PANORAMA 2017

a look at ...

Development of electric vehicle: where are we now?

Electric vehicles – a term which refers to battery electric vehicles (BEV) and plug-in hybrid vehicles (PHEV) – are regarded as one way to lower energy costs and reduce the environmental impact of transport. While mild or full hybrid vehicles are gradually becoming more widespread, the market for electric vehicles is still developing. While the symbolic threshold of one million electric vehicles in circulation worldwide was surpassed in 2015 and sales are increasing from year to year, certain limitations could nevertheless hinder this growth. High purchase prices, the need to establish incentive-based public policies to significantly increase sales, and vehicle range are challenges to overcome before electric vehicles become a sustainable part of the world's automobile fleet. This memorandum takes stock of this specific market and highlights the reasons to believe in its continued progress. It mainly discusses private vehicles (including microcars) and utility vehicles, but a specific section is dedicated to mopeds and motorbikes.

Continuous sales growth worldwide

The light-duty electric vehicle (BEV + PHEV) market has consistently grown since the arrival of the first mass-market models, which were launched at the start of this decade. While only 50,000 vehicles were sold worldwide in 2011, the market grew by more than 70% last year, reaching 565,000 vehicles sold. In 2015, for the first time, sales of electric vehicles surpassed the 1% market share threshold in seven countries (China, Denmark, France, Norway, Sweden, the Netherlands, and the United Kingdom).

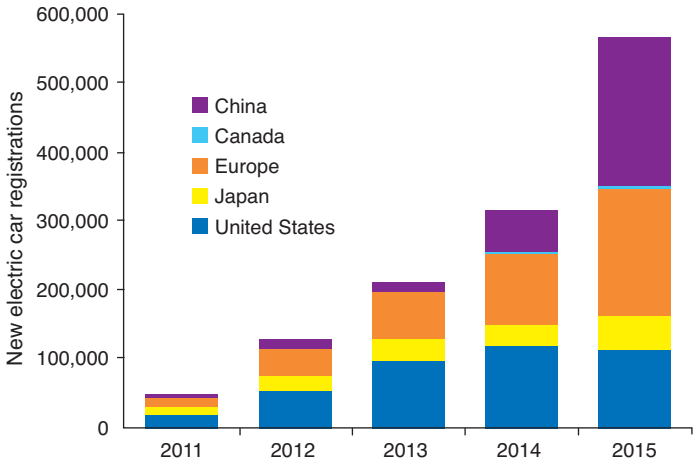
Figure 1 details the five most promising markets. Today, 95% of sales take place in these five regions: Canada, China, Europe, Japan and United States. With spectacular 345% growth and 214,000 plug-in electric vehicles sold, China was the main driving force for the growth of electric vehicles in 2015, boosted by the strength of the manufacturer BYD, an engine for growth and a world leader in terms of sales volume (60,000 electric vehicles in 2015, ahead of Tesla and its 50,600 vehicles sold). In 2015, China became the world's leading market for electric vehicles, ahead of the United States (115,300) and Japan (46,300).

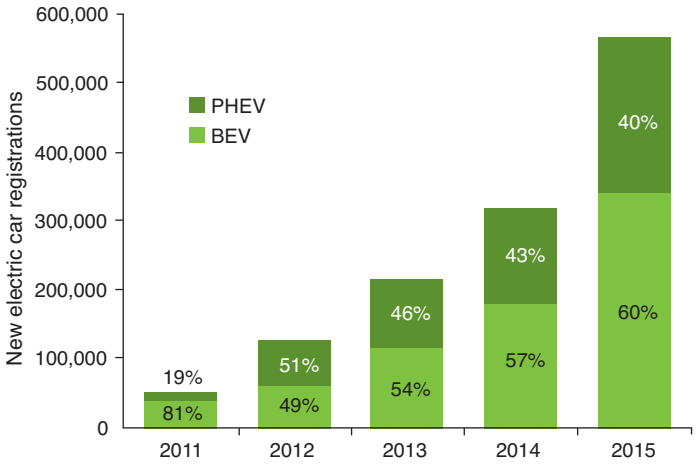
In Europe, the world's second largest electric vehicle market, registrations nearly doubled, reaching 187,000 last year. The largest contributors to this figure were the Netherlands (44,500), Norway (33,600), the United Kingdom (27,800), Germany (23,200) and France (22,800). These five countries alone totaled 81% of total sales in Europe. On the other hand, the market posted a slight 3% contraction in the United States, due to a relative lack of model renewals and falling fuel prices. Strong sales figures during the first half of 2016 show that this slowdown was short-lived (+18% compared with the first half of 2015). Lastly, it is interesting to note that in 2015, 40 plug-in hybrids were sold for every 60 battery electric vehicles worldwide. This distribution should stabilize in the coming years.

