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Is a "second car revolution" underway? How to improve our ability to answer?

(Transcription of oral comments of slides presentation)

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From the analyse of the past to a method to glimpse a possible future

We all have in mind the too often optimistic forecasts in alternative vehicles, specially in Electric Vehicles. The forecasts and the opinions are generally based on some recent trends or technical and commercial considerations, sometime on elements of the context. But which in fact did not prove anything in the sense of sustainable or temporary growth. [1]

In 2009, we have proposed a hypothesis to find a more accurate method. If we knew the conditions that allowed the "first automobile revolution", we could check whether these conditions are today fulfilling or not, for a possible second revolution. It appeared that four conditions were necessary and that these four conditions were probably fulfilling today, for the first time since the beginning of the Twentieth Century [2]. They allowed for three possible scenarios of transition to cleaner vehicles [3].

In the first part, we will make a brief recall of the "first automobile revolution", but we will add two lessons from the past. In the second part, we will examine if the conditions of possibility for a "second automobile revolution" are reinforcing or not since 2011.

1. The four no-technical conditions of the "first automobile revolution"

The four no-technical conditions that allowed the replacement of horse drawn carriage by automobile and the universal adoption of petrol Internal Combustion Engine was the crisis of horse-drawn carriage for local transport that required to find radical solutions. The financial and industrial capitalism, the railways and the steamboats had triggered a strong growth of numbers of persons and goods to transport and the concentration of people in big cities and industrial areas. So the traffic in horse-drawn carriages has increased strongly in these spaces during the third part of XIX century. The consequences were: urban congestion, air polluting, epidemic, diseases, accidents, but also reduction of cultivated areas for human consumption, land prices, production costs and prices for horse drawn vehicles, lack of skilled workers and social conflicts, divergent productivity between local transport and industry, etc. But also the wars of the second half of 19th century showed that the rapid transportation of weapons and soldiers was strategic.

The second condition was a technological and entrepreneurial effervescence in three main directions: steam vehicle, electric vehicle and oil vehicle, but also in unexpected direction as hybrid engine, compressed air… (as we can see, few things are technically completely new !).

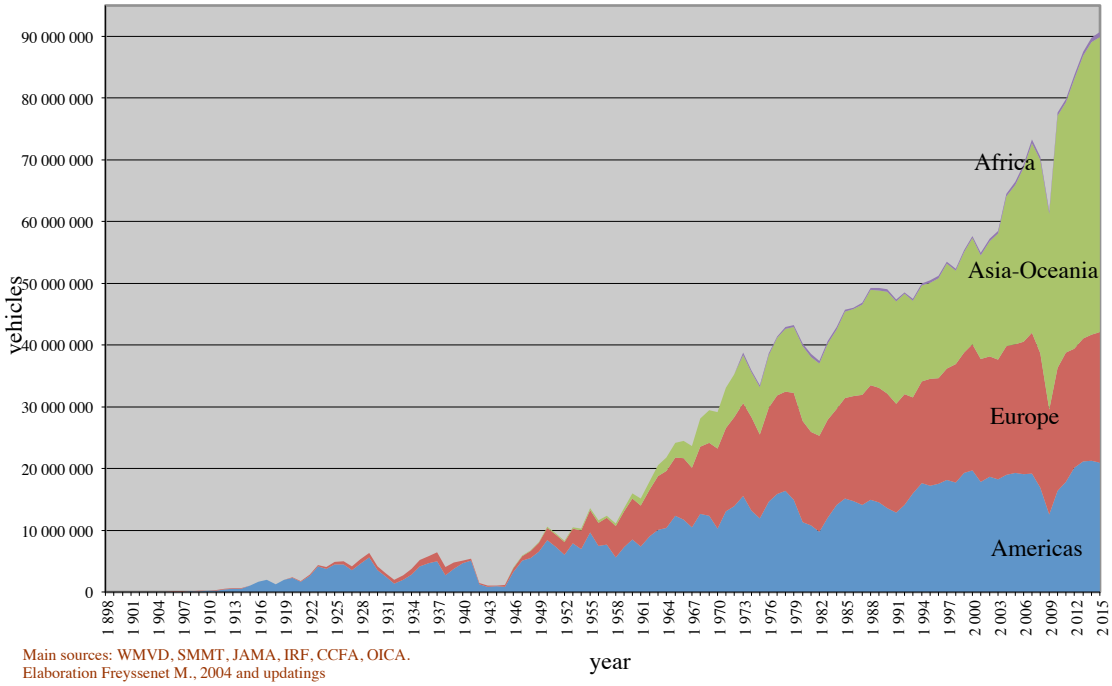
The third condition was a coalition of actors that imposed the internal combustion engine of petrol, no because of its comparative qualities, but mainly because petrol was at that time the most easily transportable and storable energy in all parts of territory. It was not the case of electricity. The Armies were a very important actor of the coalition for petrol vehicle

