

Study on internationalisation and fragmentation of value chains and security of supply

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Case Study on Electric Vehicles

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Title: Study on internationalisation and fragmentation of value chains and security of supply

This report has been prepared in 2011 for the European Commission, DG Enterprise and Industry under the Framework Contract of Sectoral Competitiveness Studies ENTR/06/054.

Abstract: The overall objective of the study is to analyse the degree and consequences arising from the internationalisation, fragmentation and security of supply of value chains for European industry. The focus is predominantly on the supply side (i.e. upstream) as opposed to the demand, downstream, side. While globalisation can indeed be a positive development for Europe, there are also risks involved.

Key subjects: Value chains, supply chain management, risk mitigation, industrial policy, competitiveness, globalisation, EU, aeronautics, electric vehicles, mobile devices, semiconductors, space...

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1 Case study Electric Vehicles

1.1 Introduction

This case study deals with the internationalisation and fragmentation and supply risks in the value chain of Electric Vehicles (EV). At the outset, it should be stated that the scope of this case study is very wide, as the range of vehicles is broad.¹

Drivers behind the electrification

The introduction of eco-technologies into the automotive value chain is driven by energy security, oil shortages as well as by global warming concerns. Within Europe, CO₂ emission reduction is a key driver (COM 443/2009), with a CO₂ emission target of 130g/km for the average of new cars sold by 2015.

Ambitions are particularly strong in urban transport, where air quality concerns are driving EU goals (as formulated in the White Paper on Transport, EC 2011) to halve the number of 'conventionally fuelled' cars by 2030 and to phase them out altogether by 2050.

In summary, a range of key drivers are pushing electrification: global warming, air quality (particularly in cities), energy security, regulations to encourage the use of low-carbon cars, regulations to establish emissions-free zones in urban areas and incentives or subsidies offered by governments and potentially by companies as well (Wells et al, 2010, p. 42).

Coming to grips with segmentation

Under the heading 'electric vehicles', an increasingly wide range of technologies and concepts is included. Definitions and segmentation are not always clear and consistent, due to the fact that different dimensions are at stake. Furthermore, automobile manufacturers are keen to present 'green' images, which can lead to a tendency to (over-) emphasise the electric component of cars – while their dependence on internal combustion techniques is still substantial. Variations are shaped by two dimensions: steps toward electrification and the assembly of the power train.

Leaving apart the basic functions such as 'idle-off' and 'regenerative braking' the following three steps in electrification can be distinguished (Union of Concerned Scientists 2010):

1. Mild hybrids; Power assistance combined with downsizing: the electric motor supplements the internal combustion engine; these are also seen as 'mild hybrids' (e.g. Honda Civic/Accord, 1st generation Toyota Prius);

¹ This case study will focus on passenger cars. Beyond these, developments in electric powering also take place in light duty trucks, heavy duty trucks, motorcycles and scooters. See for instance the Honda EV-neo demonstration project.

2. Full hybrids; allowing the vehicle to drive only with the electric motor, especially at low speeds (e.g. third generation Toyota Prius);
3. Full electric; the car is propelled by the electric engine only.

In addition, there are three types of power train in use for electric vehicles²:

- a. Series drivetrain: the electric motor receives electric power from a battery pack or from a range extending generator run by a gasoline engine (new Renault-Nissan vehicles, Chevrolet Volt, Audi A1 e-tron, Honda FCX Clarity).
- b. Parallel drivetrain: both an internal combustion engine and an electric motor share the work (Honda Civic/accord)
- c. Series/parallel drivetrain; the engine can both drive the wheels directly or be disconnected from the wheels and act as a generator (Toyota Prius)

Figure 1.1 Typology of electric cars (by step and powertrain configuration)

Powertrain	a. Series drivetrain	b. Parallel drivetrain	c. Series/parallel drivetrain
Steps in electrification			
1. Mild hybrids		I. IC-electric hybrids Honda Civic/accord Toyota Prius I + II	
2. Full hybrids	II. Plug-in Hybrids (PHEV) Volvo V70 Toyota Prius Plug-in		
3. Full electric			
a. Range extender	IIIa. Battery-electric Vehicles Opel Ampera/Chevrolet Volt/		
b. Batteries only	IIIb. Battery-electric Vehicles Renault ZE / Nissan Leaf		

Source: Ecorys

When putting together the above two dimensions, the following four types of Electric Vehicles can be distinguished:

- I. IC-electric hybrid (HEV); combining internal combustion with an electric propulsion system; within this a distinction can be made in the balance between the two engines: mild hybrids (e.g. Honda Civic/accord) which depend more on the internal combustion engine, while full hybrids have a more powerful and diverse use of the electric motor (including series/parallel drivetrains like Toyota Prius);

² Ibid

- II. Plug-in hybrid (PHEV); an electric vehicle which uses rechargeable batteries that can be connected to an external power grid; they currently have an autonomy of 30–150 km, after which the conventional IC-engine will take over (Volvo V-70);
- III. Battery Electric Vehicle (BEV)
 - a) with a range extender – a combustion engine which acts as a back-up but which is not directly connected to the wheels (Chevrolet Volt, Audi A1 e-tron);
 - b) batteries only which can be fuelled through standard sockets at home, through dedicated charging points or through battery lease – making the cars more affordable (e.g. Israel, Denmark) (Renault ZE/Nissan Leaf).

Apart from the above categories, fuel-cell electric or hydrogen-powered cars should be included, which are however based on a completely different technology (currently Honda FCX Clarity).

Currently the market is still small

As developments are so recent, it is difficult to capture them through data. PRODCOM data on the eco-technologies automotive value chain show that the EU has no commercial production of EVs and that a negligible production value of €0.5 million is realised for batteries³ in the past few years. COMEXT data for EVs reveal that the EU imported the value of €18.7 million in 2009 and exported €3.5 million in that year.

Data on country import shares for the EU show that China, Japan and the US are the most important countries that deliver EVs, batteries and motors to the EU (See Table 1.1). Note that charging infrastructure is not included in these data. Also note that for batteries the data of COMEXT are not specific to the final use in electric vehicles.