IFP Energies nouvelles

Development of electric vehicle: where are we now?

Fig. 1 – Change in annual sales of light-duty electric vehicles (BEV + PHEV) worldwide





Source: ANL and EAFO

The global electric vehicle fleet surpassed the symbolic threshold of one million vehicles in circulation during 2015, reaching 1.26 million as of December 31, 2015 (740,000 BEV and 520,000 PHEV). According to estimates based on sales volumes for the first half of 2016, the threshold of two million electric vehicles worldwide should be surpassed by the end of the year (Fig. 2).

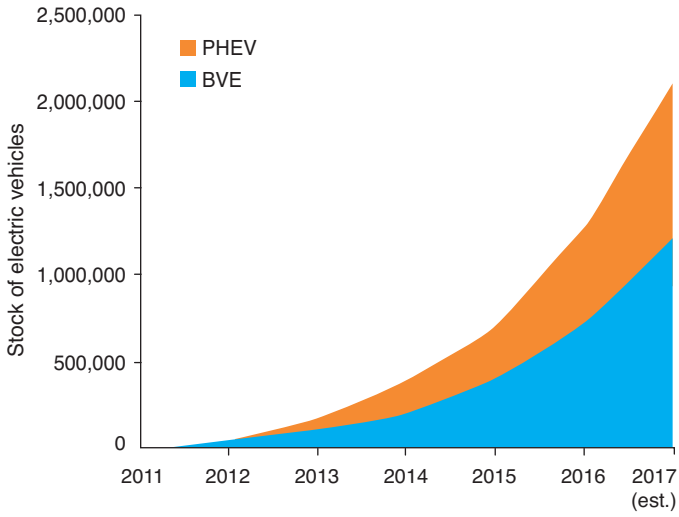
Though clearly gaining strength, the electric vehicle market remains marginal, representing only 0.1% of the global automobile fleet in 2015, while its share was 0.08% in 2014. The environmental and energy impact of the electric vehicle roll-out remains weak, but the buyers' shift in focus seems to have begun. In certain countries such as Norway, the Netherlands and China, the market share of electric vehicles has sharply risen during the past four or five years. In 2015, 22% of light-duty vehicles sold in Norway were electric, along with 10% in the Netherlands (both governments have established strong incentive policies).

Electric buses

At the end of 2015, the global electric bus fleet was estimated at 173,000 units, nearly all of them in China which had 150,000 at the end of 2015, six times more than in the previous year. The Chinese government is planning massive investments in transport electrification, which also applies to public transport in an effort to fight urban pollution. By 2020, China will have more than 200,000 electric buses on its roads, with a network of some 4,000 dedicated charging stations.

Aside from China, several countries have fleets of electric buses, but they are small compared to the Asian powerhouse (100 in India, 95 in the Netherlands, 30 in Sweden, etc.).

Fig. 2 – Change in worldwide electric vehicle fleet at January 1 of each year



Source: EV-Volumes

The market's leading models

Table 1 ranks the top ten best-selling models worldwide during the first half of 2016. Battery electric vehicles are indicated with a green background, and plug-in hybrids are noted with a blue background. Note that the top model in the microcar segment ranks 19th (Kandi K10 EV).

Looking at the same type of ranking for manufacturers (Fig. 3), China's BYD is the clear leader with 44,000 vehicles sold during the first half of 2016 (14.1% market share), followed by Nissan (30,500), Tesla (29,500) and then the Volkswagen group (28,000). Renault ranks 7th with 14,500 vehicles released worldwide (4.7% market share).