The fourth condition was the abandon of the too unequal distribution of national income that limited the car market during fifty years, especially in Europe. Afterwards, the possibility for households to acquire a car facilitated urban sprawl and specialization of spaces and a strong transformation of the way of life.

These four conditions were largely presented in previous symposium and articles. So we can focus on two complementary lessons of the "first automobile revolution" to better understand the current period.

The first lesson concerns the speed of change. The replacement of horse drawn carriage by automobile vehicle was slow and different according to transport sectors and, of course, to countries. But it was clear that the new means of transport are going to change profoundly the economic and social life, if the people could buy it. This is in that meaning that our historian colleagues of GERPISA titled rightly their famous book "The automobile revolution" [4].

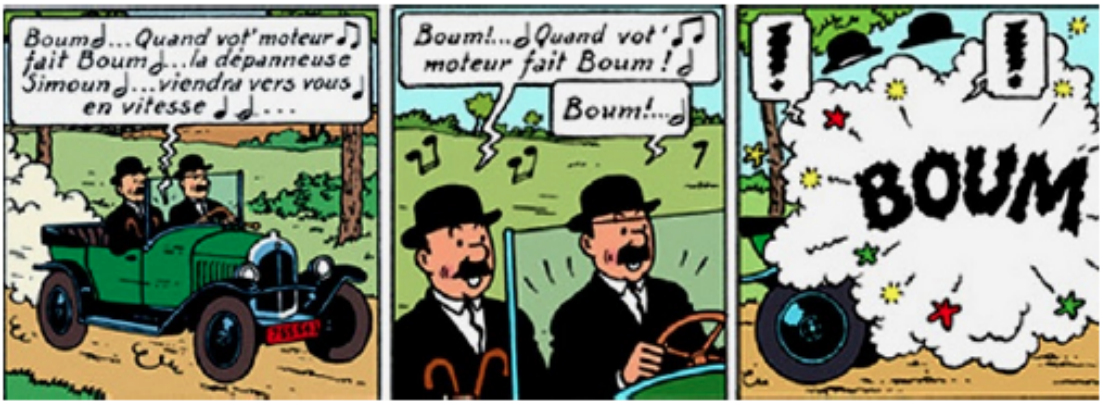
World automobile production by continent, 1898-2015



Main sources: WMVD, SMMT, JAMA, IRF, CCFA, OICA.
Elaboration Freyssenet M., 2004 and updatings

The real take off of petrol car begin after the second war. No more 6 millions automobiles are sold in the world, the best years, before the 50s, produced essentially in USA. The car fleet has surpassed the registered horse-drawn carriages, only in 1925 in USA and 1930 in France and UK [5]. The complete replacement operated in 50s and 60s only in industrialized countries. So the slow increasing of the alternative energy vehicles, especially EVs from 2012 to 2015, could not be considered the proof that the ICE would continue to dominate totally in the automobile transport.