Table 1.1 Country shares of extra EU-27 imports for EV's, batteries and motors, 2009 (%)

	Electric Vehicles	Batteries	Motors
China	19.0	46.9	51.8
India	5.3	0.6	0.6
Japan	9.6	19.1	4.4
South Korea	0.0	4.0	0.8
USA	6.5	15.2	13.0

Source: Eurostat, COMEXT data

In the US, HEVs are already sold commercially in considerable numbers; Toyota and Honda are selling HEVs and PHEVs. In Europe, Renault-Nissan will introduce BEV-electric cars on the market in autumn 2011. Although Toyota has been successful with its hybrid Prius, European carmakers have so far been reluctant to move into HEV, but instead favour more the PHEV that allows a longer drive in electricity mode. Similarly, the potential for electric vehicles with a range extender can be seen to be more prominent in markets where longer distances are important.⁴ The potential for battery-only vehicles is considered much stronger in urban settings, as is now being demonstrated in London and Paris (see Box below).

³ PRODCOM code 27202300 was taken, which stands for Nickel-cadmium, nickel metal hydride, lithium-ion, lithium polymer, nickel-iron and other electric accumulators

⁴ See for example the US-magazine Car and Driver, which clearly favours the Chevrolet Volt over the Nissan Leaf as it addresses what is commonly known 'range anxiety' (October 2010).

Box: Paris introduces an electric car-sharing scheme 'Autolib'

The city of Paris signed an agreement with the entrepreneur Vincent Bolloré for the leasing of electric vehicles called 'Autolib'. The programme, announced in September 2011, will allow citizens to hire a battery-powered Bluecar (manufactured by Pininfarina) from amounts as low as €10 a day.

The four-seated Bluecar will have a range of up to 250 km before a recharge, which will take about four hours. They will be available for hire – initially at 33 charging stations but this number is to expand to 1,000 stations by the end of 2012, when an expected 3,000 cars will be running.

An important element of the concept is to shift users from the idea of owning a car to that of using a car.

Source: <http://www.bbc.co.uk/news/world-europe-15134136>

Market potential is large

There is confidence in the potential of Electric Vehicles over the next 10 years. The European Automobile Manufacturers Association, ACEA, acknowledges the substantial opportunities that electric cars offer for Europe.⁵ European consumers meanwhile indicate they are ready for a change that combines mobility with less impact on health and the environment, since Toyota and Honda HEVs are also sold in Europe in large numbers.

The global market size for EVs in 2010 was 63,000 vehicles. In the next few years the EV market is expected to more than double each year: 268,000 in 2011, 959,000 in 2012 and 2,107,000 in 2013.⁶

The Boston Consulting Group expects by 2020 that about 14 million electric vehicles will be sold in China, Japan, the US and Western Europe, or 26% of the market. This number includes all segments, including mild and full hybrids. The market for electric-car batteries alone in those regions is expected to reach \$25 billion⁷. Cheuvreux (2009) expects that hybrids and EVs will account for 4% of European sales by 2015 and 20% by 2020.

Carlos Ghosn, who leads Renault and Nissan and who has invested €4 bn. in electric vehicles already, estimates that electric cars could account for 10% of new car sales by 2020.

Other sources expect that the global market share for EV sales will account for approximately 10% of annual new vehicle sales by 2025, according to informed industry sources⁸.

Our own best estimate is that by 2020, 5% of European sales would be for PHEV and EV while 15% for Hybrids.⁹

⁵ Zetsche, D. (2010)

⁶ Industrial Technology Research Institute (2010)

⁷ Boston Consulting Group (2010)

⁸ World Bank (2011), p.1

⁹ Underlying assumption behind this estimate: range extenders and pure EVs require much larger battery packs.

The component costs for BEVs are expected to decrease by 80% around 2020 due to economies of scale and incremental improvements in technology. PHEVs are more cost-competitive than BEVs although the gap will close gradually for smaller cars.¹⁰ However EVs will still face stiff competition from ICEs on the basis of total cost of ownership.¹¹

But sales will depend on the ability to overcome barriers

The extent to which the above potential will be realised depends, however, on the extent to which current barriers to greater market take-up can be eradicated. Deloitte – based on a survey amongst 13,500 consumers in 17 countries – found consumer expectations of electric vehicles to be unrealistic and that automakers are unlikely to satisfy them anytime soon. A number of barriers need to be tackled:

1. *Price:* Costs additions compared to ICE vehicles are currently 10% for HEV, 30% for PHEV and 100% for BEV. Most of these additional costs are due to battery packs – which now cost about \$10,000 while the willingness of consumers to pay is, according to Deloitte, closer to \$2,000. BCG expects these costs to decline by 60% in the period to 2020, from \$1,400-\$1,800 to \$ 570-\$700 per kWh.
2. *Range:* A part of these cost reductions per kWh will, however, be translated into more powerful battery packs with longer ranges. Deloitte found that consumers require a minimum range of 200 miles on a single battery charge, which is about double the current range. Based on lithium-ion technologies, BCG sees maximum ranges of up to 300 km. as technically feasible, but finds it unlikely that traditional ranges (up to 500 km) can be reached before 2020 – unless there is a technological breakthrough.
3. *Charging time:* Deloitte found that consumers expect charging times of less than two hours – while current charging times are in the range 10-20 hours.

Clearly, technological breakthroughs in battery technology are likely to be the most determining factor in the future market uptake of electric vehicles. In the subsequent parts of this case study, focus will be on this part of the value chain.

1.2 The competitive situation of the value chain

1.2.1 Early stage development – an immature value chain

The value chain for electric vehicles is in an early stage of development and a clear trend towards vertical integration seems possible through an attempt by key players to control the value chain. The manufacture of electric vehicles requires a complete rethink of car production, with batteries at the heart of the value chain. New entrants are coming to the market from entirely different directions. For example, the Chinese Build Your Dream (BYD) company is a chemical conglomerate with a strong focus on battery production, and not a car manufacturer.

¹⁰ McKinsey, A portfolio of power-trains for Europe: a fact-based analysis, p.5

¹¹ Boston Consulting Group (2011),p.5

1.2.2 EV induced trends in the value chain

A trend can be seen towards fewer mechanical and more electrical and electronic components, while the body structure will be less based on steel and more on composite and lightweight materials¹².

Crucial to the development of the battery-electric vehicles is the battery itself, as this still accounts for 50% of the total cost of a BEV. Other key technologies are motors and inverters, although batteries represent by far the highest cost and the most severe limitations to the mass take up of EVs¹³.