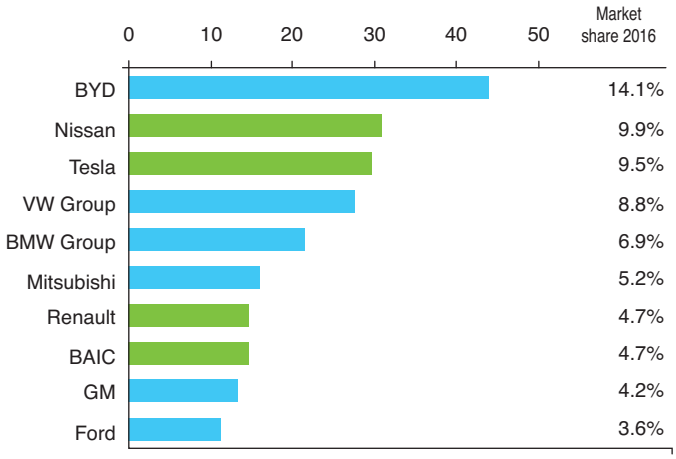
Development of electric vehicle: where are we now?

Table 1
Ranking of the ten best-selling electric vehicles in 2016

Model	Segment	Sales – S1 2016
Nissan Leaf EV	C	27,765
Tesla Model S	E	22,556
BYD Tang PHEV	SUV	19,134
Mitsubishi Outlander PHEV	SUV	15,501
Renault Zoe EV	B	11,885
BYD Qin PHEV	D	11,129
Chevrolet Volt EREV	C	11,124
BAIC E-Series EV	B	9,977
BMW i3 EV	MPV	9,271
BYD e6 EV	MPV	9,226

Source: EV-Volumes

Fig. 3 – Ranking of the top ten electric vehicle manufacturers worldwide



Source: EV-Volumes

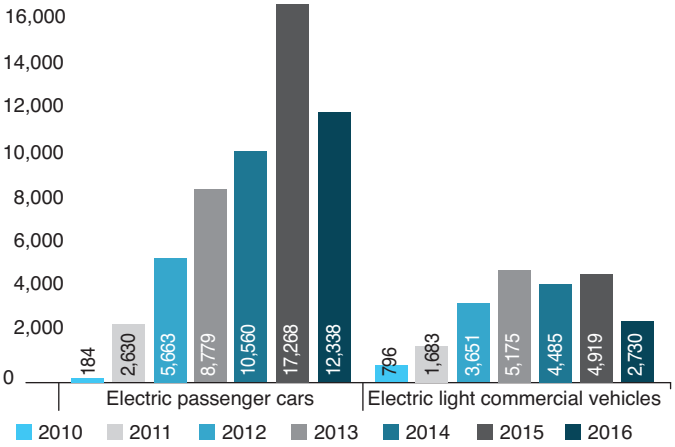
Focus on the French market

France, european leader in battery electric vehicles

In France, 17,200 private battery electric vehicles were registered in 2015 out of a market of 1.91 million units, i.e. a market share of 0.9% (CCFA figures)[1]. Stimulated by attractive buyer incentives, sales of battery electric vehicles in France leapt by 64% last year. Given the improved buyer incentives in place during 2016, professionals are optimistic about the prospects for this year[2]. At the end of the first half of 2016, 12,300 BEV had already been sold, up 54% compared with the same period in 2015, along with 2,700 utility vehicles (+34%). This enabled France to take the lead position in the European BEV market in terms of sales volume, ahead of Norway and the United Kingdom (Fig. 4).

The two leading models in this segment by a wide margin are the Renault Zoe and the Nissan Leaf, with 10,400 and 2,150 models respectively released in France during 2015.

Fig. 4 – Change in battery electric vehicle registrations in France at the end of June 2016



Source: AVERE

Plug-in hybrids: an opportunity for electric mobility

Plug-in hybrid vehicles, which also have the support of the government, have enjoyed a year of strong growth in France during 2015 (5,600 registrations, compared with 1,930 in 2014). Although buyer assistance clearly declined during the first half of 2016 (€1,000 in 2016 compared with €4,500 in 2015), there was nevertheless a marked increase in sales of plug-in hybrids (3,800 vehicles sold, compared with 2,360 over the same period in 2015). Thus, the view of users therefore seems to have shifted: electric vehicles are gradually becoming a credible alternative to internal combustion vehicles. The plug-in hybrid market is flourishing, and manufacturers are currently launching their own models, which is expanding supply as well as sales.

In the plug-in hybrid market in France, the Volkswagen Golf GTE (1,695 sales) leads the pack followed by the Audi A3 e-tron (913). They are followed by the Mitsubishi Outlander PHEV, BMW i3 REx (range extender), Porsche Cayenne S-E Hybrid, BMW X5 xDrive 40e, VW Passat GTE, BMW i8, Volvo V60 PHEV, Mercedes Class C 350 e and lastly, the Toyota Prius plug-in Hybrid.