The second point we want to emphasize is the petrol ICE had very low engine efficiency, a strong consumption of petrol and engine oil. It was less reliable. Its many breakdowns and the engine explosions were so frequent to be object of jokes, until the 30's. The driver had to be a mechanic. The petrol car was criticized by people: noise, pollution, road accidents, etc. Many competent persons, as Maurice Bixio, Director of the Compagnie Générale des Voitures in Paris, said that "the petrol car has absolutely no chance" to be adopted [6]. It is the contrary that happened … after some years as we saw. But Maurice Bixio was may be no interested by so long perspectives…



Petrol car by Hergé

After the choice of petrol for road transport, the work of engineers was concentrated to overcome the problems of ICE, but at the price of very heavy investments, not only in the automotive industry, but also in petroleum industry to invent the cracking of petrol molecules to obtain a gasoline more homogeneous, less explosive.

The other types of engine disappeared, but not completely from technical point of view, as in the case of steam motor, but also in the market, as the electric engine for taxis, ambulance, garbage trucks, and so on, in some big cities, until the 30s. So the important fact we must remember is that the initial disadvantages and limitations of a technical solution can be (almost always) circumventing, overcoming or eliminating, after the adoption of a type of energy for geopolitical reasons. That is to say, another technical solution would be adopted in others contexts. In other historical conditions of production, supply and distribution of electricity, or steam, and with other social coalitions to support them, another motorizations could technically prevail and be adopted. There is not technological determinism.

2. Were the conditions of possibility of a "second automobile revolution" reinforcing or not since 2012, and could they not be fulfilled in the future?

The crisis of petrol car has become deeper in general, but the relative importance of its causes varied and its intensity is not the same depending on the regions of the world. Several technical solutions continue to be explored, combined or not with new functions for the car. But the electrical way now concentrates more R & D funding and produces more patents comparatively to other alternative solutions. Coalitions of actors and countries have become more powerful and their confrontation is stronger. But the coalition for the electric vehicle has taken a step ahead, making more expensive attempts to fill

the gap. Macroeconomic and political decisions to generalize a solution have been taken by some countries, but it is too early for many others. We will take the China case to illustrate our questioning method

2.1. *What has changed in the petrol car crisis are the degree of importance of the different processes that have caused it and the choice of energetic model by some countries*

The main processes pointed in 2009 were: trend of oil price to increase in the long run because peak oil, oil dependence of important countries for car market growth, opportunity for some emerging countries as China to become car manufacturers without having to catch up with traditional manufacturers, global warming and air pollution. Today the two last processes seem to be the main reasons for many people and big cities to accelerate the transition for cleaner vehicles. But the other processes have not disappeared and continue to develop, even if we talk about it less.

The intensity of petrol car crisis depends on the countries and explains their energy preference for the future. So, we are developing a composite index taking in account: car density for 1000 inhabitants, lost of time, traffic congestion, GDP lost, direct and indirect deaths, injuries and diseases, energy resources, oil dependency, gasoline price, automobile share in household budget, vehicle constrained use rate, local and global pollution, CO2 by inhabitant, climate warming and disasters, urban sprawl and specialisation of space, and so on. Data collection and harmonization are slow to achieve. But, temporarily, we can reason more qualitatively and distinguish three degree of crisis intensity by country based on oil dependence, population density, type of urbanisation: low for Russia for example, medium for USA and Brazil, high for EU countries, Japan, China, India, etc.

Our foreseeing method consists to examine for each country if the processes of the auto crisis have changed since 2012. Let's test on the China case.

1. Does the transfer of polluting industries outside metropolises, as London did in the 1950s, make it less urgent or even unnecessary the radical change in the motorization of vehicles? London case shows that is not enough. This metropolis is obliged since 2000's to restrict the use of petrol vehicles. The car density in Beijing and Shanghai is now at the same level.
2. Is the China dependence on hydrocarbons so serious? National oil production is declining trend. Oil imports account for 64.4% of total energy consumption in 2016. Car transportation accounts for 60% of hydrocarbon consumption. China does not control oil prices.
3. Can it carry out an imperial policy securing oil supplies, as did the United States with the Middle East and Latin America until the beginning of the XXI century? China tries to ensure supplies of some materials and foods, but China is not able to do the same for petrol.
4. Will "New Energy Vehicles" help to solve the respiratory crisis or increase it? Indeed electricity is mostly produced by the combustion of coal or hydrocarbons. But the share of renewable energies and the depollution of thermic power plants are rapidly increasing.

