Electric vehicles: Shifting gear or changing direction?

Impact of game-changing technologies in European manufacturing

Future of Manufacturing in Europe

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Executive summary

Electric vehicles are based on two overarching concepts: Electric vehicles that rely on energy stored in batteries and Electric vehicles that provide the energy on board by a fuel cell or any other alternative. Both concepts are predicted to reduce carbon dioxide emissions.

Batteries are the most discussed direction in the political discussion on electric vehicle technology. Lithium-ion batteries are regarded as the best long-term option because of advantages such as durability, low weight and high energy density. The batteries of Electric vehicles need to become less expensive to produce and have better capacity to compete with conventional cars. The production of the batteries, as such, is also predicted to bring added value in terms of revenues, profits and influence on the value chain. Hence, it is important for European automotive manufacturers to create a value chain in Europe for batteries.

Most of the electric vehicle manufacturers are developing both Electric vehicles and cars with combustion engines. For nearly all automotive manufacturers this means (or meant) broadening the scope of their activities.

Further take up of Electric vehicles changes the value chain. Deployment of charging infrastructures is essential for the adoption of Electric vehicles. This implies that new actors are going to be introduced in the ecosystem, in addition to established operators of gas/fuel stations. New operators of charging infrastructures, public, private and hybrid, are experimenting with new and innovative business models. Furthermore, IT firms, mobile phone companies and electricity companies are also going to be involved in the ecosystem of Electric vehicles. The entrance of new actors in the value chain is predicted to be a game-changing aspect of the deployment of Electric vehicles.

Other technologies like Advanced industrial robotics (AIR) and Industrial internet of things (IIoT) are used in the manufacturing of Electric vehicles. Together, this leads to further automation of the production processes, with electrical vehicles creating a momentum to modernise or replace factories and production lines.

The barriers and drivers of the uptake of the electric vehicle technology can be divided into four categories: technological developments, institutional and regulatory settings, charging infrastructures and customer demand and public opinion. Technology is a driver. So is the increased emphasis of governments, citizens/consumers and companies on environmental sustainability. An overarching driver is that European automotive manufacturers need to stay competitive. The main barriers for the uptake of the electric vehicle technology are the high production costs of batteries (leading to high purchase price of Electric vehicles), the range and life-span of the batteries and reluctance of suppliers to invest (heavily and quickly) in the production of components for Electric vehicles that might not yet be demanded by the manufacturers, or at least not in large volumes.

The transition to Electric vehicles will mostly affect manufacturing sub-industries like motor vehicles, trailers and semi-trailers, repair and installation of machinery and equipment, rubber and plastic products, basic metals and chemicals and chemical products. In addition, non-manufacturing industries like utilities are affected through the establishment of the charging infrastructure. The electronics and IT industries benefit as they are involved in the development, production and, to some extent, maintenance of Electric vehicles.

The production of the electric drivetrain and the batteries of Electric vehicles will lead to changes in the production line and in the value chain. The current trend is that the automotive manufacturers themselves aim to produce the batteries and keep the control and added value in-house. Another option for manufacturers of Electric vehicles is to outsource the battery production or to develop partnerships with companies that have specific competences in battery technology and battery production. Furthermore, the transition to Electric vehicles will lead to an increased use of electronics and IT. Therefore, collaborations between electric vehicle manufacturers and companies with
competences in electronics will increase. However, this is a general trend for the automotive manufacturers and not solely an impact of the migration to Electric vehicles.

Beside the production of Electric vehicles, new modes of mobility enter the arena. **Self-driving cars** and **car sharing** are parallel trends to Electric vehicles that will lead to new business models. Self-driving cars, like electric cars, implies that the importance of electronics further increases. This increases the importance of IT companies for the car industry. Car sharing is an opportunity for users to test Electric vehicles without risking too much economically.

Furthermore, deployment of **charging infrastructures** means involving new actors like utilities, charging infrastructure owners and mobility providers. The transition to Electric vehicles will lead to less demand for fossil fuels and instead an increased demand for electricity. This implies that **oil/gas industries** (production, storage, distribution are affected. Furthermore, the aim of increasing the range and durability of Electric vehicles will lead to **new materials** for batteries and fuel cell stacks. In line with this, new sources for lithium (for batteries) are going to be explored as well as materials to make the Electric vehicles lighter and increase their range (number of kilometres).

How the production of Electric vehicles affect **work processes** is debated in literature and discussed by our interviewees and workshop participants. The majority of the experts argue that the transition to Electric vehicles will lead to **minor changes of the work processes**. In short: car manufacturing is highly automated and current and planned production lines for Electric vehicles are quite similar to production lines for conventional cars. However, Electric vehicles require less components compared to conventional cars since (mechanically) the electric motor is less complex than an internal combustion engine. As such, there are **less steps in the assembly process**. Increased automation is also predicted for the production of batteries and battery packs.

The **magnitude and timing of the impact** of Electric vehicles on production processes and work processes depends on three different factors: the pace of the evolution from combustion engines to hybrids and to all Electric vehicles; the link between the self-driving technology and the electric vehicle technology; the role of the new actors with competences in IT.

In general, **hybrids** will affect the production processes and work processes to a lesser degree than all-Electric vehicles. However, manufacturing hybrids still requires new equipment and adds complexity to the production line. The manufacturing of **all-Electric vehicles** will lead to increased automation that will affect the manufacturing processes to a higher degree. Furthermore, an integration of **self-driving technology** into the electric vehicle technology is predicted to generate higher impacts such as the need for IT components. The effects show that the development of Electric vehicles technologies are not solely a problem on the powertrain technologies but also have a strong impact on the whole eco-system of vehicles.

The transition to Electric vehicles, and changes in the value chain, will influence **tasks and jobs** and the demand for **skills**. The required new skills are most often related to using **new materials**, producing and developing the **batteries**, increased use of **IT**, and designing and operating the **production process itself** (for example process engineering). In addition, skills are required to integrate the electric vehicle technology into cars.

The production of Electric vehicles changes the tasks within assembly line jobs, for example by the increased emphasis of assembling electronic components. Furthermore, **IT skills** will be required to develop and produce **Electric vehicles** but also to design, develop, implement and operate **production lines** for manufacturing Electric vehicles. The demand for IT skills will be higher if the self-driving technology is integrated into the electric vehicle technology. **Multidisciplinary skill sets** such as mechatronics are going to be an asset for manufacturing Electric vehicles. There will also be a demand for upgraded skills in the wholesale and retail vehicle sector, to explain and present different types of Electric vehicles. On the other hand, the **relevance of mechanical skills decreases**. Manufacturing Electric vehicles is less labour intensive compared to manufacturing conventional cars.

Manufacturing of Electric vehicles will lead to **new high-qualified occupations** such as in IT and electronics. Manufacturing of Electric vehicles requires a wide range of engineers, for example power electronics. High-level research chemists are required for producing the batteries. Computer analysts,
material scientists and different categories of engineers are demanded for R&D and for designing Electric vehicles. Since Electric vehicles will lead to further automatization of the production processes, IT-experts will be required. Though, this will be an effect of other game-changing technologies such as AI and IIoT rather than an independent effect of the electric vehicle technology. New actors like Apple and Tesla have hired people with competences in electronics, IT (software and hardware) and engineering to develop and manufacture Electric vehicles.

Production and uptake of Electric vehicles will also lead to new occupations outside the manufacturing industry. The establishment of charging infrastructures creates new jobs in energy, construction and service sectors. Furthermore, Electric vehicles will be installed with technological features that will lead to further customised output. This will lead to new jobs in product design and sales. On the other hand, Electric vehicles require less maintenance and less use of fossil fuel which could decrease employment in these sectors.

The migration to Electric vehicles is predicted to have a minor impact on working conditions in the automotive industry. Electric vehicles will lead to further automatization of the production processes which could lead to increased mental stress but less physical burdens for employees. Furthermore, the risks of dealing with high voltage and batteries are disputable. However, employees dealing with high voltage are most likely required to have some qualification or certificate.

The new skills required for manufacturing Electric vehicles implies that the existing workforce has to re-skill or up-skill. Two points of attention are whether automotive manufacturers and suppliers are quick enough to invest in training and whether they engage as many segments of the workforce as possible, including employees with low or medium levels of formal education, and employees that are near retirement.

