South Korea	3 295	5 766
India	2 171	3 823
Rest of Asia & Pacific	677	1 231
North America	**13 367**	**22 891**
The USA	13 031	22 252
South America (Mainly Brazil)	**686**	**1 410**
Brazil	450	1 168
Rest of the world (Mainly Israel, Iran)	**609**	**1 086**
TOTAL	**55 466**	**99 293**

Source: DECISION Études & Conseil

[48] Factories, sales offices, design offices, offices dedicated to test drive as well as engineering offices dedicated to motorsport are excluded from the analysis.

Bar charts - 2017 - Global repartition - Automotive electronics from automakers engineering offices (hardware & software)



[1] 28 member states, Germany represents 54% of the total employees and production (in euro)

[2] North America = Canada, the USA and Mexico. More than 90% of the employees are located in the USA, the rest in Canada and no employees are located in Mexico.

[3] Mainly in Brazil

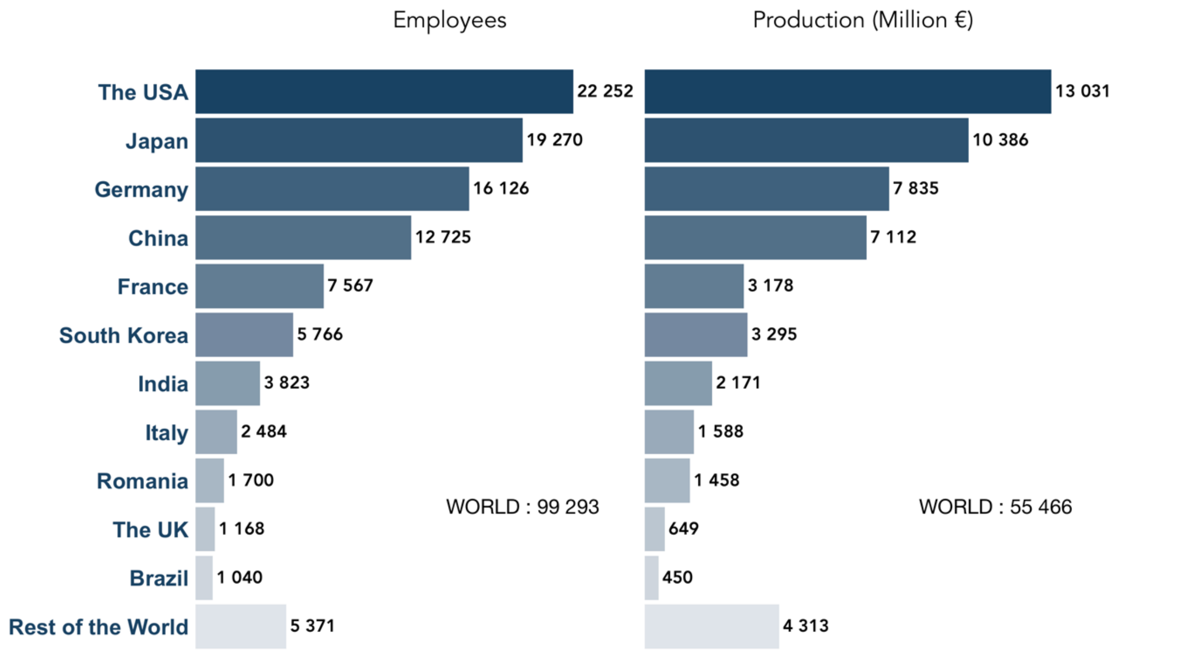
[4] Mainly in Russia and Turkey

[5] Mainly in Israel and Iran

<u>Methodology :</u> Engineering offices and headquarters from automakers only. Factories, sales offices, design offices, offices dedicated to test drive as well as engineering offices specifically dedicated to motorsport are excluded from the analysis.

Source: DECISION Etudes & Conseil

Bar chart - 2017 - Global repartition - Automotive electronics from automakers engineering offices (hardware & software)



Methodology : Engineering offices and headquarters from automakers only. Factories, sales offices, design offices, offices dedicated to test drive as well as engineering offices specifically dedicated to motorsport are excluded from the analysis.

Source: DECISION Etudes & Conseil

The USA and China are the two single countries which hold significant automotive electronics engineering workforce from foreign automakers.

In the USA, automotive electronics engineers employed by foreign automakers represents almost 3 603 employees and € 2 135 M of turnover in 2017.

In China, automotive electronics engineers employed by foreign automakers represents almost 2 700 employees and €1 560 M of turnover in 2017.