So the response for a possible fall of intensity of auto car crisis is rather negative, if there is no change of type of engine. So China still seems to fulfil the first condition for radical change.

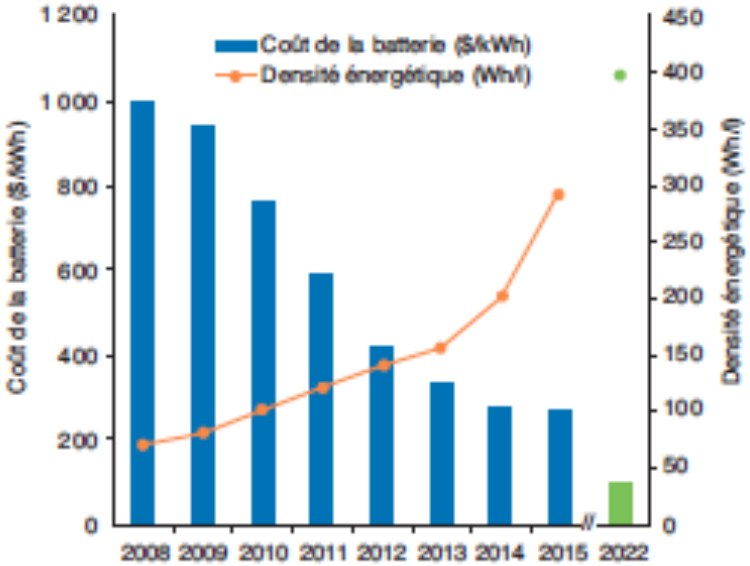
2.2. Is the technological and entrepreneurial effervescence, that is the second condition, is still observable?

As during the "first automobile revolution", expected and unexpected solutions are explored and tested: low-consumption combustion engine, natural gas, liquefied gas, biogas, flexfuel, hybrid, plug-in hybrid, electric battery (with autonomy extender or not), fuel cell (hydrogen liquid or solid), compressed air, solar cars, and so on. But since 2012, these solutions were unequally studied, supported and implemented, in general and in the different countries. As for the "first automobile revolution", some new industries joined automobile industry to think a new type vehicle. The main fact, from this point of view, is the grafting, more or less easy, of new functions on automobile vehicles: connection, driving automation and car sharing.

So a race for offering the most mature technology is in progress. In capitalist context, the aim is to force the others solutions to make more spending to catch up, is to increase the engineering outlay for the others.

Electric battery solution is taking an advance. The batteries autonomy and reliability increased more quickly and their prices have decreased more drastically than it was expected. The economies of scale have not been necessary until now to lower costs. The main manufacturers are working on the 1000 km battery

Fig. 5 – Progrès des batteries en termes de coût et de densité énergétique



Source : département de l'Énergie américain (DOE)

The technological and entrepreneurial effervescence in China is not so visible for us than in other countries, for administrative and media reasons. We know few ground researches about this topic. The main indication we have is the number of patents concerning Lithium-ion battery, for which China is the most productive country, but nothing about more promising solutions: sodium, graphen, etc.

Table 1. Leading countries in publication of scientific papers and patents for batteries lithium-ion for EV (1995-2015)

Country	Patents	Scientific articles
China	6.547	1.206
Japan	3.005	366
United States	2.193	1.361
South Korea	1.167	283
Germany	976	344
France	268	196
Taiwan	163	128
United Kingdom	104	143
Canada	41	142
Others	236	734

Source: Patent information systems Orbit and Analyze search results Scopus.