New actors in automotive manufacturing like Tesla, Apple and Google may pose risks to working conditions in the automotive industry. Employees of Tesla have complained about bad working conditions including mental and physical risks. In addition, Apple released some of its staff when the company changed the direction of its Electric vehicles project. This illustrates the uncertainty about business strategies, markets and, therefore, labour markets.

Public and public-private actions and strategies for promoting the transition to Electric vehicles require collaboration between the industry and higher education institutions to ensure that the high-qualified skills needed will be distributed. A fast transition from hybrids to all-Electric vehicles will lead to higher automatization of production processes that will lead to higher demand for new skills. Furthermore, higher integration of the self-driving technology into the electric vehicle technology will increase the demand for high-qualified skills. In addition, several new players will enter the electric vehicle ecosystem. Establishment of charging infrastructures requires strategies from industry, policy makers and society in general (for example: charging stations in living areas). This is important for enabling or promoting the further deployment of Electric vehicles.

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Introduction

Purpose and context of the study

This report about Electric vehicles (and the underlying technologies) is one of the deliverables of a study that explores the impact of five technologies on manufacturing industries in Europe. Interactions with service industries are touched upon. The time horizon is 2017-2025.

The main purpose of the study is to better understand, and allow stakeholders to anticipate and address the impact of new technologies on production processes and work. As such, the three components of the study are:

1. the level of maturity and the scope of applicability of the technologies, in terms of specific sub-industries and geographic areas across Europe;
2. the (potential) qualitative impact on the production process including the impact on value chains, business models, productivity and output/products; and
3. the (potential) qualitative impact on work, in terms of employment (e.g. occupations that are emerging or disappearing), tasks (e.g. changes in physical, social and intellectual tasks), skill types and skill levels, education/training needs, working conditions.

The study also explores the interactions between companies, industry associations, trade unions, education/training institutions, governments and other stakeholders, during the changes that are affecting manufacturing industries. In short: actions by social partners. The detailed research questions are listed in Appendix A.

To set the scene for this study:
- The study takes technology as the point of departure…
- …but acknowledges that technological trajectories are influenced by established actors (with vested interests), new entrants (e.g. disruptors), path dependencies, social partners, policy and regulation, and much broader economic, social and environmental developments.
- The context of the study includes cross-cutting technologies such as ICT…
- …and economic, societal and policy debates about global value chains, industry 4.0 (and overlapping concepts such as factories of the future, smart industry and advanced manufacturing), re-shoring, 21st century skills, lifelong learning, flexible labour markets, resource scarcity, etc.

Note that the qualitative approach implies that the study complements quantitative studies about the impact of technologies (and automation and robotisation) on the number of jobs in specific industries and occupations. As such, this study is more about exploring the relevant mechanisms, uncertainties and important details such as changes in tasks and working conditions. This is done by means of looking into specific technologies and their application in specific industries.

The study about game changing technologies in manufacturing industries is part of the programme The future of manufacturing in Europe (FOME) financed by the European Parliament, under responsibility of DG GROW. The main theme of this programme is the revival of manufacturing in Europe. The economic and social importance of this revival are explained in the 2014 European Commission Communication ‘For a European Industrial Renaissance’ (COM/2014/014/final). Under the umbrella of this policy agenda, specific policy actions coordinated by the European Commission address Key Enabling Technologies (such as ICT and biotechnology), research and innovation (e.g. the Leadership in Enabling and Industrial Technologies programme in Horizon 2020), the European internal market for products and services (e.g. standard setting for digital services), re-industrialisation of regions (e.g. using the Smart Specialisation Platform and the European Structural and Investment Funds), support for entrepreneurs and SMEs (e.g. the Enterprise Europe Network), skills development (e.g. the Erasmus+ programme) and collaboration between education institutions, research organisations and companies (e.g. the Knowledge and Innovation Communities within the European Institute of Innovation and Technology).
Electric vehicles: shifting gear or changing direction?

The FOME programme is executed by Eurofound, the European Foundation for the Improvement of Living and Working Conditions.

The study is conducted by Technopolis Group, between May 2016 and July 2017. The study team would like to thank the interviewees (Appendix B), workshop participants (Appendix C) and our clients and sparring partners at Eurofound (Enrique Fernandez, Eleonora Peruffo, Donald Storie, Ricardo Rodriguez Contreras and John Hurley).

Five game changing technologies

This report is about the impact of the transition to Electric vehicles (EV) and the technologies that enable this transition. This implies that the report is most relevant for one industry (car manufacturing) and addresses changes in products (with an emphasis on electric cars) as well as manufacturing processes and work. A similar approach is taken in a second report, about Industrial biotechnology (IB).

The other three reports focus on cross-cutting technologies: Additive manufacturing (AM), Advanced industrial robotics (AIR) and the Industrial internet of things (IIoT). These three technologies are at the heart of industry 4.0. They influence or redefine manufacturing processes and often also have an impact on products. Two examples are customisation and enabling new product-service bundles (cf. servitisation).

Figure 1 visualises how the three cross-cutting technologies are relevant for Electric vehicles and Industrial biotechnology (and many other industries or products).

**Figure 1: Five game changing technologies**

![Diagram showing the relevance of technologies for Electric vehicles and Industrial biotechnology](source: Technopolis Group, 2017)

Research methods used

The study started with a structured literature review. Because the phenomena studied are quite recent, we used academic articles but also grey literature such as reports prepared for policy makers and industry associations and reports prepared by consulting firms. The Scopus database and Google Scholar were used to identify articles/reports with key words such as the five technologies and industry 4.0 combined with key words such as value chains, jobs, tasks, working conditions and social partners. The emphasis was on publications from 2013-2016 but in some cases older publications had to be used to fill white gaps (such as publications related to the impact of technologies on work).
Appendix A contains the list of 100+ references. Using ATLAS.ti software and a coding scheme, relevant statements about drivers, barriers, industries affected, changes in tasks, etc., were coded and counted.

Subsequently, 30 leading experts were interviewed, covering the five game changing technologies as well as specific backgrounds (such as industry, research and policy). A detailed questionnaire was used, to ensure that the three main parts of the study were covered (in short: technology, production process and work). Appendix B contains the list of interviewees that addressed Electric vehicles.

The third and final step consisted of five regional case studies (one for each technology) with companies, researchers, cluster organisations and other stakeholders. Figure 2 introduces the five workshops. In four cases, a workshop was organised. The case study about Industrial biotechnology relied on stakeholder consultation during a conference and a small-scale event. Figure 2 introduces the five regional case studies.

**Figure 2: Five regional case studies**

The regional case studies were effective for validating the findings of the literature review and interviews; for filling white gaps; for providing real-life examples of technologies being tested or implemented by companies; and for discussing responses by social partners.

**Outline of the report**

Next section addresses Electric vehicles, the underlying technologies, and the adoption in specific industries. The following ones explore the impact on production processes and address the impact of these changes in production process on work and mentions examples of responses of social partners. The final section concludes.

Annex A contains the detailed set of research questions. Annex B and C list the interviewees and workshop participants, respectively.
Characteristics and adoption of Electric vehicles

Introducing Electric vehicles and the underlying technologies

The Roadmap to a single European transport area – Towards a competitive and resource efficient transport system (European Commission, 2011) highlights how transport is fundamental to the European economy and society. The Roadmap emphasises that whilst transport enables economic growth and job creation, it must also be sustainable to face current and future challenges in society (European Commission, 2011).

In April 2010, the European Commission presented a strategy for clean and energy efficient vehicles. The strategy aimed at encouraging the development and market uptake of these vehicles (European Commission, 2010). Electrification of transport, so called ‘electro-mobility’, is a priority in the Community Research Programme. Furthermore, it is an important part in the European Economic Recovery Plan within the framework of the Green Car Initiative. For example, the European Commission has supported a Europe-wide electro-mobility initiative, Green eMotion, worth 41.8 million euro, in partnership with 42 partners from industry, utilities, electric car manufacturers, municipalities, universities and technology and research institutions (European Commission, 2011).

The development of cleaner vehicles is also a growing priority for European vehicle manufacturers. The European Commission’s Transport White Paper sets a goal of reducing CO2 emissions initiated by transport by 60 per cent until 2050. This leads to more demand for increased energy efficiency in combustion engine powered vehicles (e.g. through the use of lighter materials and more efficient energy recovery systems) as well as vehicles that are not powered by fossil fuels (Cedefop, 2014).