A number of strategic alliances are being formed between battery producers and European car manufacturers (e.g. Audi AG with Sanyo Electric Co.; Daimler with Evonik; Volkswagen with Toshiba)¹⁴. Other alliances include those between GM and BASF as well as those between Daimler and Bosch. In Japan, Nissan is partnering with NEC and Toyota with Panasonic in order to integrate batteries in the design and production of electric vehicles. The advantage of these alliances is that car makers can define the technical specifications of batteries to fit in their models. The disadvantages are that there is less competition among battery producers and that carmakers bear the risk of production disruption when their battery producer defaults. Traditional suppliers also go electric by partnering, e.g. Bosch with Samsung, a Korean battery manufacturer.¹⁵

Figure 1.2 represents the EV value chain. Lithium-ion *batteries* are key in the EV value chain, as they have very high energy and power densities and can therefore be lighter and smaller while delivering higher outputs. This case study cannot cover the entire EV value chain, hence only the white boxes in the figure will be analysed. Batteries actually have a value chain of their own consisting of materials, cell components, cells, electronics and packs. The costs of a lithium-ion battery can be broken down as follows: cell components (29%), labour for cell manufacturing (16%), electronics (22%), packs (2%), warranty (1%), and gross profit (30%).¹⁶

¹² Wells, P. and P. Nieuwenhuis, H. Nash, L. Frater (2010), pp. 14, 22 and 45

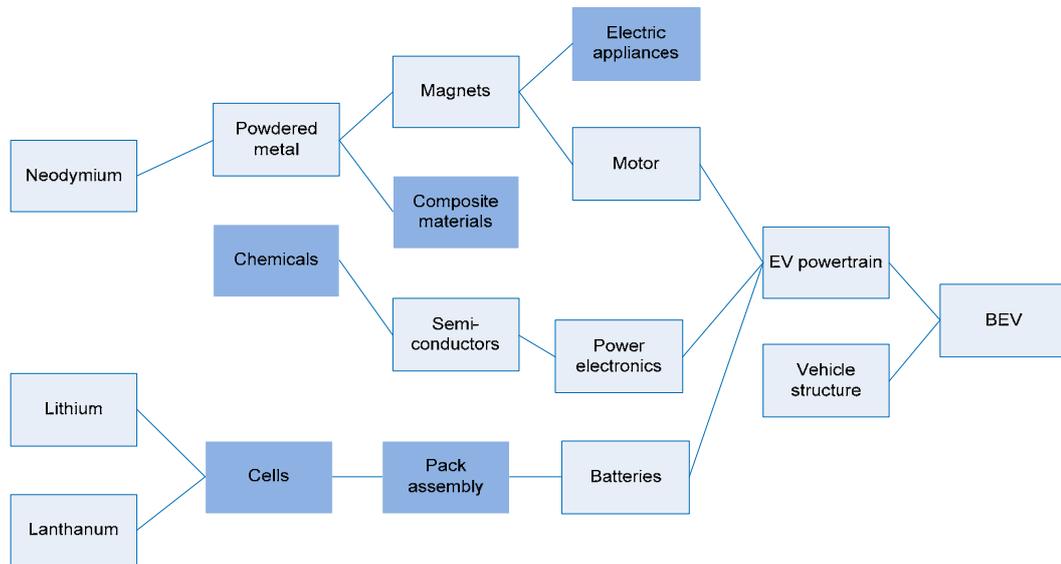
¹³ The battery management system that monitors the flow of energy to avoid damage and ensure safety is still an underdeveloped area according to AVERE, the European Association for battery, hybrid and fuel cell vehicles.

¹⁴ Electro To Auto Forum (2009)

¹⁵ The leader in Korea's EV battery sector is LG Chem, which has constructed the world's largest lithium-ion battery plant. Source: JoongAng Daily, April 19, 2011.

¹⁶ Lowe, M. et al (2010)

Figure 1.2 Automotive – EV value chain



Another part of the low carbon vehicle is the *body/chassis structure*. In the case of EVs, it is often more cost-effective to reduce weight, even by using exotic materials, than increase battery capacity. This would help firms with expertise in carbon fibre composites, aluminium, magnesium, thermoplastics, etc. The EU has a competitive advantage in this area.

Infrastructure is crucial for EVs, and therefore needs to be included in the value chain, especially for full electric vehicles. Utility companies are emerging as important players in this downstream part of the value chain. For example, Volvo is collaborating with the renewable energy company Vattenfall on the introduction of the Volvo V60 Plug-in hybrid.¹⁷ Renault is working with other utility providers, for example in the Netherlands with Essent. A push can be discerned towards the use of 'clean' renewable energy – a strong point of Europe in comparison to the US where utility management is fragmented, while electricity generation in China and India is still based on coal.

Reuse of batteries for power storage is possible when the old batteries are bundled. Umicore Battery Recycling, a company in Belgium is engaged in recycling lithium-ion and nickel metal hybrid batteries. This also helps to delay the depletion of lithium.

There is also a market in Europe for smaller companies that replace old batteries in HEVs¹⁸, like Toyota Prius, to rebuild existing cars e.g. Volkswagen Passat into an electric car (Innosys, Delft), to integrate electro motors in the wheels (E-Traction, Bussum), or produce fast charging poles (Epyon, a TU Delft spin off).

¹⁷ <http://www.vattenfall.com/en/presskit-joint-venture-with-volvo.htm>

¹⁸ Source: Interviews with Lotus Engineering and TU Delft

1.2.3 Internationalisation of the value chain – a limited role for Europe?

Internationalisation is crucial for European automobile manufacturers overall. It is estimated that around 40% (in value terms) of the components of a car is imported by German, French or Italian car manufacturers, 25% of which comes from other EU countries. For manufacturers in smaller countries these shares are estimated to be significantly higher¹⁹, which is evidence that the automotive value chain is becoming increasingly global.

With saturation on the European automotive market itself, European car makers can only grow by exporting to emerging markets where car ownership is still lower.²⁰

However, the EU automotive industry is making a rather late appearance in the electric vehicles market with EV-production currently still limited. Of the global market of 63,000 EV-vehicles in 2010 (excluding hybrids), only a small portion was manufactured in Europe. Low-volume trial production is conducted by Audi, BMW, Fisker, Ford, Mercedes-Benz, Porsche, Renault, Rolls-Royce, and Volvo. Microvett – an Italian company dedicated to the design and production of electric vehicles – is cooperating with Fiat.²¹ Renault-Nissan is the first company to put EVs commercially on the market in Europe, and will manufacture in both the EU and the US rather than in Asia.²²

Despite the limited current production, the potential for EU production remains significant. The fact that the European carmakers work on their own on these trial productions, instead of working together, shows that a competitive advantage is seen and that the PHEV and EV are on the brink of being commercially produced²³. Furthermore, the range of European responses to the EV-challenge allows European manufacturers to be 'plugged' into a range of technologies through global alliances with US (e.g. GM), Chinese (e.g. Volvo), and Japanese (Renault/Nissan) players.