Currently, the range of these vehicles when operating in electric mode remains modest, from 25 km for the Toyota

(1) Committee of French Automobile Manufacturers (CCFA)
(2) Since January 1, 2016, the government has established a €10,000 super bonus for the purchase of an electric vehicle and the scrapping of a diesel vehicle more than 10 years old

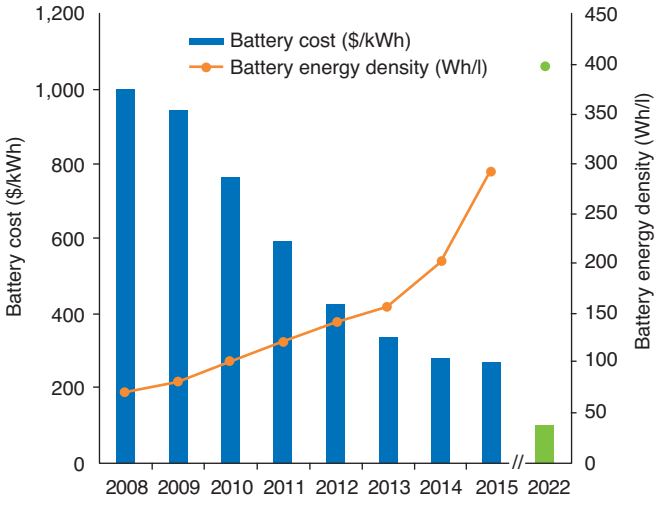
Development of electric vehicle: where are we now?

Prius to 50 km for the Volkswagen Golf. Only the BMW i3 with a 150 km range stands apart, a true electric car with a range extender. With higher capacity batteries, this range should significantly increase in the coming years.

Is range still a critical point?

Even though the current range of EVs can cover most day-to-day journeys, it remains one of the main impediments to buying, following sales price excluding buyer assistance. Nevertheless, there are real technical advancements, and manufacturers are continuing to invest in expanding battery range as well as their weight, by improving their energy density. Figure 5 shows that the cost of batteries has fallen fourfold since 2008, reaching approximately $265/kWh according to the US Department of Energy (DOE). This relates to the price of cells. The price of the rest of the battery pack, specifically the cooling system, the casing and the management system, must be added to this. The total price is around $450/kWh. Tesla and GM announced highly ambitious goals to reduce costs for 2020 and 2022, to approach the $100/kWh bar for cells. At the same time, energy density is rising sharply (around 295 Wh/l for the best cells which represents specific energy of 150 to 180 Wh/kg). This will also allow improvements in EV range, to meet buyers' expectations. According to the DOE, manufacturers are aiming to achieve energy density of 400 Wh/l by 2022 (i.e. approximately 200 to 240 Wh/kg), a 36% improvement over current levels. Of course, these values are still far removed from the energy density achieved by petroleum fuels (around 9,400 Wh/l for gasoline).

Fig. 5 – Progress of batteries in terms of cost and energy density



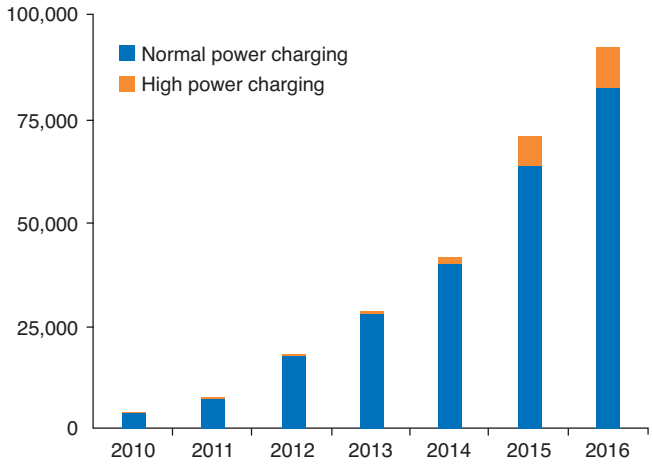
Source: US Department of Energy (DOE)

In practice, most models (Zoe, Leaf, i3, eGolf) have a li-ion battery capacity ranging from 22 to 33 kWh. Ranges announced by these model manufacturers fall between 190 and 310 km. Of course, this depends on the on-board capacity as well as vehicle weight and the efficiency of the electrical machine. Tesla has taken a different position, opting to equip its models (Model S) with higher capacity batteries, from 70 to 90 kWh. The range is increased, along with weight and price. The range therefore achieves a value between 370 and 500 km, for a price between €77,000 to €105,000 (by way of comparison, even though it is not the same vehicle range, the Nissan Leaf 30 kWh is sold at €35,300 for a 250 km range).