An electric vehicle is any vehicle that is powered entirely or partially by electricity. Electric vehicles can be categorised into following main types: Hybrids (HEVs), Plug-In Hybrids (PHEVs), Battery Electrics Vehicles (BEVs) and Fuel Cell Electric vehicles (FCEV). Furthermore, there are other vehicles like electric scooters, electric bikes and electric buses, that are being implemented at the moment.

Electric vehicles are based on two overarching concepts:

1. The vehicle relies on the storage of externally generated energy that is stored in batteries and used in the vehicle. In that concept, there is no electricity generation technology in the car. Those cars are referred to as Battery Electrics Vehicles (BEVs).

2. The vehicle provides an on-board electricity generation by a fuel cell or any alternative (fossil or non-fossil fuel based) generator. Examples are FCEVs (e.g. hydrogen) and PHEVs (that have been well-received in consumer markets).

BEVs and FCEVs are two complementary technologies within electric mobility that offer complementary solutions. BEVs are better customised for urban use, while FCEVs are better suited to cover long distances (Germany Trade & Invest, 2015). However, recent and coming BEV models are better equipped to cover longer distances than earlier models. One example is the all-electric 2017 Chevrolet Bolt. Manufacturers also refer to Neighbourhood Electric vehicles (NEVs) and Extended-Range Electric vehicles (ER-EVs).

Both battery based Electric vehicles and FCEVs could reduce carbon dioxide emissions. However, the source of the hydrogen is a decisive factor in how efficient FCEVs are going to be in reducing emissions (Cambridge Economics, 2013). Concepts of wind to gas equipment for FCEVs as well as increased current from sustainable resources for BEVs might solve that problem. Since the all-Electric vehicles are nowadays produced with increased battery capacity and at cheaper costs they are getting more attention in this chapter. Hence the all-Electric vehicles are regarded as the real potential game-changer. The future of the all-Electric vehicles is rather unclear with different actors applying different strategies in their targets to increase the battery capacity, to reduce the weight of the vehicles and developing other features such as self-driving technology. Hence, the forecast is at times rather speculative, as not even the interviewed experts are certain of the future.
The game changing aspect of Electric vehicles in manufacturing

In Europe, an increasing number of Electric vehicles is being manufactured and imported. Several of the larger Original Equipment Manufacturers (hereafter OEMs) have released models of Electric vehicles. Furthermore, start-ups as StreetScooter GmbH enter the market. StreetScooter GmbH, that received Venture Capital from the Deutsche Post AG, today is the number four on the German market for BEVs behind Renault, BMWi and Tesla (data as of April 2017). Ever since 2010, the total number of electric vehicle releases has increased annually and Europe is now experiencing a transition from testing the technology towards full-scale commercialisation. The number of electric vehicle models has increased from three to just under 30 in the years 2010-2014, in the European market. The market share of hybrid-Electric vehicles accounted for 1.4 per cent of all new car sales in 2013 and 2014 (European Commission, 2015); ICCT, 2015). Even though this percentage is rather small, it is twice as high as two years earlier (European Commission, 2015). Estimations imply that Electric vehicles will represent 10 to 15 per cent of the total global care market in 2020 (Accenture, 2014).

One of the most critical aspects of Electric vehicles is the battery production and the development of the battery technology. Today, lithium-ion batteries are regarded as the best long term option for Electric vehicles. The technology of lithium-ion batteries has advantages such as durability, low weight and high energy density (Germany Trade & Invest, 2015). Recent pure electric vehicle models such as BMWs i3 and Chevrolets THE 2016 SPARK EV both use lithium-ion batteries.

The ‘battery challenge’ has been addressed by an EU initiative (called the Green eMotion initiative) that has involved a range of different actors. For example, industrial actors, research institutes, universities, municipalities, energy actors and PEV-manufacturers (International Economic Development Council, 2013). National support for electric vehicle initiative members’ RD&D (Research, development and demonstration) has focused mostly on fuel cells and batteries because of the high cost of these components (International Energy Agency, 2013). The majority of interviewees addresses the batteries as the core for the further deployment of the Electric vehicles. According to interviewees, the batteries of Electric vehicles need to have increased capacity (range and durability) as well as being cheaper to produce, to compete with conventional vehicles. In addition, several interviewees and workshop participants stress that battery production brings added value and ensures a level of control over the value chain. Therefore, it is important for the European automotive industry to establish a value chain for battery production in Europe.

Most manufacturers that develop and manufacture Electric vehicles also produce conventional cars. Exceptions are Tesla and start-ups such as StreetScooter that solely manufacture Electric vehicles. The parallel production of conventional cars and Electric vehicles changes the business models of the automotive manufacturers. According to (Accenture, 2014), the automotive manufacturers need to make adjustment of core processes to prepare for a mass production of Electric vehicles and other non-conventional cars. Several interviewees and workshop participants mention that established automotive manufacturers need to adjust the production lines to manufacture Electric vehicles and hybrids alongside conventional cars. This implies highly flexible or, in some cases, parallel production lines.

Electric vehicles will change the value chain, including the inclusion of new actors and adaptation of production processes (Accenture, 2014). This is the most game-changing aspect of the technology, according to the workshop participants. For example, new actors are going to be introduced in the ecosystem to establish and expand a much-needed charging infrastructure (Accenture, 2014). The establishment of charging infrastructure also lead to new and innovative business models (Amsterdam Roundtable Foundation, 2014). Nearly all interviewees as well as the workshop participants stress that the establishment of charging infrastructure is necessary for the further deployment of Electric vehicles. Hence, petrol stations will be replaced by charging stations or diversify and provide charging stations.
Furthermore, cameras, sensors and displays are likely to be installed in Electric vehicles to complement the eco system need for Electric vehicles. The use of IT is going to introduce new actors into the value chain, such as mobile phone companies, IT-firms and electronics companies. In short: software, hardware and networking/telecom. In addition, battery production is likely to result in new entrants. At the same time, the role of well-established actors in current value chains (and their skills and competencies) will become less relevant. Electric vehicles lack engines, gear boxes and alike which today contribute strongly to wealth of the automotive industry. Mechanical engineering competencies will be replaced by competencies in electro engineering and informatics.

In general, other game-changing technologies like Advanced industrial robotics (AIR) and Industrial internet of things (IIoT) are changing the production processes in car manufacturing industry (European Commission, 2014). The deployment of Electric vehicles is likely to lead to further automation of the production processes (European Commission, 2014). Among other things, the migration to Electric vehicles creates a momentum to expand the number of robots and their functions (Metra Martech, 2011).

**Why manufacturing companies invest in Electric vehicles**

The main drivers for electric vehicle technology uptake into the manufacturing industry are political and environmental, followed by financial drivers. The drivers and barriers for Electric vehicles mentioned in the literature can be categorised as follows.

- Technological developments, such as improvement of battery system components (like high voltage cables, propulsion power converters and electric cooling compressors) and fuel cells;
- Institutional and regulatory settings, for example political support for a greener economy; and
- Customer demand and public opinion, for example related to energy efficiency and air quality.
- Charging infrastructure;

As in many innovations, technological developments are an important driver (Schaufenster-Elektromobilität, 2015). In the specific case of Electric vehicles, industry as well as civil society see technological development as an opportunity to increase energy efficiency and contribute to other improvements of environmental sustainability. According to a Norwegian study, 41 per cent of buyers of Electric vehicles stated that saving money was the main reason to buy an electric vehicle. However, 29 per cent of the buyers state that environmental motives were the main reason (Amsterdam Roundtable Foundation, 2014).

Aligned with industry and civil society interests, governments launched programmes to support R&D related to Electric vehicles, finance or deploy charging infrastructures and/or coordinate actions to adapt education and training to stimulate the development and production of Electric vehicles (The Boston Consulting Group, 2010). In addition, cities such as London have used congestion charges/taxes to improve air quality, while indirectly stimulating Electric vehicles as these are exempted from congestion charges. This is believed to be one explanation to the increase of EV registrations in the UK (European Commission, 2015).

An overarching driver for industries, governments and other social partners is to ensure that the migration to Electric vehicles does not weaken the competitive position of established industry players, countries and regions (European Commission, 2010). For instance, studies predict that the volume of car production in Asia increases, at the expense of production in Europe (CE Delft, 2012). Here, interviewees and workshop participants often refer to battery producers and car manufacturers in China. They also refer to strengths of the US in IT and the increased relevance of IT for Electric vehicles and car manufacturing in general.