Off shoring also takes place in the EV value chain to locations where raw materials are located, such as lithium salts (for batteries) and neodymium (for magnets) in China.

1.3 Critical factors

We distinguish as the two most critical factors: 1) the supply concentration of EV batteries in Japan and the IPR development linked to batteries in Japan and Korea; 2) relatively stronger industrial policy support for EV related activities in the US and China.

1.3.1 Justification of the critical factors

The first critical factor – *concentrated battery production* – is justified by the concentrated supply of batteries and the related issue of access to new technology in the supply chain configuration. As can be seen in figure 4-2, batteries form a crucial element of the EV

¹⁹ European Commission (2009), p.13

²⁰ Cheuvreux (2009), p.7

²¹ http://www.micro-vett.it/chisiamo_en.php

²² <http://www.renault-ze.com/en-gb/electric-motoring/renault-z.e.-in-detail-1953.html>

²³ Cheuvreux (2009), p.21

powertrain. The global market for EV batteries in 2009 amounted to US\$1.3 billion (BCC Research, 2010). Asia has the majority market share of lithium-ion battery manufacturing, with Japan accounting for 57% (Sanyo, Sony, Panasonic, Hitachi, Maxell), Korea 17% (Samsung, LG Chem) and China 13% (BYD, BAK, ATL). Japanese companies secured their market share from high demand from an established electronics industry. According to Japan's government industrial technology development organisation, NEDO, the global supply chain is dominated by Japanese components in every major fragment of lithium-ion battery manufacturing (cathodes, anodes, electrolyte solutions and separators)²⁴. The US is more involved in battery pack assembly. A leading battery assembler Johnson Controls Inc. is the joint-venture partner of SAFT, a French battery manufacturer²⁵.

China is able to produce lithium batteries on a large scale, as well as electric motors, as it has a dominant share in rare earth production. In combination with a rigorous industrial policy support program for EVs, China is expected to obtain global leadership in EVs.²⁶

The second critical factor group is the political support provided to the making of electric vehicles by *third countries* which may put Europe's current technological advantage in the automotive industry at risk.

As will be shown below, Japan, China, Korea and the US have installed important and comprehensive public support programmes – including both industrial support through taxes and loans, but also through sales subsidies and additional infrastructure investment. For example SAFT, the French battery producer now controlled by Johnson and producing batteries for BMW and Mercedes, will move much of its production capacity in a new lithium-ion plant in Michigan (USA), where the US Federal Government has invested US\$299 m – while an additional US\$148 m will be provided by the State of Michigan in the form of tax credits.²⁷

Table 1.2. presents a more detailed overview of the critical factors identified for the electric vehicle case.

²⁴ Electro to Auto Forum (2008)

²⁵ Cheuvreux (2009), p.24

²⁶ World Bank and PRTM (2011), p.12.

²⁷ <http://www.saftbatteries.com/MarketSegments/HybridandelectricvehiclesJCS/tabid/400/Default.aspx>

Table 1.2 Overview of critical factors in the electric vehicle value chain

Generic critical factor		Problems identified in literature	Selected for further study
Input needs	Resources		
	Technology	IPR, Patents	
Supply chain configuration	Structure	Concentration	V
	Relations		
“Localised” risks, high density problems	Natural		
	Socio-political	National industry policies in support of the EV supply chain	V
	Security		
“Global” risks, ubiquitous problems	Macroeconomic		
	Global governance		
	Competitive		

Source: Ecorys

Table 1.3 sets out the risks, impacts, mitigation and government role for the above two critical factors which will be dealt with in more detail in sections 7.3.2, 4.3.2 and 4.3.3.

Table 1.3 Electrical Vehicles – Risk Matrix

Critical factor	Risk	Impact	Mitigation	Government/EU role
Oligopolistic Asian suppliers of batteries for electric vehicles	Without batteries the EU industry will have a marginal role in the EV value chain; Losing technological control to competitors; EU carmakers are dependent on imported batteries	High	Mergers & acquisition with Japanese and Korean battery manufacturers Support battery development in Europe since these are needed near to the European carmakers	Increase support to R&D in battery development Set durability and safety rules on batteries for EVs
Socio-political / various national industry policies in the world; e.g. US and China actively supporting the creation of an EV supply chain	Third countries drive the formation of the EV value chain, leaving the EU far behind	Medium to high	Ensure equal level playing field with respect to industrial support	EC to Monitor differences in various national industry policies by third countries Member States can stimulate demand for EVs and provide incentives to attract EV component manufacturing

Source: Ecorys

1.3.2 Critical factor 1: oligopolistic battery suppliers

a) Risk

Five non-European producers of Li-ion batteries for EVs can between them control almost 80% of the market by 2015.²⁸ This oligopolistic structure will not be a favourable point of departure for the European car industry restructuring towards electric vehicles.

The cost of batteries is crucially sensitive for the commercial exploitation of electric cars. Battery prices will fall when production is for mass volumes. By 2020, BCC (2010) predicts a global sale of 14 million electric cars. Japan is at present better positioned to benefit from this developing market than the EU.

The Japanese R&D Agency, NEDO, released in March 2008 its “Next Generation Vehicle Storage Battery Development Roadmap 2008” which sets out key requirements for the development of batteries in terms of energy density, power density, cost reduction, durability, safety and State of Charge (SoC is the range in which batteries can be used). Particular focus of the Roadmap is on higher energy density and a wider SoC.²⁹

As can be seen from the below shares of the main players in the global lithium-ion battery global market, Japan’s position is followed by Korean and Chinese firms:³⁰

1. Sanyo (Japan)	23%	6. BAK (China)	6.6%
2. Samsung (Korea)	15%	7. Panasonic (Japan)	6.0%
3. Sony (Japan)	14%	8. Hitachi Maxell (Japan)	5.3%
4. BYD (China)	8.3%	9. ATL (China)	3.8%
5. LG Chem (Korea)	7.4%		

The data above show that the main companies of Japan and South Korea together have over 70% of the global market share of lithium-ion batteries, whilst the main players in China and the US have global market shares of 19% and 2%, respectively. Japan takes up 41.3% of global employment in the lithium-ion battery industry, China 38.4% and Korea 20.3%. The following Japanese companies produce lithium-ion batteries for HEVs and EVs: Automotive Energy Supply Corp, Hitachi, Toshiba, Sanyo, Blue Energy and Lithium Energy Japan³¹. Roland Berger (2011) expects that in the medium term there will be an overcapacity of battery manufacturing capacity. The risk, however, is that the present alliances between Asian battery producers and car producers will have first mover advantages in electric car production because they will remain the most competitive in this technological environment for the larger part of this decade.