Charging stations

An efficient electric recharging network is required for the success of electric cars. Most drivers prefer to charge vehicles at home, in a parking place or a garage. This charging method is estimated to represent around 80% of electric vehicle charges. However, to be able to travel further than between home and the workplace, for example, it is necessary to create a network of public charging stations. It is clear that investment in recharging infrastructure can accelerate the adoption of electric vehicles. Future alternative solutions appear promising, such as charging by induction on the motorway, or partial charging of electric buses at each stop.

Fig. 6 – Development of charging infrastructure in Europe



Source: EAFO

At the end of 2015, it is estimated that a total of 1.45 million charging stations were operating worldwide, including 1.3 million private stations, 162,000 "slow" public charging stations and 28,000 "rapid" charging stations. The growth in the number of charging stations generally tracks the rising sales of electric vehicles, but most are home-based

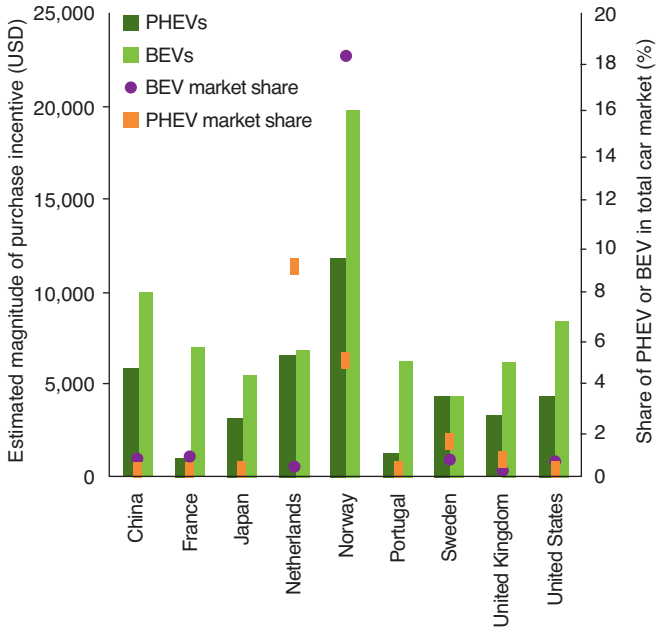
charging stations. However, it should be noted that, with regard to rapid charging stations, China and Japan are in the lead, with more than two-thirds of the market. In Europe, infrastructure is gradually being implemented (Fig. 6). In France, there are currently 12,100 slow public charging stations and 1,300 rapid charging stations, divided among approximately 4,000 stations. In 2013, there were only 5,300, and the government has set a target of 50,000 public stations by 2020.

Incentive-based public policies

Because road transport and merchandise are one of the main producers of GHG (Greenhouse gas) emissions and local pollution in urban areas, a number of governments have launched ambitious policies to transition to more energy-efficient and less-polluting transport methods. Even though the environmental benefits of EVs remain sensitive to assumptions concerning the electricity mix and battery recycling, its growth is currently supported through implementation of numerous support systems worldwide.

The gradual electrification of an automobile fleet, so long as it relies on low-carbon electricity production, enables governments to address previous challenges, i.e. reducing GHG emissions from transport (source of approximately 20% of total GHG emissions in Europe), limiting local pollution, and gradually reducing domestic consumption of petroleum products.

Fig. 7 – Estimate of electric vehicle (BEV + PHEV) purchase incentive and share of local markets



Source: IEA

There are numerous incentives that may lead buyers to choose an electric vehicle. Most are economic and financial in nature, such as the tax on CO_2 emissions, buyer assistance, free motorway tolls, research and development support and support for installation of charging stations. But, certain governments and urban communities also choose to support electric vehicle owners in practical ways, through preferential parking, the right to drive in bus lanes and other benefits. The IEA has aggregated the various buyer assistance options for nine countries (Fig. 7), and has superimposed the market share of electric vehicles. The Norwegian government's proactive policy to promote electric vehicles (and penalize combustion-powered vehicles) is very clear. Today in Norway, one out of every five cars sold is electric.