Lady Tatiana Bermudez Rodriguez, Flavia L. Consoni, " Scientific and technological trends of lithium-ion batteries for electric vehicle: insights from the application of bibliometric and patents analysis", Gerpisa

2.3 The third condition is the formation of economical, political, social actors coalitions to support the different solutions and the choice of a transition scenario

The level of oil reserve, population density and type of urbanisation, generally explain the energy preference of States for alternative cars, but with some interesting exceptions.
(table under construction)

racteristics	Crisis intensity degree	Oil low consumption (included hybrid)	Gas (GNV+GPL)	Biofuels Flexfuel	Electric (BEV + PHEV)	Fuel cell
Great oil reserve, low population density, concentred urbanisation	low	Iran, Iraq, Saudi Arabia Venezuela, Libya, Nigeria,	Russia, Algeria			
Medium oil reserve, low population density, extensive urbanisation	medium	USA Mexico		Brazil	California Norway	

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Little oil reserve, medium population density, concentred urbanisation	high				China Great Britain	
No oil reserve, medium population density, concentred urbanisation	high	Turkey			India Spain	
No oil reserve, high population density, concentred urbanisation	high		Italy	Sweden until 2010	France, Denmark Netherland, Belgium Sweden, Swiss, Austria,	Japan South Korea

For example: Japan, South Korea, Brazil, Norway, Italy … How can we explain these cases? The oil supply guaranteed by geopolitical alliances until now can explain Japan, and South Korea cases. Trust in supplying by countries producers: Russia and Libya for Italy, Irak for Turkey. Strong political coalition of public or private interests, as in Brazil, Mexico. Long-termism vision as Norway. The Norwegian politicians were able to anticipate the end of oil reserves and to preserve the resources for other uses. So, some aspects of high crisis or low crisis can be temporary overcome by geopolitical alliances, powerful coalitions for private interests or political vision.

Five years ago, we have proposed three scenarios for cleaner car and the conditions of possibility of each one. In the "diversity scenario", the countries don't prefer the same energies and the manufacturers produce all types of engine. In the "progressive scenario", countries and manufacturers prefer a slow transition from hybrid to fuel cell. In the "rupture scenario": countries and manufacturers choose the direct shift to EV.

Scenario		Diversity	Progressivity	Rupture
Characteristics		« Revolution » is carried out over a very long period, spreading out of R&D investments. States favor different energies : oil, agrofuel, electricity, hydrogen, etc. Manufacturers offer all the engines.	Progressive transition from the low power thermic engine to the electric motor, bathery and fuel cell.	Direct shift to EV (rechargeable, hybrid , electric cars) . Changing architrcture and automotive functions
Conditions de possibilité	Magnitude of the energy, environmental and geopolitical crisis.	Variable, depending on the country, given their resources, demographic and economic growth.	Slow rise of energy, environmental and geopolitical difficulties in most of countries.	Sufficient strong and durable. Demanding quick and mass solutions.
	Tecnological innovations	Equal in each of the technical channels	Transition to electric , technically, industrialy, and financially controlled, starting with high range and niche vehicles.	Effervescence, transfer of innovations from other sectors, starts-ups, notably in the production and storage of electricity
	Coalition	Different, depending on the energy geopolitics of the countries concerned	Formed by global manufactureres and the States of their country of origin.	Some countries, car makers and new entrants, seeking to seize the opportunity to become leaders.
	Macroeconomic and societal conditions.	At least one country with an important auto market, leader in each of the possible routes	Slowdow in the pace of growth rate of emerging countries and of their political wehigth.	Public aide for purchase in a first phase, penalization of the thermic engines. Progress in purchasing power.
Consequences		Plural revolution , intensity according countries. Markets heterogeneity.Sharp vestments rise .	« Revolution » taking place over a very long period, spreading out investments in R& D.	A thrilling « Revolution » diffusion by spots. But generaliisations spread over decades.

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But the recent confrontation of opposed coalitions (Dieselgate, Programmed end of ICE in China and India, etc.) has obliged the carmakers, that had adopted the "progressive scenario", to decide to accelerate and to produce quickly all types of powertrain in the same time. The "progressive scenario" is replaced by the "all at once scenario", that is finally become the same that the "diversity scenario" considered, not only between countries, but also in each country. Some researchers have objected that a " ICE resilience scenario" is possible. The alternative cars could remain only market niches.