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Another overarching driver, at least for governments, is the goal to reduce dependence from countries and companies that produce oil (Amsterdam Roundtable Foundation, 2014).

Two important barriers are situated at the demand side: the high costs of Electric vehicles and the small to medium range of Electric vehicles (Accenture, 2014). The latter is even referred to as range anxiety, the fear that an electric vehicle has insufficient capacity to reach its destination. Interviewees and workshop participants positioned this in the broader context of (some) consumers being reluctant to adopt new technologies and products and change their behaviour.

A third barrier is the limited coverage of charging infrastructures (International Energy Agency, 2013). In addition to companies, local, regional and national governments are investing in charging infrastructure (International Energy Agency, 2013). One aspect is standardisation and interoperability. European drivers must be sure they have access to compatible EVSE (Electric Vehicle Supply Equipment) networks when they drive from one country to another (International Energy Agency, 2013). An evaluation of the Green eMotion project confirmed this picture (Green eMotion, 2015). Furthermore, vehicle manufacturers work for a transatlantic standard, through TTIP (Transatlantic Trade and Investment Partnership), for sockets and plugs. Since both the USA and the EU have domestic manufacturing of Electric vehicles, this is expected to promote the electric vehicle market in both the US and the EU (European Parliament, 2015). Limitations in the availability and interoperability of charging infrastructures are a barrier both for battery based Electric vehicles and FCEVs. Instead of charging locations, FCEVs need refuelling locations (Amsterdam Roundtable Foundation, 2014).

However, according to interviewees, the main barrier for uptake of the electric vehicle technology in the European automotive industry is the high production costs of batteries as well as the range and life-span of batteries. Along the same lines, the costs of fuel cells are still very substantial and hinder large-scale adoption (Cambridge Economics, 2013). These financial barriers are linked to technical challenges, e.g. difficulties in engineering batteries to manage both hot and cold temperatures) and battery costs (The Boston Consulting Group, 2010).

Demand-side, charging infrastructure, financial and technical barriers influence the entire value chain. Several interviewees state that small and medium-sized enterprises (SMEs) are reluctant to produce components for Electric vehicles since the market is still evolving. These SMEs but also large suppliers are uncertain what components are worth producing, at which scale. More in general, uncertainty complicates decisions about the timing and size of investments in electric vehicle technology and production lines.

Only to some extent, uncertainty is reduced by the roadmaps of large car manufacturers. Here, interviewees added that the evolution of Electric vehicles is influenced by related (rather than required) trends such as self-driving cars and car sharing. For example, car-sharing removes barriers such as high purchase price since customers do not buy the cars themselves (Amsterdam Roundtable Foundation, 2014).

Box 1. Environmental and, therefore, political drivers of Electric vehicles

Electric vehicles are understood to play an important role for EU Member States to achieve their CO2 reduction targets. In line with this, the Netherlands and the UK are two of many countries where an increasing number of Electric vehicles is evident. Both countries have implemented tax incentives to promote the transition towards Electric vehicles. The buyers of Electric vehicles are to a large extent choosing clean vehicles based on environmental and fiscal incentives. Electric vehicles are also predicted to lead to cleaner air, especially in cities. Therefore, Electric vehicles can have a significant positive impact on public health. This is likely to have positive impact on the public opinion. London (congestion charge) and Oslo (no tolls for Electric vehicles) are two successful examples of cities that have implemented actions for cleaner air even so based on the current mobility paradigm that focusses on individual traffic.

Demand-side, charging infrastructure, financial and technical barriers influence the entire value chain. Several interviewees state that small and medium-sized enterprises (SMEs) are reluctant to produce components for Electric vehicles since the market is still evolving. These SMEs but also large suppliers are uncertain what components are worth producing, at which scale. More in general, uncertainty complicates decisions about the timing and size of investments in electric vehicle technology and production lines.

Only to some extent, uncertainty is reduced by the roadmaps of large car manufacturers. Here, interviewees added that the evolution of Electric vehicles is influenced by related (rather than required) trends such as self-driving cars and car sharing. For example, car-sharing removes barriers such as high purchase price since customers do not buy the cars themselves (Amsterdam Roundtable Foundation, 2014).
Foundation, 2014). However, as some interviewees mention, these trends should be treated independently from the electric vehicle technology.

**Applications of Electric vehicles in specific sub-industries**

The development and introduction of Electric vehicles industry is influenced by various drivers and barriers (see above) and will influence different industries. Established companies in established value chains will be challenged to compete (or collaborate) with new entrants. Cooperation is considered a necessity, involving actors such as vehicle manufacturers, vehicle suppliers, providers of electricity, gas companies, grid managers, battery producers and manufacturers of electronic components (European Commission, 2010).

Our literature review indicates that the following five sub-industries are most likely to be affected by the transition towards Electric vehicles:

- **Motor vehicles, trailers and semi-trailers** are affected in two ways. First, manufacturing of an electric vehicle is different than manufacturing of cars with combustion engine. As such, the division of labour between OEMs and suppliers will change, also opening a window of opportunity for new entrants such as producers of electric drive trains, batteries and related electronics. Secondly, the major value driver today, the combustion engine, is substituted by the major value driver in Electric vehicles, the battery. It is not clear yet whether the battery production will be provided by car producers or whether, for instance, exclusive alliances between battery producers and car manufacturers will become the dominant model.

- **Repair and installation of machinery and equipment.** First, this concerns repair and installation of production lines for Electric vehicles or flexible production lines (or modules) that can deliver electric as well as traditional cars. Secondly, this concerns maintenance of Electric vehicles, which will be different from maintenance of cars with combustion engines. Several major components are no more needed which will have an impact on garages.

- **Rubber and plastic products,** to make the electric vehicle lighter. The usage of new materials will have a strong impact on traditional body suppliers as well as on suppliers of components.

- **Basic metals,** to make the electric vehicle lighter. Demand for traditional materials is changing towards less weight and larger material strength.

- **Chemicals and chemical products,** mostly regarding the battery production. Enhanced storage capacities in batteries as well as lower prices by enhanced performance by fuel cells will be addressed by new chemical solutions.

The impact on the production of motor vehicles is most direct (note that we focus on cars). Electric vehicles are manufactured by two categories of manufacturers: those that solely develop Electric vehicles, that are based on battery stored energy (e.g. Tesla) and those that produce Electric vehicles and internal combustion engines (e.g. Toyota that pioneered hybrids cars). The Technology Readiness Level (TRL) of Electric vehicles depends on the specific technologies used. Some technologies are just in the development phase (e.g. technologies for Extended-Range Electric vehicles, ER-EVs), while others are demonstrated and commercialised (e.g. Plug-In Hybrids, PHEVs).

Compared to hybrids, manufacturing of all-Electric vehicles such as Teslas, has greater impacts on the various sub-sectors in the value chain. This mostly concerns supplier industries such as rubber and plastics, basic metals, chemicals and electronics (CE Delft, 2012) (IKA, 2014). As mentioned above, suppliers of components are still reluctant to produce components for Electric vehicles. Therefore, it is likely that when established automotive manufacturers move towards solely developing and producing all-Electric vehicles (instead of hybrids), suppliers would be more certain what components or electric drivetrains are needed. A similar effect emerges when new entrants sharply increase their market shares in (electric) vehicle markets. This is based on the assumption that the mobility concept will Since Electric vehicles manufacturers and suppliers aim to supply cheap, safe and reliable battery solutions, there is a great growth potential in the lithium market (Germany Trade & Invest, 2015). Battery producers as well as car companies are looking for skilled labour in Eastern and Central
Europe. Spain is also regarded to be a potential market of skilled workers in the production of batteries and other electric vehicle components (Cambridge Economics, 2013). In Slovakia, the production of three clean vehicles created almost 1000 new jobs (Cedefop, 2014). However, the lithium market is mostly based outside Europe. Nearly all interviewees mentioned that battery technologies are less developed in Europe. Asian companies have technological advantages as well as large home markets. So far, chemical companies have been reluctant to enter the battery market. This is partly due to the high costs of developing and producing batteries (cf. entry barriers).