The Chinese figures are rising at impressive paces for two reasons:

1. China is already the first automotive market and will be even more significant within the coming decades. Automakers want to set up engineering office close to this market in order to facilitate the interactions between Chinese production facilities and engineering offices and to gain a better understanding of the Chinese automotive ecosystem.

2. Since 1994, the Chinese government forces foreign companies investing in China to set up joint ventures and prevents them from owning more than 50% of the shares of these joint-ventures.

Methodology

	Name of companies	% World motor vehicle production
Entreprises studied	**Toyota, Volkswagen, Hyundai, GM, Ford, Nissan, Honda, Fiat, Renault, PSA, Daimler, BMW**	73 %
Repartition of other producers in terms of headquarter location		
China	SAIC, Changan, BAIC, Dongfeng, Geely, Great Wall, Chery, Anhui Jag Automotive, FAW, BYD	12 %
Japan	Suzuki, Mazda, Fuji, Isuzu, Mitsubishi	10 %
India	Tata, Mahindra	2 %
Iran	Khodro, SAIPA	1 %
Rest of the world		3 %
TOTAL		101 %

Source: DECISION Études et Conseil

The following table present the methodology we used to estimate the global repartition of the production of value in automotive electronics from automakers engineering offices. We directly studied the annual reports and other relevant information of the top 10 global automakers as well as BMW and Daimler. Those 12 automakers represent 73% of the global motor vehicle production. The other 27% have been estimated only using our expertise and the headquarter location of the automakers.

iii. Appendix 3 – Eurostat SBS industry database figures

In the figures below, the data come from the SBS industry database (Structural Business Statistics, Annual detailed enterprise statistics for industry, Eurostat). Four variables are analyzed:

- Turnover produced;
- Employees;
- Added value at factor costs;
- Investment (Net investment in tangible assets).

Therefore, the following sequence of diagrams shows the EU repartition of turnover, employment, added value and investment in terms of manufacture of electrical and electronic equipment for motor vehicles in the EU.

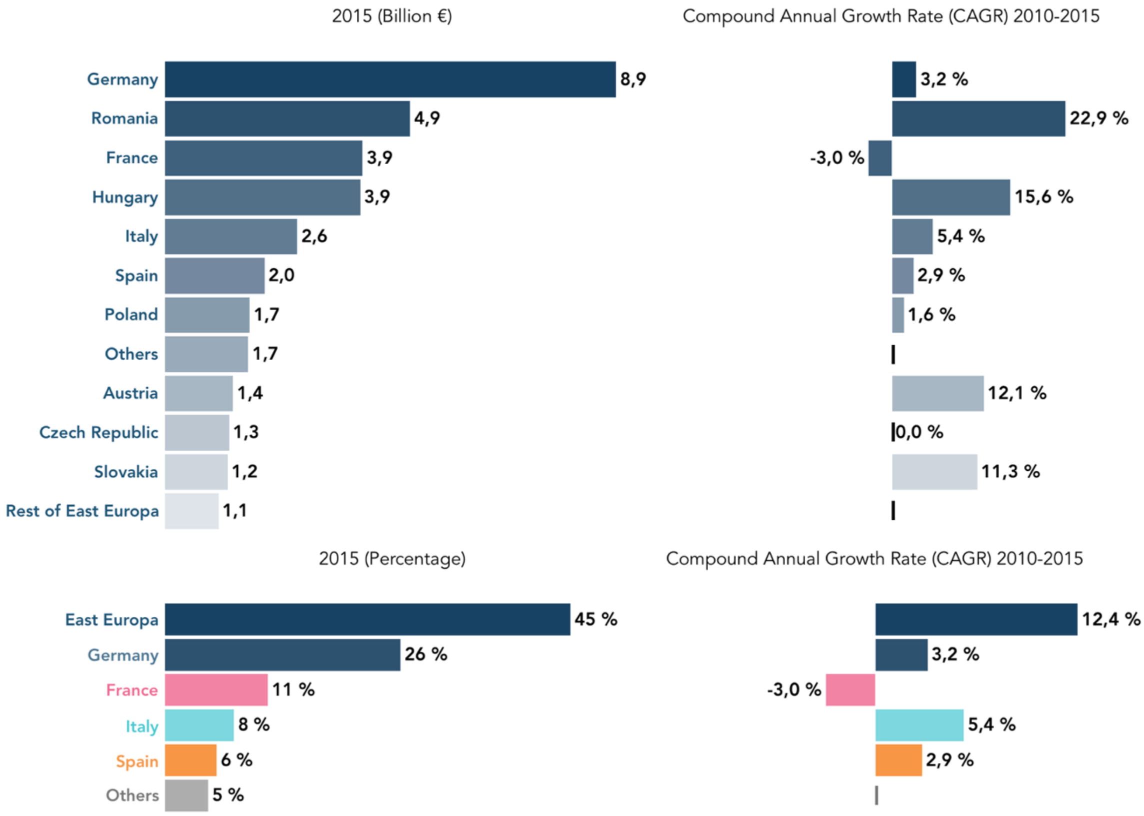
They bring forwards the predominance of Germany and its hinterland (Poland, Czech Republic, Slovakia, Austria, Hungary, Romania, etc.). In 2015, east European Union represented 45% of the EU in terms of turnover, 72% of the EU in terms of employees, 41% of the EU in terms of added value and 63% of the EU in terms of investment. Germany alone represented 26% of the EU in terms of turnover, 10% of the EU in terms of employees, 26% of the EU in terms of added value and 17% of the EU in terms of investment in 2015.