What are the most effective incentives?

The European SCelecTRA project, coordinated by IFPEN and carried out in partnership with IFFSTAR, Kanio, EIFER and Thinkstep, sought to identify public policies that promote the development of electromobility in Europe by 2030, and to assess their environmental impacts and external costs. Simulations of more than sixty electric vehicle penetration scenarios for the European market were performed. To prepare these scenarios, public policies for the development of electromobility were divided into two groups depending on whether they addressed supply or demand.

Some were more effective than others. The deployment of charging infrastructure and rising energy prices are decisive factors in the rise of electromobility. Likewise, scrapping programs and purchase incentives for electric vehicles seemed to better promote broader acceptance than fuel taxes.

Outlook for growth of electric vehicles

The outlook for the growth of electric vehicles is highly dependent on the public policies to be chosen in the future. Even though technical advances are now undeniable, such as improvements in vehicle range, they are not enough to lead future purchasers to consistently choose electric vehicles. They must be supported by incentive-based public policies, whose impact has already been demonstrated. As noted above, the examples of Norway and the Netherlands demonstrate the close link between the market share held by electric vehicles in a given country and the scope of its support mechanisms.

According to the most optimistic scenario, the results of the SCelecTRA project show that electric vehicles could capture up to 30% of the European automobile market

by 2030. On the contrary, without incentive measures (the most pessimistic scenario), the share of electric vehicles in Europe in 2030 will not surpass 15%.

At the global level, forecasts of market share for electric vehicles in 2030 range from 7 to 22% for the most optimistic. In the IEA's 4DS scenario for example – central scenario - growth will be fairly moderate, with the number of electric vehicles on the road reaching 23 million in 2030 (7% market share). According to the hypothesis, this will achieve savings between 0.3 and 0.5 million barrels of oil per day.

Among the most optimistic scenarios, Bloomberg indicates a 22% market share for electric vehicles in 2030, and 35% in 2040 (corresponding to a total of 121 million vehicles on the road in 2030 and 420 million in 2040). According to them, the total number of vehicles in circulation will represent one-quarter of the global light duty vehicle fleet in 2040. According to our estimates, consumption of around 2 million barrels of oil per day would be replaced by 2030, moving to consumption of 400 TWh of electricity for the year. By 2040, this would correspond to 7 million barrels of oil per day being translated to consumption of 1,400 TWh of electricity for the year (i.e. approximately 5% of annual global demand in 2015).

Still at the global level, the Lima-Paris action plan, at the heart of COP21 negotiations, sets forth several major initiatives concerning the growth of electromobility. The action plan calls for the deployment of 100 million electric vehicles worldwide by 2030. Finally, according to the IEA, to achieve the goals of the 2°C scenario (limiting the increase in global surface temperature to 2°C), it will be necessary to reach 140 million electric vehicles in 2030. This would represent a 20% market share and, in the end, a 40% share by 2040.

In conclusion, it should be noted that in 2030-2040, there is a significant discrepancy between the most optimistic and the most pessimistic scenarios. These disparate visions reflect the great uncertainty concerning the scope and sustainability of policies to promote the expansion of electric vehicles, technical advancements to be achieved in the field, and the price of liquid fuels at the pump.

Electrification of two-wheelers

The gradual electrification of transport methods also concerns two-wheelers, whose market is also growing slowly. In 2015, the IEA estimates[3] that 40 million electric two-wheelers were sold worldwide. In total, around 20% of mopeds and motorbikes in circulation worldwide are electric. However, the market is highly localized: with 220 million electric two-wheelers in circulation (i.e. nearly 50% of the moped and motorbike fleet), China is the global leader and the only one to achieve such high sales levels. Today, most electric two-wheelers are sold in China, following restrictions on the use of internal combustion motorbikes established in the country's major cities during 2009 to reduce urban pollution. As in China, the action plan in the Paris Declaration urges the extension of this deployment worldwide, with a goal of 400 million units (electric mopeds, motorbikes and three-wheeled vehicles) by 2030, i.e. a 70% market share.

(3) For the global two-wheeler market, estimates are most frequently discussed since reliable data on sales – particularly in China – is more difficult to obtain than data on private vehicles. Uncertainty continues to surround the stated figures.

Cyprien Ternel – cyprien.ternel@ifpen.fr
Final draft submitted in September 2016