Manufacturers of materials are affected as well. Manufacturers of Electric vehicles use different kinds of materials to make the vehicle lighter. The all electric BMW i3, for example, uses carbon composites for its body. According to Greentech Media, electric vehicle manufacturers are likely to follow BMW and intensify the search for new and lighter materials (Hunt, 2015)². However, weight is not the only parameter. EVANNEX is a company that is involved in components of Tesla’s model S. The company expects that the body and chassis of the new, all-electric Tesla Model 3 will be made of steel rather than aluminium. This change is due to lower production costs, including lower materials costs, lower skills and trainings required for working with steel and the lower cost of steel workers compared to aluminium workers (Pressman, 2016)¹. However, steal means higher weight, which reduces the driving range per charge.

In addition, non-manufacturing industries, such as utilities (Accenture, 2014), public sectors involved in charging infrastructures (Amsterdam Roundtable Foundation, 2014) and the IT industry (Abuelsamid, 2015)³ are all affected by the migration to Electric vehicles. For instance, both Tesla and Chevrolet have recently cooperated with IT and electronics companies when developing and producing Electric vehicles. Interviewees mention how the IT component of cars is getting more and more important.

Since most batteries are produced in Asia, European regions that manufacture and produce complete battery based Electric vehicles are not common. Nissan, however has a plant that produces batteries for Electric vehicles in Sunderland (Tyne and Wear) for vehicles that are later manufactured in Barcelona. The Region Västra Götaland (where the workshop took place) is regarded to be a possible European frontrunner of manufacturing Electric vehicles. According to the workshop participants, the local battery production is an important challenge for the region in its aim to become a leading manufacturer of Electric vehicles. Recently, Volvo stated that all car-models that will be launched by the company from 2019 are going to be either hybrids or all-electric. This affects the production both in Torslanda (Region Västra Götaland) and in Gent (Belgium).⁵

Other European regions that manufacture all-Electric vehicles are Bayern and Sachsen (Germany)⁶, Baden-Württemberg (Germany)⁷, Niedersachsen (Germany)⁸, Mladá Boleslav (Czech Republic)⁹.

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5 http://www.gp.se/nyheter/ekonomi/volvo-ska-bar-bilar-tillverka-1.4413878
6 Porsche Engineering Group GmbH and BMW AG (all electric BMW i3)
7 Audi AG and Daimler AG
8 Volkswagen AG
9 Škoda Auto
Impact on production processes

To what extent are electric vehicle technologies changing processes within the value chain?

There are different views on the magnitude of changes in the value chain, but studies and interviewees do indicate that battery production is becoming a crucial part of the value chain. Moreover, providers of IT and electronic components/equipment will play a larger role. The views differ with regards to changes in the factories and production lines of car manufacturers. One the one hand, these production lines has been highly automated for over 20 years. Additional, incremental changes are mostly due to Advanced industrial robotics and the Industrial internet of things (and Additive manufacturing for design, prototyping and specific components). On the other hand, Electric vehicles contain less components and more IT and electronics. For example, the powertrain is no more needed; electric engines are easy to assembly; less fluid connections are needed; and brake systems will be different (and relying more on electronics than hardware). This simplifies the production process (less assembly). Moreover, new factories, like the ones built by Tesla, are state-of-the-art and may also include new types of management, inspired by experiences in the IT and electronics industries. As such, Electric vehicles and new entrants provide extra triggers for car manufacturers to modernise their factories as quickly as possible.

As mentioned above, battery production is key. The batteries of the Electric vehicles are predicted to lead to changes in the production processes of the automotive industry. There are two options for battery production that will affect the production processes: 1) car manufacturers produce the batteries themselves; 2) battery production is outsourced to preferred suppliers (Klug, 2013).

The battery based Electric vehicles includes a separate value chain for battery production. The value chain of battery production involves identifying new materials, the development of new components as well as the production of cells and batteries (Germany Trade & Invest, 2015). Several interviewees state that the trend for vehicle manufacturers is to keep as much of the production as possible in-house. The issue is not only whether batteries will be produced by car manufacturers themselves but also whether the production of the batteries will geographically be close to the company. Workshop participants sketched a scenario in which the design of the batteries is made by car manufacturers while the production of batteries (at least the cells) is done by suppliers. Furthermore, workshop participants consider it possible to establish regional production centres for batteries (and their materials and components) in specific European regions. One of these regions is Västra Götaland. At the moment, it is unclear whether the mix of competences and the financial resources needed for these initiatives, are available in Europe.

Companies in Asian countries such as China, Korea and Japan show comparative advantages in the production of batteries for Electric vehicles. China, Korea and Japan produce about 95 per cent of the advanced batteries in the world and own mineral mines or have long-term relationships with material suppliers.

10 Peugeot Citroen
11 Renault
12 Renault (all electric Renault Kangoo)
13 Renault (all electric Renault Twizy)
14 Fiat
suppliers (International Economic Development Council, 2013). As such, there are alliances with companies such as Toyota and Honda. The main US example is Tesla. In its efforts to reduce the costs of batteries, Tesla invested in a battery factory called the Gigafactory. Workshop participants explained how several car manufacturers are exploring similar strategies to control the value chain. For instance, Volvo is investing in fuel-cell technology and in research and training programmes for battery technology.

In the context of battery based Electric vehicles as well as FCEVs, many European governments that have large care manufacturers (OEMs) are aware of the impact on value chains. Through prioritising the technological development of Electric vehicles, governments try to keep most parts of the value chain in their country (Amsterdam Roundtable Foundation, 2014). Here, one of the challenges is that new technologies can lead to new entrants, which means new jobs created are not bound to well established companies (Cambridge Economics, 2013).

The increased use of electronics will lead to changes in the production process and the value chain. For example, Apple and Google have entered the electric vehicle market. They develop cars, while leveraging their expertise in electronics and IT. Smartphone expertise like batteries, displays, sensors and cameras is likely to be of importance in the supply chain of Electric vehicles (Elmer-Dewitt, 2015)\(^\text{15}\). Interviewees explain that this concerns a broader trend in car manufacturing (‘cars are computers’) that is not specific for Electric vehicles. Interviewees also explain how ‘more IT’ also poses challenges for quality control during the production process and across different companies in the value chain.

Other parts of the value chain will also change. Electric vehicles are part of the e-mobility ecosystem with different actors that are not directly part of the industry but are essential for its success. Examples are owners and operators of specific charging locations and large-scale charging infrastructure; IT service providers; mobility providers; vehicle users; leasing enterprises; and utilities (Accenture, 2014). As such, adoption of Electric vehicles will lead to a combination of established and new actors in the value chain (Accenture, 2014).

The value chain can be defined even broader. Car sharing is a trend that could spur the adoption of Electric vehicles and change value chains or business models. As such, car sharing can accelerate the adoption but also the positive environment impact of Electric vehicles, unless car sharing triggers more people to drive more (Clean Energy Ministerial, EVI & IEA, 2013). Interviewees mention that the providers of car sharing platforms, like car rental agencies, can develop into powerful actors in the value chain. Their requirements and business models will influence manufacturers of Electric vehicles,  

for example the trade-offs between weight and durability and between range and costs. Moreover, car sharing platforms can develop (exclusive) partnerships with manufacturers of Electric vehicles.

**How are these technologies affecting the demand for materials and intermediate products?**

The further deployment of Electric vehicles (BEVs and FCEVs) will lead to a change from fossil fuel towards an increased demand for electricity. This transition will lead to new technologies markets as well as new markets. As mentioned above, battery technologies are at the heart of this transition. For successfully implementing and scaling up Electric vehicles, the technologies required need to be integrated in the energy supply system for more efficient energy production, storage and distribution (Germany Trade & Invest, 2015).

Increasing the capacity (range and durability) of Electric vehicles requires extraction of new materials for the batteries and fuel cell stacks. Natural resources like lithium are important inputs for making batteries for plug-in Electric vehicles (PEV). Because lithium is a scarce metal, car manufacturers (OEMs) reduce their risks by securing access to lithium and by exploring alternatives (or complements) such as brine extraction, aluminium and graphene (Accenture, 2014). Still, lithium-ion batteries are widely regarded as the best long-term option because of their low weight, long durability and high energy density. However, European and other companies that seek technological leadership in Electric vehicles should invest in improving lithium-ion battery technology and alternatives (Germany Trade & Invest, 2015). Interviewees mention that the demand for chemical products is going to increase as chemicals are needed for making the batteries. Workshop participants add the safety perspective. Battery production and possible establishment of chemical companies in the Region Västra Götaland has led to discussions about risks and safety issues, for example regarding spill wastage. With respect to fuel cell stacks, interviewees mention that platinum will have to be replaced by new materials, because of increased scarcity and rising prices of platinum.