Japan is leading in patents related to lithium-ion batteries filed in the US as well as internationally, which are measures of know-how and international competitiveness in the industry. International patents related to lithium-ion batteries held by countries during 1998-2007 were distributed as follows: Japan (52%), US (22%), South Korea (15%), Europe (6%), China (1%), others (3%). The top applicants by number of lithium-ion battery patents in the

²⁸ Roland Berger (2011)

²⁹ Electro to Auto Forum (2008), The future, as envisaged in the Development Road Map published by a Japanese governmental R&D planning agency, NEDO.

³⁰ Lowe (2010), p.18

³¹ Lowe (2010), pp. 21-22

US are: 1. Samsung SDI (South Korea), 2. Panasonic (Japan), 3. Sony (Japan), 4. Sanyo (Japan), 5. LG Chem (South Korea)³². The depth of expertise in lithium-ion batteries is clearly in Asia. Especially after 2020 this dependency on Asia will be felt since the ICE technology will for the remainder of this decade still be able to continue improving energy efficiency and reduce emissions. The raw material lithium is produced in Chile, Argentina and Tibet. Bolivia has the largest world's lithium reserves. The localisation of battery production is more oriented to proximity to car manufacturers than to access to the source of the raw material. Instead of lithium-ion batteries, the Toyota Prius used the nickel-metal-hydride battery module. However, the energy-density of lithium-ion batteries is expected to become better than from the nickel-metal-hydride batteries.

In sum, the EU currently has limited capacity in lithium-ion battery R&D with actual lithium-ion battery manufacturing capacity only existing in France as a Joint Venture between Johnson Controls and SAFT – however much of which is moving to the US. In Germany, the UK, Portugal and Spain, investments in production plants for lithium-ion batteries are planned³³. The Renault-Nissan JV is planning to produce electric vehicle batteries from a plant in Flins (France) as well as from a factory in Aveiro (Portugal) by 2012. The Bolloré Group sources the batteries for the electric vehicles used in 'Autolib' from factories in Brittany and Canada.

b) Impact

According to Electro to Auto Forum³⁴, companies that control rechargeable batteries also control the new-generation automobile market. The impact on Europe will be that European battery manufacturers remain unable to produce the appropriate batteries in terms of size, cost, and durability for the expected increasing demand of PHEVs and BEVs. The development of an electric vehicle supply chain in Europe will be hindered by the undeveloped state of battery manufacturing and the backlog in know-how of lithium-ion batteries. In this scenario, European car makers will have to import such batteries or partner with Japanese or South Korean electric battery producers. The long-term consequence will be that by the time there is a mass market for EVs, the technological competitive advantage in car making may have shifted from Europe to Asia.

c) Mitigation

More emphasis is needed on R&D for EVs and batteries in the EU as recommended by ACEA³⁵. In the US significant public investments are already being made under the American Recovery and Reinvestment Act in the battery supply chain comprising firms in mining lithium, manufacturing of chemicals and electronics and assembling of battery packs.

Research funding for companies that manufacture batteries and battery components as well as universities that do research in battery technology will further the development of electric batteries in Europe that are needed to power EVs. The European industry itself sees the need for an integrated evolutionary approach whereby the key stakeholders (Automotive industry, energy suppliers and distributors and local and national authorities) collaborate in a coordinated way for the electrification of the transport system.

³² Lowe (2010), pp. 24-25

³³ Lowe (2010), p.28

³⁴ A forum of the Tokyo based consulting firm TechnoAssociates, Inc.

³⁵ EUCAR (2009)

d) Government role

Car manufacturers themselves need to invest in R&D for the new batteries for EVs. The government can complement private investments in R&D for European lithium-ion battery development by making public research funds for R&D available. The government at Member State level can play a facilitating role in the infrastructure for the charging stations. The Member States can furthermore provide incentives to build up capacity for battery manufacturing.

Safety aspects also play a role in recharging batteries. The EC could set safety standards for batteries to mitigate the import of unsafe electric batteries from third countries.

1.3.3 **Critical factor 2: strong industrial support for EV related activities**

a) Risk

The general threat of third countries providing relatively more industrial support to their automotive industry, in transition to making EVs, is that the European car industry will be operating under less favourable conditions to make that transition and eventually will lose its leading position in global sales. Examples are provided below of industrial support provided to this new EV industry by the US, China, Japan and South Korea.

US industrial support

Already in the early 1990s the US government and US automotive industry formed a Partnership for a New Generation of Vehicles. At the same time, Chrysler, Ford and GM established the US Advanced Battery Consortium to develop the electrochemical energy storage industry.

At State level, Michigan and California provide related incentives and regulation, e.g. Michigan grants tax cuts to new battery companies to lower their construction costs; California maintains from 1990 onwards a Zero Emission Vehicle Program to transform cars and fuel away from petroleum. At city level electric vehicles have preferential lane access and designated parking space.

By 2009 the United States provided US\$25 bn in loans for advanced auto manufacturing that would achieve 25% higher fuel economy. The US Department of Energy budget for lithium-ion battery development exceeded Japan's government funding for that same item (NEDO, 2009) in the last decade. The higher budgets in the US are the result of the American Reinvestment and Recovery Act of 2009 and DOE's Advanced Battery Manufacturing Initiative.

The Obama administration provided US\$42.4 bn in support to lithium-ion battery manufacturing.³⁶ This large investment may lead to overcapacity in battery production for electric cars, since consumer demand for electric cars is still limited in the US. A 2009 study on the market penetration rate of electric cars, as a function of world oil prices and the relative price of drive trains, had a baseline forecast of 64% of US light-vehicle sales by

³⁶ GCC (2010), p.20.