The figures of Romania regarding employment are surprising. According to Eurostat, Romania alone represented 14% of the EU in terms of turnover, 34% of the EU in terms of employees, 13% of the EU in terms of added value and 32% of the EU in terms of investment in 2015. That seem a little too high compared to the other countries in comparison with our other data sources.

Manufacture of electrical and electronic equipment for motor vehicles - Turnover

European Union (28 Members)

- 34,4 Billion euros in 2015
- 9,2% Compound Annual Growth Rate (CAGR) 2010-2015



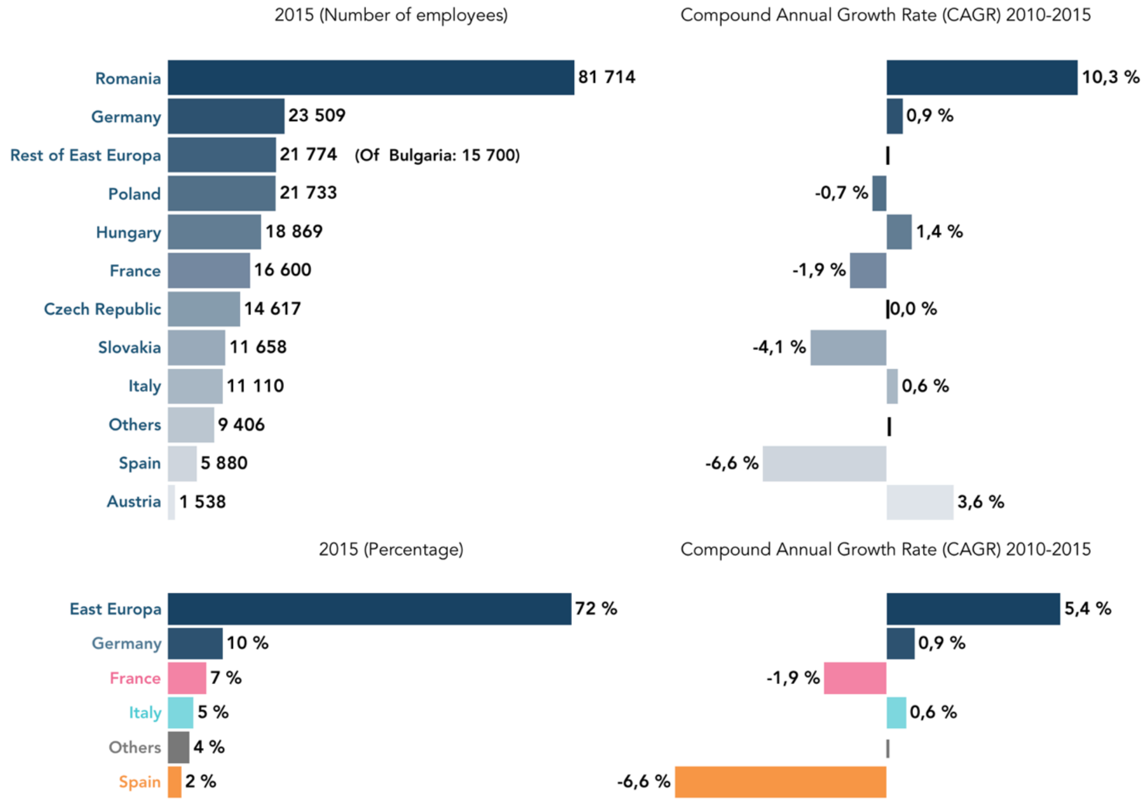
Source: Eurostat, DECISION Etudes & Conseil