Demand for established and new materials is influenced by the ambitions of car manufacturers (and suppliers of components) to make Electric vehicles lighter. Lightweight materials such as carbon fibre, plastics and aluminium are likely to replace steel (CE Delft, 2012). According to interviewees, this trend is persistent. Segments of the material industry that focus on lightweight materials, will benefit. Moreover, electrical vehicles increase the demand for electronic components, ranging from sensors and actuators to microprocessors and user displays (European Commission, 2014). Along the same lines, demand for software increases. For instance, computers ensure that the right amount of electricity is distributed to the powertrain (Cambridge Economics, 2013). Battery charging can be controlled by software-based load management systems hosted on mobile phones or computers and Electric vehicles are likely to interact with a smart charging system (Accenture, 2014).

**In what way does adaptation of the technologies impact work processes within the industry?**

Overall, manufacturing of Electric vehicles is expected to cause minor impact on work processes within the automotive industry. As discussed above, Electric vehicles require less components than vehicles with an internal combustion engine (CE Delft, 2012). Interviewees and workshop participants discussed the impact on work processes. There may be less components but manufacturing of individual components (such as the powertrain and user-interfaces, including electronics and software) require diverse and complex technological processes. These processes are highly automated. There will be less traditional assembly steps (such as welding and gluing) which imply that the volume of mechanical activities decreases. According to workshop participants, the new balance between mechanical activities and electronics/IT activities does not imply that very different types of management are needed (process operators, people management, financial management, etc.).

Production lines for Electric vehicles will be highly automated, in line with the overall trend in car manufacturing, and aimed at increased productivity and quality (CE Delft, 2012). The increased use of electrical components will further increase automation of production processes (European
Commission, 2014). Moreover, automated manufacturing control systems are used for putting together different components of the electric vehicle (Cambridge Economics, 2013). Interviewees and workshop participants confirm that the migration to Electric vehicles will lead to further automation of production processes. They also mention how the introduction of Electric vehicles is an extra trigger to modernise factories and production lines.

Increased automation will also take place in battery production. Again, productivity (such as cost reductions) and increased quality are the main drivers (The Boston Consulting Group, 2010). Workshop participants confirm this trend and mention that this it also applies to linking of batteries (into battery packs). Safety doesn’t appear to be a driver; it’s mostly about productivity.

**Box 3. Innovation in the production process: the role of new partnerships**

It is rather common that electric vehicle manufacturers want to spread the costs of developing advanced technology. For example, this can be done through collaboration among car manufacturers. Other options to decrease the costs of developing Electric vehicles is the use of a wide range of suppliers that through competition with each other bring down costs, or to invest in joint development programme with a supplier/partner. For instance, of General Motors (including Chevrolet) created a partnership with LG when developing the all-electric 2017 Chevrolet Bolt. LG has expertise in developing electronic products and is now manufacturing millions of electric motors per year. General Motors is using LG’s expertise to improve the assembly of powertrains that have been developed by General Motors. In addition, the LG and General Motors partnership covers charging systems, power distribution, power electronics, communication systems, instrumentation and infotainment. The collaboration between LG and General Motors is deeper than other recent collaborations of General Motors.

**How are these impacts likely to expand and evolve in the next ten years?**

This chapter presented several predicted impacts of Electric vehicles with a time horizon of 2025. To what extent these impacts will affect the automotive industry depends on three variables. Firstly, the pace of the migration from combustion engines to hybrid Electric vehicles and/or to all Electric vehicles. Secondly, the links between self-driving technology and Electric vehicles technology. Thirdly, the role of new actors with expertise in batteries, electronics, IT and the role of providers of charging infrastructures.

Studies, interviewees and workshop participants acknowledge the uncertainty whether hybrid Electric vehicles or all-Electric vehicles will be the main option in 2025. Even when hybrid cars are still leading the race in 2025, the take up of Electric vehicles leads to an increased demand for power electronics, electric motors, batteries, etc. (CE Delft, 2012). Note that hybrids are more environmental friendly than conventional cars, even though the manufacturing process is more complex and cars have ‘two engines’ (Germany Trade & Invest, 2015). For instance, Volkswagen implements a modular manufacturing system that enables their brands and models to use the same set of components as well as a similar platform. Therefore, they can efficiently install a plug-in hybrid system in their various models (Accenture, 2014). Interviewees confirmed that hybridization increases the complexity of manufacturing processes, with car manufacturers finding efficient solutions. The trend of increased automation is considered to be robust, i.e. not depending on the exact take up of hybrid cars and fully-electric cars.

Debates about self-driving cars and Electric vehicles (and the underlying technologies) have to some extent been combined. These two trends are not necessarily or exclusively linked. Still, there are market activities and technological considerations to combine both trends. Apple, Google and Tesla combine the development of Electric vehicles with adding self-driving technological features. However, it is believed that Apple has abandoned the plans of making its own self-driving car and
instead is focusing on self-driving technology (McGoogan, 2016). Tesla has previously (in October 2015) updated the software of its 60,000 sensor-laden vehicles. The software update contained an autopilot for changing lanes and parking. MIT Technology Review regarded the autopilot update as one of ten breakthrough technologies in 2016. Interviewees and workshop participants mention that the increased importance of IT and electronics applies to electric cars and self-driving cars, which allows for synergies when electric cars have self-driving features.

As mentioned in Chapter two, the rise of car sharing is another factor. It facilitates leasing of cars and subscription models. This mitigates the (current) high prices of electric cars. It could mean that the take up of Electric vehicles accelerates, with the impact on production processes emerging more quickly than in other transition scenarios. Along the same lines, the deployment of charging infrastructures will influence the adoption of Electric vehicles but not the production process.


Impact on work

The impact of Electric vehicles on working tasks, skills and competences

Much like the manufacturing of cars with combustion engines, the manufacturing of Electric vehicles requires a high level of management skills (design and operation of production lines), product design and marketing skills, operational skills at blue-collar level, plus skills for quality management. Because the production of Electric vehicles requires changes in the value chain and the production process, several new skills are required. These new skills are related to new materials, batteries, electronics, IT and management of the production process.

Although electric cars are already being produced, some of the skills are needed for research and development rather than manufacturing. R&D to increase the range and durability of batteries is a priority area (European Commission, 2014). Skills in physics, chemistry and battery (system) engineering are required. Research about new materials is an important area (making the vehicle lighter). Material scientists are required (Cambridge Economics, 2013). In electronics and IT for Electric vehicles, the main challenges lie in development and testing rather than in research. Interviewees stress that car manufacturers that prefer in-house solutions (for example regarding batteries and IT) need for new skills will be substantial.

The transition to Electric vehicles will stabilise or reduce the demand for mechanical engineers and other workers that focus on mechanical components of cars (CE Delft, 2012). This effect will not (yet) emerges when hybrid cars continue to be an important type of Electric vehicles. Interviewees mention that there will always be mechanical components, with the exact impact on skills needs depending on the degree of automation of production lines and quality control mechanisms.

Assembly will change, with fewer but more complex components, including battery packs, electric powertrains, more electronics and IT (among other things). This means that the workforce has to learn new skills related to assembling (European Commission, 2014). The number of assembly line jobs is likely to decrease, since the production of Electric vehicles is less labour intensive (Cedefop, 2014). This applies to car manufacturers (OEMs) but not necessarily to suppliers (such as producers of power electronics and communication systems).

Having a rich mix of skills (multidisciplinary experts and teams) is considered an important asset for manufacturers of Electric vehicles. This point is stressed by interviewees and workshop participants. For instance, mechatronics is a combination of electrical engineering and mechanical engineering. Mechatronics is required for designing and managing (and linking) different steps of the production process, e.g. equipping cars with electronic actuators, wired and wireless communication within the car, information storage and strategic control systems (Cambridge Economics, 2013).

Nicholas Roche, a mechanical engineer at Tesla, states: “A balance between textbook, theoretical and hands-on technical skills will also be required.” He also stresses as communicative skills and the importance of being able to learn new skills as the automotive industry rapidly changes as well (cf. lifelong learning)18.