2030 comprising 24% of the US light-vehicle fleet³⁷. The calculations included a US\$7,500 consumer tax credit for electric car purchases, switchable lithium-ion batteries with network operators offering pay-per-mile contracts. In July 2010 the Administration's goal included putting one million PHEVs on the road by 2015, and increasing US plants' capacity in order to produce batteries and components for up to 500,000 EVs per year by 2015. To increase electric car purchases, the President has recommended converting the US\$7,500 consumer tax credit for electric cars into a rebate at the point of purchase by consumers. The US incentives for infrastructure investment include US\$400 m for demonstration projects and US\$100 m for a 5-City EV Project infrastructure deployment. Nonetheless, a congressional research service report considers it difficult to achieve the goal of one million electric cars by 2015 due to the high battery costs varying between US\$8,000 and US\$18,000 per vehicle³⁸.

Chinese industrial support.

China has a New Energy Vehicles (NEV) programme to promote the development of EVs and HEVs.³⁹ The programme covers policy development, technology development and new business models. On policy development the program aims to address global climate change, energy security, urban pollution and auto industry growth, although the program's actual background is that China wants to rely on its own electricity sources. In addition, it is found that through electric propulsion China will have a faster global presence than through internal combustion engines. In 2009 the Ten Cities Thousand Vehicles Program was initiated to stimulate large scale electric vehicle development in ten cities. This program was expanded to 25 cities and contains consumer incentives in five cities. At state level consumers receive purchase subsidies per vehicle. Hence, at both national and provincial level the use of EVs is promoted.

In terms of technology development China is making progress in battery manufacture and reducing battery costs and in the charging infrastructure (rapid battery exchange systems and battery swap stations). China is also developing new business models, i.e. commercial models for developing the infrastructure, the leasing of batteries and provision of other vehicle services.

A recent World Bank report classifies China's NEV programme as possibly the world's most aggressive to transition its public and private vehicle fleet to EVs and HEVs. Nonetheless in August 2011, the achievement of the Chinese targets to have one million electric cars on the road by 2015 and five million by 2020 was debated by the Government⁴⁰, implying that the original ambitious targets most likely will not be met.

In June 2011 China signed agreements with Germany to undertake joint research and investments in green technology in the field of e-mobility. This means China wants to import foreign technology for the production of electric cars from Volkswagen, Daimler and Siemens⁴¹. China's own budget contains RMB 100 billion (\$15.2 billion) over the next decade to develop electric vehicles.

³⁷ Becker, Th. A. *et. al.* (2009)

³⁸ Canis, B. (2011)

³⁹ World Bank and PRTM (2011)

⁴⁰ Financial Times, China debates electric car policy, August 22, 2011

⁴¹ Financial Times, June 28, 2011, China and Germany launch green initiative

Japanese industrial support.

The Government of Japan has focused on battery-powered vehicles, but pure EVs are not yet on the market. The domestic market of Japan is too small for a take-off of EV production on a large scale. For this Japan will be dependent on access to foreign markets. Since 2009, the Japanese government has a Green Vehicle Purchasing Promotion Measure, including tax deduction and tax exemptions. The purchase subsidies are higher when a new owner of a green vehicle scraps an older vehicle. Toyota's production and sales of the Prius hybrid surpassed the one million vehicles in 2008. The Japanese Ministry of Economy, Trade & Industry has established targets that hybrids and electric cars should account for 50% of new car sales by 2020. These targets seem overambitious according to industry sources⁴².

South Korean industrial support.

In South Korea the Ministry of Knowledge Economy expects that the South Korean car makers (GM Korea Co., Ssangyong Motor Co. and Hyundai Motor Co.) will roll out electric vehicles by 2012, based on a package of government subsidies, tax incentives, parking discounts and the necessary infrastructure. A law allows commercial low speed EVs on designated road lanes. By 2020 domestic sales of EVs in South Korea are planned to be 10% of small-sized cars and South Korea plans to have by 2020 a share of 10% of global EV sales. The 70,000 hybrids on the road in South Korea in 2010 are expected to triple by 2013.

In sum, the industrial policies of the above countries support both the demand and supply side for the development of EVs. On the demand side there are purchase subsidies and investment in infrastructure and development of new business models. On the supply side the industry is assisted with research, access to finance and incentives to set up factories.

b) Impact

The enormous support provided to the EV value chains in the US, China, Japan and South Korea results in a non-level playing field that creates disadvantages for the European car industry. The industrial policies in these countries give clear directions to their domestic automotive sectors that their governments support EV development.

The EU has followed a different industrial policy for the EU car industry whereby different solutions are promoted to achieve environmental improvements. For example, the option to combine the ICE-technology with electric powertrains. Because Europe has not been focusing on one solution there has been relatively limited support and public investment in EVs thus far. The impact will be that the above third countries will have sooner EVs that will be commercially feasible for mass production.

c) Mitigation

European car makers are all global companies. However, to date the US and China are not willing to agree on a global standard for EV charging. At least a start could be made with an internal market for EV charging standards and EV incentives in the EU.

Industry should take the lead in developing the production capacity and the value chain for producing EVs and in developing business models to maintain an EV network system.

⁴² Automotive New, posted by Eric Loveday on the internet, April 20, 2010

Clearly, a broader and more holistic approach is needed, taking into account both demand and supply considerations. A 'cradle to grave' rather than a 'cradle to gate' approach, so that besides policy impacts on industry also attention is given to environmental and sustainability implications.

d) Government role

The European Commission could start making voluntary agreements on EV charging standards and EV incentives with the 27 Member States. Furthermore given the more aggressive industrial policy support for EVs in the US and China, international policy development in support of this sector needs to be monitored on impact which is a natural role for the European Commission.

The Member States can assist in stimulating demand for EVs as well as giving incentives to increase manufacturing capacity.

1.4 Critical regulatory framework conditions

Identification of critical regulatory framework conditions and their impact on the value chain are as follows.

1.4.1 Outside the EU

Industrial policies (incentives).

Different incentives to stimulate demand of EVs will have an impact. The purchase subsidies range from €2,190 per car purchased in China to €5,474 in France, Germany and UK. In Japan certain programs offer €7,299 in EV incentive. In the US, a purchase subsidy of \$7,500 is under consideration.

Japanese companies dominate the EV related patents.

In particular Toyota has had an aggressive patenting strategy holding 4000 EV related patents worldwide (43%). EU competitors are left to license Toyota technology and Japan holds the key to lower battery manufacturing costs and longer battery life times. As already noted above, the costs of batteries play a significant role in producing EVs commercially.

Backlog in R&D support of EVs.