East Europa = Romania, Bulgaria, Croatia, Slovenia, Hungary, Austria, Czech Republic, Slovakia, Poland, Lithuania (excluding Latvia and Estonia because of missing values)

Rest of East Europa = Bulgaria, Croatia, Lithuania and Slovenia

Manufacture of electrical and electronic equipment for motor vehicles - Number of Employees

European Union (28 Members)
- 238 408 employees in 2015
- 4,7% Compound Annual Growth Rate (CAGR) 2010-2015



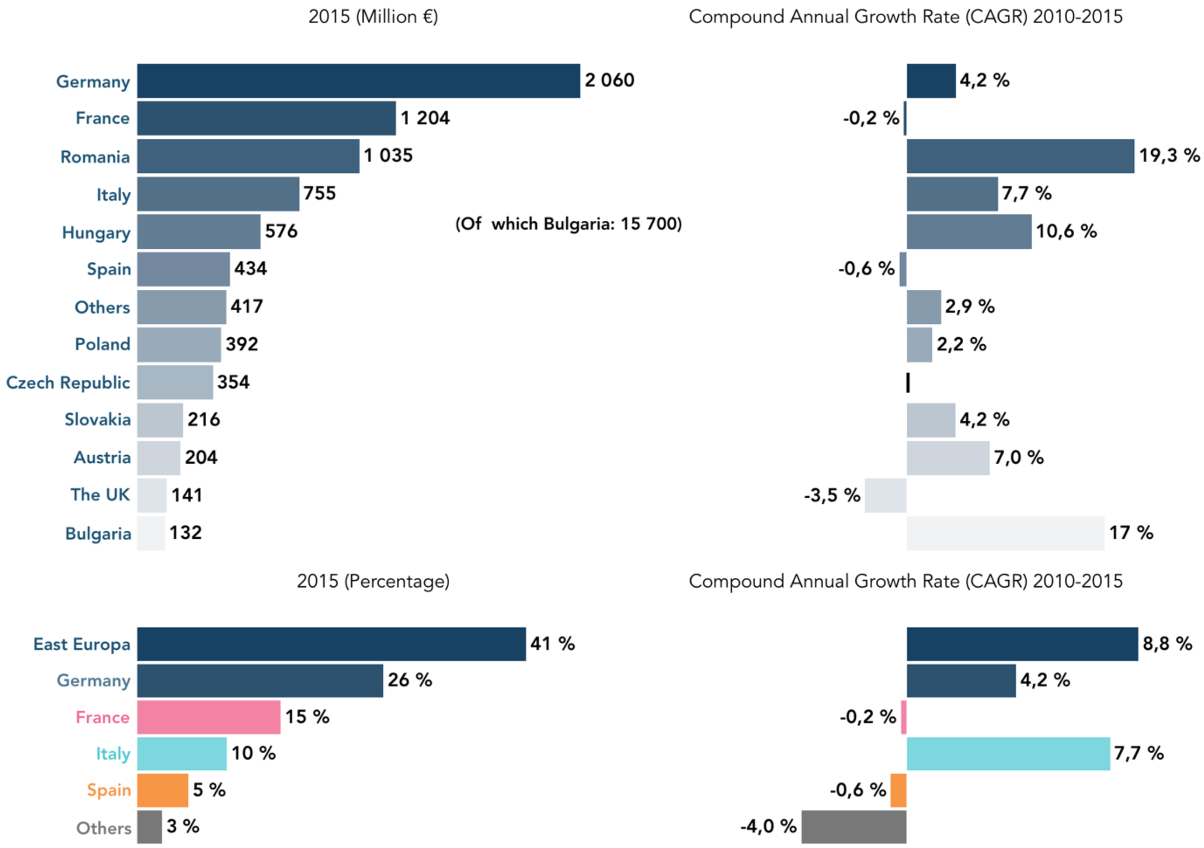
Source: Eurostat, DECISION Etudes & Conseil

East Europa = Romania, Bulgaria, Croatia, Slovenia, Hungary, Austria, Czech Republic, Slovakia, Poland, Lithuania (excluding Latvia and Estonia because of missing values)

Rest of East Europa = Bulgaria, Croatia, Lithuania and Slovenia

Manufacture of electrical and electronic equipment for motor vehicles - Added value