Expertise in electronics and IT is an important part of the skills mix. If electric cars will also be self-driving cars, demand for electronics and IT skills will be even higher. It is likely that knowledge transfer from smartphone technology components and systems will be an asset in manufacturing future Electric vehicles (Elmer-Dewitt, 2015)19. The adoption of Electric vehicles will also affect the skills requirements in the wholesale and retail vehicle sector, such as the knowledge and skills to explain (and sell) the various types of electrical vehicles (Cedefop, 2014).

Electric vehicles: shifting gear or changing direction?

Box 4. A smooth transition towards Electric vehicles: education and training
One of the workshops for this study took place in Gothenburg, Sweden. Workshop participants described the Region Västra Götaland as ambitious and motivated to become an important manufacturer of Electric vehicles. For example, both Volvo and NEVS are developing fully-Electric vehicles. The transition towards making all-Electric vehicles in the region is expected to be smooth and incremental. For example, the curriculum at (technical) universities has already been changed to include more chemical engineering (batteries), IT and mechatronics. Volvo provides in-house training for its staff and also hosts interns. Workshop participants stressed that highly trained engineers, designers and IT experts will be essential for manufacturing Electric vehicles. On the other hand, low-skilled work will be less demanded. Workshop participants concluded that the Region Västra Götaland and Sweden in general requires more skills in IT.

Occupations in manufacturing industries affected by these changes
In line with the observations in the previous sections, studies conclude that production of Electric vehicles will be less labour intensive than production of cars with a combustion engine. This is mostly due to the lower number of components, against the background of the industry trends of ever increasing automation. Mechanical engineers and mechanical production workers will be the one affected most (CE Delft, 2012).

However, literature review, interviews and workshop participants indicate that new kinds of occupations will occur as a result of the migration to Electric vehicles. Results from the interviews and the workshop clearly indicate that jobs in electronics and IT are to some degree going to replace mechanical jobs. This also means that the demand for highly qualified jobs is going to increase. A report by European Commission states that half of the 461,000 job openings created by the production of cleaner vehicles will require high level qualifications (European Commission, 2014).

Engineers with different kind of skills (such as power electronics and mechatronics) are needed to apply R&D results into new production lines for Electric vehicles. Industrial designers are required to optimise the design of Electric vehicles, including the aerodynamics, the materials used, the user interfaces, etc. Battery production requires high-level research chemists (Cambridge Economics, 2013). Deployment of Electric vehicles will increase the demand for electrical engineers as well as for chemical engineers (Accenture, 2014), material scientists and experts in electronics and IT (European Commission, 2014).

Interviewees explain how IT experts needed for developing and manufacturing Electric vehicles should also have a basic understanding of related fields such as Advanced industrial robotics and the Industrial internet of things. For instance, robots are used to install battery packs in powertrains and in cars. As mentioned throughout the report, production of Electric vehicles (and relevant jobs and tasks) is affected by a combination of technologies.

An illustration of the various occupations affected by the transition to Electric vehicles is provided in an article about Apple’s Project Titan, which is believed to be the name of the project that develops an electric vehicle. Apple is hiring electronic engineers, software developers and sales staff, with a background in the car industry, IT and other industries20. Other relevant occupations are developers of

20 Hern, Alex. 2016-04-21 “Is Apple's next product an electric car?”. https://www.theguardian.com/technology/2016/apr/21/is-apple-next-product-an-electric-car-telsa
batteries and process engineers with expertise in physics, chemistry or electrochemistry (for the production of batteries) and in advanced computing or data analytics.\footnote{Roche, Nicholas. “The Future of Electric vehicles”. http://careers2030.cst.org/articles/future-electric-cars/}

Moreover, the increased use of electronics and IT in cars (not just in Electric vehicles) leads to more data being collected about vehicles, components, traffic, roads, drivers, weather, etc. (cf. big data). This data allows for detailed analyses to the benefit of manufacturers, drivers, owners, transport agencies and other stakeholders. The individual car may be improved (for example software updates), the model may be improved, the production process may be improved, etc. Data analysts/scientists are needed.


Deployment of charging infrastructures for Electric vehicles will create jobs. Estimations suggest that the annual costs of European charging infrastructures (for Electric vehicles) is going to increase from 26 billion euro to 80 billion euro in 2050, which is expected to create new jobs in energy, construction and service industries (Cedefop, 2014). On the other hand, fuel-efficient vehicles could lead to a decline in oil consumption, thus to a loss in employment, for example at gasoline stations and in oil/gas production and transport (CE Delft, 2012). Note that these predictions are at an aggregated level and do not present different scenarios (or impacts) related to hybrid cars, FCEVs and battery based Electric vehicles. Interviewees and workshop participants add that hybrid cars could, for the time being, lead to stable or even growing demand for staff. In short, hybrids need old and new skills.

Changes to working conditions

A review of the literature indicates that the production of Electric vehicles will only lead to small changes in working conditions. The same picture emerges from our interviews and workshop.

There are safety risks (or at least uncertainties) caused by the increased use of electronic components, such as high voltage batteries (Cambridge Economics, 2013). This is considered to be an additional driver for further automation or robotisation of the production process (Cambridge Economics, 2013). Interviewees disagree whether the safety risks caused by using batteries are substantial. Still, even when these risks are small, there is a need for additional qualifications/certifications (‘how to safely work with batteries and high voltage in general’).

The transition to Electric vehicles could influence wages. Several European countries have a shortage of qualified engineers in the car manufacturing industry. This shortage could become more severe under scenarios in which hybrid cars dominate (‘old and new components’), in which the development of electric cars and the development of new production lines (temporarily) requires more engineers and in which automation proceeds incrementally. As a result, wages can increase. However, another scenario is one in which fully Electric vehicles dominate, with new production lines deployed that are specific for fully Electric vehicles and are highly automated. This will reduce scarcity of engineers and may not lead to wage increases (CE Delft, 2012; Cedefop, 2014). Interviewees mention that shortage of engineers is also influenced by international competition such as car production moving to Asia or, instead, re-shoring as a result of robotisation.

Interviewees add that the transition to Electric vehicles, being a trigger for further automation, is likely to reduce the physical burden on workers. The mental burden may increase, depending on the number of workers to operate or oversee production lines and individual machines.
The use of batteries and other new components - and the changes in production processes - requires the existing work force to learn new skills. Studies and interviewees indicate that this will be more difficult for employees that have little educational background. Furthermore, companies may be reluctant to invest in education for employees that are close to retirement (Cambridge Economics, 2013).

In the recent past, the entry of actors like Apple, Google and Tesla had negative effects on the working conditions in the automotive industry. In particular, working conditions in Tesla plants are subject to discussions. Current and former employees of Tesla have witnessed that working for this company is associated with low wages, intense pressure, mandatory overtime and safety issues. New entrants can create opportunities for workers but uncertainty can be another effect. New actors such as Apple have changed the direction of their Electric vehicles projects. As a consequence, people were fired. The rather uncertain direction of the future of Electric vehicles, and small or large roles for new actors such as Google and Apple, implies uncertainty for staff.

**Box 5. New innovative entrants: importing working conditions from other industries?**

Tesla’s car factory in Fremont, California is an example of advanced manufacturing, including the use of large and versatile robots. Tesla representatives have hinted that the electric vehicle manufacturer aims to establish factories in Europe as well, benefitting from local European suppliers. Despite modern robots and Tesla factories being innovative in other aspects, employees have witnessed about bad working conditions in the factory.

Former and current employees of Tesla have witnessed a hard-working culture including long working hours and external pressure. This is confirmed by the fact that ambulances have come to the factory over 100 times since 2014, according to incident reports. In addition to the injuries and working under hard pressure, employees have stated that the wages are low. Several employees refer to a start-up mentality and an IT mentality that does not fit a manufacturing context.

**Actions and strategies**

Interviewees mention that social partners have to acknowledge the various scenarios for the transition towards Electric vehicles, including uncertainty about the pace of the transition from traditional cars to hybrids and to all Electric vehicles. As mentioned above, four specific uncertainties are the role of battery manufacturers, the links between Electric vehicles, self-driving cars and car sharing, the role of IT-based companies such as Google and Apple, and the deployment of charging infrastructures (timing, ownership, business models, interoperability, etc.).