Development of electric cars is faster in the US, Japan and China. Hence, more emphasis on R&D for EV and batteries in the EU is recommended by ACEA⁴³.

Different standards for battery charging.

The physical connection between the vehicle and the grid comprises of socket, outlet, plug, cable, connector vehicle inlet. In the EU the plug supports 240V and 360V. There should be no difference in infrastructure and plugs across Member States in the EU, which is not the case today. In the US the plug supports however 120V and 240V, whereas the Japanese plug

⁴³ EUCAR (2009)

can go up to 500V for fast charging. ACEA recommends a global agreement for standard AC charging and a common agreement on quick charging.⁴⁴

1.4.2 Inside the EU

The level of taxation of gasoline.

In the EU where fuel prices are taxed highly, there is a relatively high incentive to purchase EVs.

EV incentives.

Within the EU Member States ought to harmonise their EV incentives. According to ACEA,⁴⁵ national and regional governments of 16 EU Member States provide a wide range of incentives for the purchase and use of (H)EVs, including tax reductions and exemptions and bonus payments.

The EU adopted Regulation 443/2009.

The EU regulation on CO₂ emissions of 130g/km for the average of new cars sold by 2015 will gradually cause a shift toward more production of (H)EVs by European carmakers. To reduce vehicle emissions by a factor six by 2050 the 130g/km should go down to less than 30g/km according to Chan (2010).⁴⁶

Table 1.4 summarises the different regulatory framework conditions:

Table 1.4 Summary of regulatory framework conditions

Regulation	Positive impact	Negative impact	Long-term impact
Outside EU			
A. More aggressive industrial support for EVs		EU car industry is at a disadvantage because of less support	
B. Japan dominates patents of batteries		EU carmakers are dependent on Asian battery makers	Joint ventures of EU carmakers with Asian battery manufacturers
C. Different charging standards of EV in US and Japan (but also across EU Member States)		Cost increases for all stakeholders in EV market	Less global welfare in EV market as markets remain fragmented
Inside EU			
A. Level of taxation of fuel	High tax on fuel stimulates EV driving		Large demand for EVs
B. Different EV incentives in EU MS		Distortive allocation effects in the EU	Most EV activities in places where the incentives are large
C. EU regulation on CO ₂ emissions	Regulation stimulates EV production		Larger supply of EV

Source: Ecorys

⁴⁴ ACEA's position and recommendations for the standardization of the charging of electrically chargeable vehicles, Brussels, 2 March 2011.

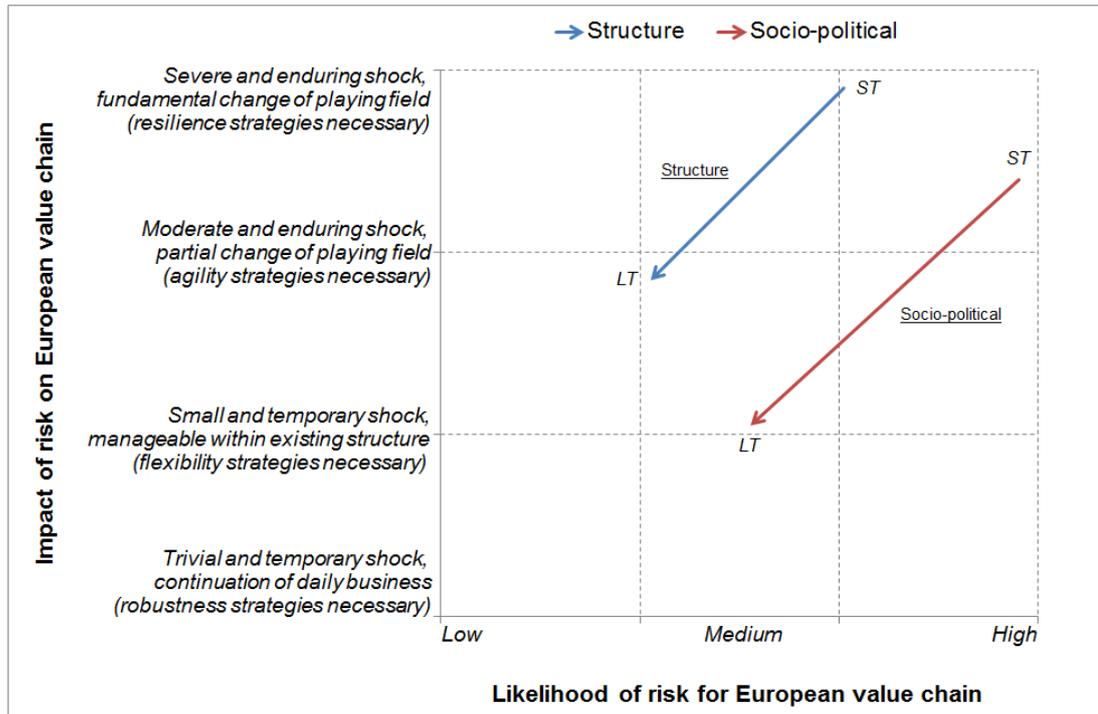
⁴⁵ ACEA (2010)

⁴⁶ Chan, C.C. (2010)

1.5 Strategic outlook

The above two risks have been ranked in terms of impact and probability in Figure 1.3, both for the short- and long-term.

Figure 1.3 Impact and probability of risks: short-term (ST <3 years) vs. long-term



The more aggressive industrial policies in third countries in favour of electric cars have a medium/high impact because the EV market will not be fully commercially developed in the short term. The probability is high because the US, China, Japan and South Korea have consistently more clear industrial EV policies than the EU. In the long run the impact of this risk will be lower in case EU industrial policy for the automotive industry will converge in line with the world-wide trend towards electrification of the car. The probability that the European value chain will be impacted will decline when the industrial policy regimes for this sector will be aligned. The question remains whether an EU-response would come in time, as first-mover advantages will have been made by others. The size of the EU-market – the world's biggest – will however make it attractive for global players to draw up alliances with European players. The Renault-Nissan merger is in this respect an excellent example, but not necessarily typical. More likely than alliances between automobile manufacturers will be alliances with battery and component suppliers, as well as with actors downstream in the value chain – for instance with utility companies or local and regional governments.

The lack of battery manufacturing capacity is seen as a short-term and high impact risk. The probability of the risk is medium because of the partnerships and corporate alliances between European carmakers and battery manufacturers. When Europe develops more know-how and capacity of battery manufacturing the risk and the probability of the risk will decline in the long term.