European Union (28 Members)
- 7,9 Billion euros in 2015
- 7,3% Compound Annual Growth Rate (CAGR) 2010-2015



Source: Eurostat, DECISION Etudes & Conseil

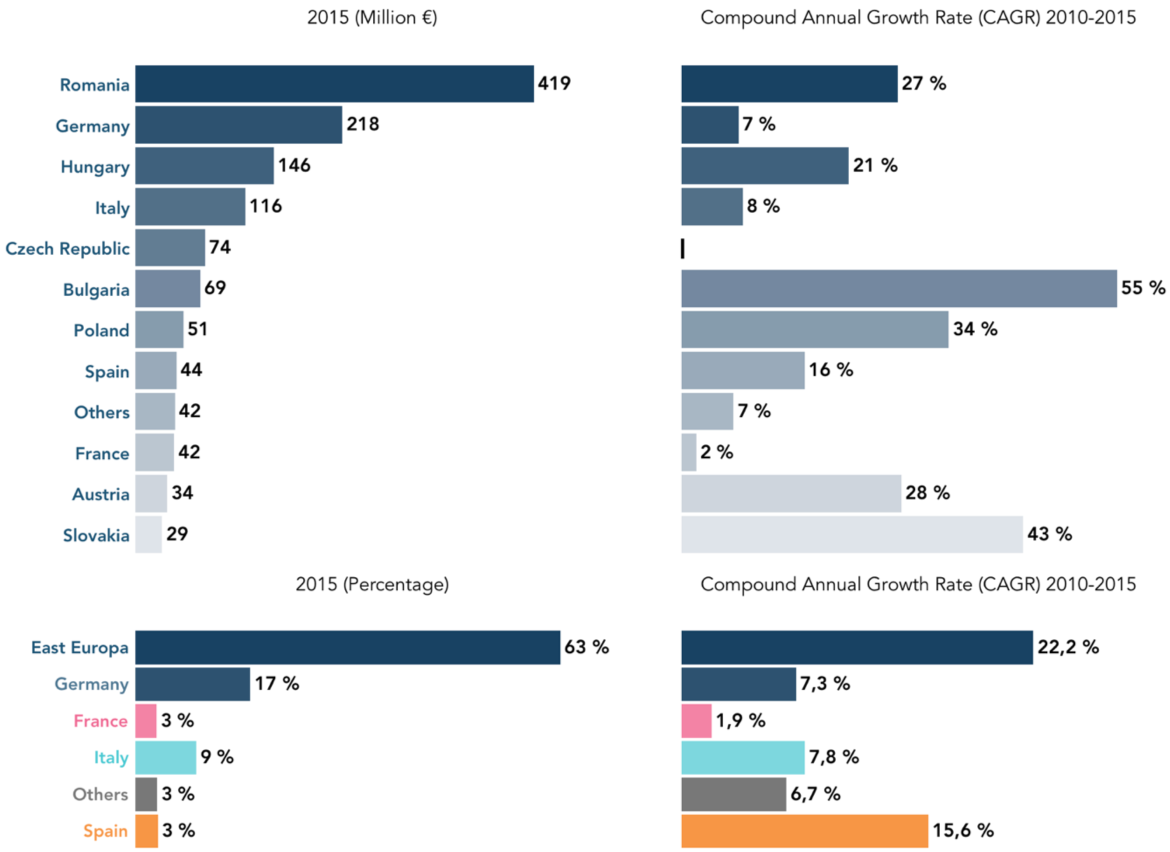
East Europa = Romania, Bulgaria, Croatia, Slovenia, Hungary, Austria, Czech Republic, Slovakia, Poland, Lithuania

Definition - Added value at factor cost= Gross income from operating activities after adjusting for operating subsidies and indirect taxes. Formula : Turnover + Capitalized Production + Other operating income + Increases or decreases of stocks - Purchases of goods and services - Other taxes on products which are linked to turnover but not deductible - Duties and taxes linked to production

Manufacture of electrical and electronic equipment for motor vehicles - Investment

European Union (28 Members)

- 1,3 Billion euros in 2015
- 16% Compound Annual Growth Rate (CAGR) 2010-2015



Source: Eurostat, DECISION Etudes & Conseil

East Europa = Romania, Bulgaria, Croatia, Slovenia, Hungary, Austria, Czech Republic, Slovakia, Poland, Lithuania (excluding Latvia and Estonia because of missing values)

Definition Investment= Net investment in tangible assets. Formula : Gross Investment – Depreciation

European Commission

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