This also implies that actions and strategies by public and public-private partnerships could target actors that recently joined the car manufacturing value chain. For instance, many regions and countries address the increased importance of IT skills by means of IT programmes or horizontal programmes (i.e. programmes that are relevant for several industries). Other skills are more specific for Electric vehicles, such as mechatronics.

The need to develop actions and strategies to address (or prevent) skills gaps is more urgent in scenarios with a steep uptake of fully Electric vehicles, produced by means of new and highly

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automated production lines (including Advanced industrial robotics). Especially the development, implementation and fine-tuning of these production lines will require training of staff.

According to most the interviewees, the combination of Electric vehicles and self-driving features will increase the urgency of staff training. In this scenario, the importance of skills related to electronics and IT further increases.

Education institutions are adapting as well. Skills - at high education levels - of electrical and chemical engineers are needed for the production of Electric vehicles. This is leading to changes in the curricula of (higher) education institutions. According to the workshop participants, *Swedish Electromobility Centre* serves as a link between industry and *Chalmers University of Technology*, by providing input from the industry to the university. This allows for timely and relevant changes in the curricula of education institutions. Workshop participants highlight that type of collaboration is important for a smooth transition to Electric vehicles.

To some extent, the car manufacturing industry continues to need technically-skilled assembly lines workers (European Commission, 2014). Here, the main model is training by automotive manufacturers themselves and certified training partners (European Commission, 2014). In addition, changes in the skill set of assembly line workers, leads to changes in curricula of education institutes.

Interviewees also mentioned that actions and strategies can be needed to increase collaboration (and trust) between actors from various industries now becoming part of the electric vehicle value chain. One of the topics should be quality management. This concerns the interaction between various components (and steps in the production process), from battery packs and IT to assembly, testing and shipping. Environmental regulation, safety regulations and standardisation are among the points of attention. The Industrial internet of things is mentioned as a technology that can facilitate quality management.

Public-private actions and strategies are also needed for the deployment of charging infrastructures. Possible roles for governments are co-financers and coordinators, to ensure interoperability, ease the process of obtaining permits (for example for charging stations in urban areas) and provide trust towards private investors (Amsterdam Roundtable Foundation, 2014). This suggestion was also made by workshop participants, when discussing the slow deployment of charging infrastructures as an important barrier for the transition to Electric vehicles.
Concluding remarks

The preceding chapters discussed several scenarios for the transition towards Electric vehicles. The studies and experts indicate that substantial steps will be made in the period between 2017 and 2025. However, not all technologies are mature enough. Battery Electric Vehicles (BEVs) and Fuel Cell Electric vehicles (FCEV) require additional R&D to increase range and durability of battery packs and other components. Improving batteries and battery stacks are among the priorities of car manufacturers and their suppliers and research partners. Hybrid Electric vehicles are helpful for promoting Electric vehicles. They are preparing consumers for fully-Electric vehicles, while also being a competitor of Electric vehicles.

Another factor in transition scenarios is deployment of charging infrastructure, based on electricity (BECs) or gas (FCEV). These infrastructures need not be a bottleneck, if governments and other stakeholders act quickly and in orchestrated ways. It would mean that the attention of governments in environmental sustainability is translated into specific actions that facilitate Electric vehicles, in addition to providing fiscal incentives and/or supporting R&D.

Manufacturing of fully-Electric vehicles will lead to more extensive impacts on automotive manufacturing since it leads to (even) more electronics and IT, less mechanical components, new and dedicated production lines and further automation. One of the implications is that IT related tasks, occupations and skills will become more important or numerous. This would lead to scarcity of IT specialist, mechatronics experts and engineers and, as a result, higher wages. The need for training and for adapting curricula will increase.

However, these changes are perceived as incremental. Other game-changing technologies like Advanced industrial robotics and the Industrial internet of things are having a bigger impact on the production processes in the automotive industry and, therefore, on working conditions and the balance between physical, intellectual and social tasks. The transition to Electric vehicles is an additional trigger to modernise factories and production lines. Along the same lines, any scarcity of IT skills will be caused by changes in several industries, not just car manufacturing.

Development and use of battery technologies is at the core to a large-scale transition towards Electric vehicles. Here, it was stressed that European automotive manufacturers try (or should try) to keep these value adding activities in Europe and/or within their corporation. This will also increase their influence on value chains, opposed to solutions such as relying on independent suppliers or non-exclusive partnerships with partners from Asia, the US or other regions. Asia has advantages in battery production through the nearness to brines (lithium) and more expertise and experience in battery technologies. The trend is that both new companies (such as Tesla) and established car manufacturers produce batteries themselves, and keep the added value in-house. The development and production of batteries and battery packs also creates employment; the need for staff with education and training in physics, chemistry and electrochemistry will increase.

The transition towards Electric vehicles will lead to new actors in the automotive industry, such as Tesla and perhaps actors like Apple and Google. Established car manufacturers do open brand new factories and production lines. However, outsiders have less historical links to well-established ways of producing cars, organising work processes, defining tasks, recruiting staff, etc. This could result in innovative ways of producing cars. For example, Tesla has already established two factories in US that use state-of-the-art robotics and that experiment with new work procedures. However, Tesla’s ambitions of being a frontrunner in Electric vehicles have negatively affected the working conditions for employees. When established automotive manufacturers such as Toyota, BMW and Renault-Nissan lead the development and manufacturing of Electric vehicles, the changes in work processes are likely to be incremental. Here, there could be a trade-off between moving carefully and risking that other companies take the lead.

It is unlikely that companies like Apple and Google are going to produce electric vehicle on their own. It is more likely that these companies will act as suppliers to established car manufacturers. Still, the threat that IT companies start producing cars will mean that incumbent car manufacturers continue to
invest in Electric vehicles, in increasing the productivity of their production process and in developing partnerships with leasing companies and car sharing platforms.

The preceding chapter also addressed how two trends - self-driving technology and car sharing - can accelerate the transition to Electric vehicles. These trends would further increase the relevance of skills in electronics and IT. In addition, there will be changes in downstream services such as maintenance, repair and charging (relatively large charging stations) and taxi services.

A challenge for this study was that there are many possible paths for the adoption of different types of electric vehicle technologies. Therefore, it is difficult to predict the impact on production processes and, especially, on work. Above, we sketched a number of plausible scenarios. However, it is still possible that ion-lithium batteries will not become the ‘final’ solution for Electric vehicles. This would radically change the estimated impacts on the European automotive industry and, hence, on the people that work in this industry and its upstream and downstream industries.
References


Green eMotion (2015), *Project Results*, Green eMotion.


Annex A: Research questions

1. What aspect of new technologies can be considered game changing to the manufacturing industry?
2. In what area of the industry are technologies entering into the manufacturing process?
3. What drivers and motives of enterprises shape the uptake of these technologies in the subsectors of the European manufacturing industry?
4. How likely is the increase and uptake of the technologies within manufacturing?
5. To what extent are the five technologies changing processes within the value chain?
6. How are these technologies affecting the demand for materials and products required within the European manufacturing industry?
7. In what way does the adaptation of the technologies impact work processes within the industry?
8. How are these impacts likely to expand and evolve in the next ten years?
9. How are the technologies changing employment, notably in terms of:
   - The need for new skills and competences
   - Increased demand in existing skills and competences
   - New occupation development
   - Increased demand of existing occupations
10. How are the (potential) changes caused by the technologies affecting working conditions in terms of job quality, contractual arrangements, health and safety and work organization?
11. How are social partners responding to and preparing responses to the changes in working conditions, occupational demands and skill needs?
### Annex B: interviews

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<tr>
<th>Expert</th>
<th>Organisation</th>
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<tbody>
<tr>
<td>Jürgen Dispan</td>
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<td>Johannes Fisel</td>
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<td>Elna Holmberg</td>
<td>Swedish Electromobility Centre</td>
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<td>Wolfgang Schade</td>
<td>M-Five GmbH</td>
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<td>Friedbert Pautzke</td>
<td>FH Bochum</td>
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<td>Jerome Perrin</td>
<td>Renault</td>
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<td>Carolina Sachs and Daniel Borrmann</td>
<td>Fraunhofer</td>
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## Annex C: Workshop participants

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<td>Volvo</td>
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<td>Elna Holmberg</td>
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<td>Chiel Scholten</td>
<td>Technopolis Group</td>
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<tr>
<td>Markus Lindström</td>
<td>Technopolis Group</td>
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