At present the market for full electric vehicles is still in an incubation phase. Factors that are decisive for the commercial development of this market are: 1) the cost of the vehicle and the cost of the battery which constitutes the major part of this, - now ranging between USD 8,000-18,000; 2) the international price of oil; 3) the installation of the charging infrastructure; 4) legislation and other framework conditions including those relating to carbon emissions; and 5) consumer acceptance.

Within twenty years the battery costs are expected to drop considerably, world prices of and taxes on oil will be higher and the charging infrastructure will be expanded in Europe inter alia by EV Network Operators offering battery switching services. Enforced regulations to cap CO₂ emission will have lower targets. The price of an EV with pay-per-km service contracts is expected to be lower than the purchase price of a fuel efficient ICE car⁴⁷. Consumers may be prepared to pay for the environmental advantages of EVs and accept a shorter driving range. In this scenario it can be predicted that hybrids will be completely accepted by consumers and that full electric vehicles are utilised at least for short-distance commuting.

A SWOT on the key issues is presented in Table 1.5.

Table 1.5 SWOT of the European Electric Vehicle value chain

Strengths	Weaknesses	Opportunities	Threats
The EU car industry has a competitive advantage in safety, technology and producing light vehicle body structures	EU industry lags in battery manufacturing	EU has strong energy management systems that can facilitate the charging infrastructure in urban areas	Intellectual property assets for lithium-ion batteries remain for years to come in Japan, US and South Korea; dependence on Asian batteries
The EU car industry is exchanging best experiences with ACEA.	EU carmakers are still in the trial phase of making EVs.	EU has better utility companies than e.g. in the US and India; European utility companies can become partners in building EV networks	EU continues to have less clear political direction on EVs than the US, China until 2015
EU carbon policy is conducive to the EV market	Third country industrial policies disadvantage EU manufacturers	There is a need to be more sensitive to environmentally healthy environments so consumers have to accept EVs	EU car industry still has no standardization of infrastructure and plugs An internal market for EVs is missing by 2015.
			China is a low-cost manufacturer for the remainder of the decade

Source: Ecorys

To strengthen the European EV-industry and increase its competitiveness the following is recommended:

- At policy level (EU, national governments): the standardization of infrastructure and plugs at EU level, durability and safety rules for EVs, harmonisation of EV incentives by EU Member States to create an internal EV market, making available public funds for

⁴⁷ The company Better Place proposed to split the ownership of an EV and the battery. The EV owner will lease a battery or pay for a per km based battery service contract.

R&D of batteries for EVs and monitoring of EV industrial support in nations outside the EU;

- By sector organisations: function as platform for discussions on EVs by European car makers and battery manufacturers;
- By companies: invest in R&D efforts, join partnerships in the short-term with Asian battery manufacturers.

1.6 Annex 1: interviews

Mr./Ms.	Name of interviewee	Title	Organization	Country
Mr	P. Nieuwenhuis	Lead Expert on Sustainable Automobility	Cardiff University	UK
Mr	S. Yoccoz	EV Project Director	Renault-Nissan	France
Mr	Ph. Assourd	Director	AVERE	Belgium
Mr	T. Vleesschauwer	Director Automotive	IHS Global Insight	UK
Mr	P. Dolejsi	Director Sustainable Transport	ACEA	Belgium
Mr	S. van Dijk	Coordinator Research on electric mobility and transport	TU Delft	Netherlands
Mr	Ph. Barker	Chief Engineer	Lotus	UK

1.7 Annex 2: data issues

Relevant Data Used

Primary data sources for this case study were:

PRODCOM

Eurostat's PRODCOM database contains data on total production in current price Euros by just under 3900 product codes, giving some scope to identify detailed products which form part of the Aeronautics sector, over the period 1995-2009 (although often there is missing data for some years). In this case study we have identified the following products as being relevant;

This data provides detailed production for the EU (at an individual member state level) although does not include any non-EU countries. With respect to the Electric Vehicles case study, the data includes final product data for cars, separating out 'other' motor vehicles into a separate category, but nonetheless one in which electric vehicles represent only a small proportion of the total. Many intermediate products are either grouped together with products for all cars (where the final product could be used in any kind of motor vehicle) or with other potential final uses (as is the case with batteries and other categories).

COMEXT

Eurostat's COMEXT database contains data on trade (imports and exports) between EU member states and major trading partners, by value and volume, on a country by country basis across 1995-2010 (although some data points are missing), with data split across over 28,000 product codes. This data, unlike PRODCOM, does include military as well as civil aeronautics. The following product codes were used in the case study;

The COMEXT data captures on a (relatively) consistent basis the trade between various states (and, more significantly, between the EU27 and major trading partners) across detailed product codes. However the product codes are not specific to the final use in electric vehicles and it is not possible to separate out the trade in a product that relates only to the electric vehicles sector. The gaps in the data also lead to some inconsistencies, with certain years including some product codes but not others, which is not always apparent in the final aggregated data.

UN COMTRADE

UN COMTRADE includes data on imports and exports in value (US dollars) and volume (kgs) terms on a product-by-product basis, and provides a similar level of detail to the COMEXT database (albeit on a different classification system, which presents an issue of having to map from PRODCOM or Combined Nomenclature codes to the SITC or HS system used by UN COMTRADE) for non-EU countries, so helping to complete the global picture/comparison. However, data is only available for a very limited number of years (2007-2009).

Toyota published accounts

The published accounts were used to source information on the number of EV-related patents held by the firm. These data can be used to give an illustration of the level of R&D activities being undertaken in automotive firms, although there is a danger of reading too much into a single data point for one firm. Lowe M. et al (2010) provides a range of statistics relating to lithium-ion batteries. While data were available for the period 1998-2007, in those cases where a single year of data was used, the year 2007 was adopted, being the most recent available data.

Data gaps and requirements

There is a clear lack of detail in the classifications related to Electric Vehicles. While this may improve with time, it is likely that any crowding out of traditional motor vehicles by electric vehicles will simply see the shares within the currently outlined sectors change, rather than an increased granulation of the available data. The only data that does exist is typically from company accounts and lobby groups, and it is difficult to first of all corroborate this data and then to compare to other data sources – consolidation of this data would help significantly. The industry is developing very quickly, and a further concern is that any data published is out of date almost immediately afterwards – one group specifically identified this as a reason for not disclosing data.

1.8 Annex 3: literature

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