Scenario		Diversity and « all at once »	Rupture	Resilience?
Characteristics		. States favor different energies: oil, LPG, agro-fuel, electricity, hydrogen, etc . The manufacturers offer all the requested engines.	. Direct shift to EV (rechargeable, hybrid , electric cars). . Changes on architrcture and automotive functions	Carmakers react and made substantial improvements in energy performance and ICE depollution. Alternative engines never competitive.
Conditions de possibilité	Magnitude of the enegy, enviromental and geopolitical crisis	Variable, depending on the country, given their resources, demographic and economic growth	Sufficiently strong and durable. Demanding rapid and mass solutions.	Average to low
	Technological innovations	Equal in each of the technical channels	Effervescence, transfer of innovations from other sectors, starts-ups, notably in the production and storage of electricity	Studies and investments concentrated on a new generation of ICE.
	Coalition	Different depending on the energy geopolitics of the countries concerned.	Some countries, car makers and new entrants, seeking to seize the opportunity to become leaders.	Strong lobbying of traditional car-makers on public authorities. Defeat of « ecologist ».
	Macroeconomic and societal conditions	At least one country with an important auto market , leader on each of the routes.	Public aid for purchase in a first phase, penalization of the thermic engines. Progress in purchasing power	Abandonment of aids for the purchase of alternative vehicles. Abandonment of restrictions on petrol cars.
Consequences		Plural revolution, intensity depending on the country, hetergeneous market. Strong investment increase	A thrilling « Revolution » diffusion by plates. But generaliisations spread over decades.	

To be possible, this scenario requires that the intensity of energy model crisis decreases, R & D investment in thermic engines should be significantly increased to achieve a drastic reduction of all gasoline pollutants, a strong lobbying of traditional carmakers on public authorities and the social and political defeat of "ecologist" movement, abandonment of alternative vehicles aids and of restrictions on their use.

The "dieselgate" shown that the auto producers had a lot of difficulties to reduce the emissions of pollutants of their vehicles and had preferred to use misleading software. The result was the decline of diesel cars sales and the necessity for car-producers to plan quickly EVs models. So the conditions of possibility of the "resilience scenario" seems not to be fulfil for the moment.

The coalitions for EV solution were the first formed in many countries. They are the most reactive and large and now the most powerful. The leadership to accelerate the diffusion of EVs has been taken by the major world metropolises and by some important countries as China for the development of car market and industry. They has just been spectacularly strengthened by the recent rallying of car builders, previously opposed to them: VW, Mercedes, Toyota, Honda, Hyundaï, Fiat, PSA, Suzuki, or reluctant as GM and Ford. They announce all a complete range of PHEV and EVs.

As all coalition, the EVs coalitions are temporary alignment of divergent interests and objectives. But, for the moment, the coalitions for other solutions are weakened by unfavourable conditions and are not able to create dissensions in EVs coalitions.

The current coalitions for different alternative vehicles
(table under construction)

	Oil low consumption ICE (included hybrid and E85)	Gas (GNV + GPL)	Biofuels Flexfuel	Electric (BEV + PHEV)	Hydrogen Fuel Cell
Public authorities, countries	Trump Administration	Italy	Brazil, Sweden until…	The majority of urban metropolises, Europe, China, India, Québec, California, Israel, Ireland, etc.	
Department	Armies, Transport	Transport	Transport	Health, Housing	Armies
carmakers	Toyota until 2013, Piech's VW	Fiat	- Brazilian subsidiaries of Fiat, VW, Chevrolet, – Ford, Volvo, Saab until…	Tesla, BYD, Bolloré, Mitsubishi, Nissan, Renault, BMW, Mercedes, VW, GM, Ford, VW, Toyota, Honda	Toyota, Honda, Hyundaï, BMW, Daimler
Suppliers			Magnetti Marelli	Continental, Valeo, Bosch General Electric, software industry, internet companies,	
Professional organisations					
Energy producers and suppliers	Some oil companies	Gazprom, Sonatrach,	Agrobusiness	Total, Shell All electric companies All batteries producers	Hydrogen producer (Air liquide)
Insurance, Banks				Maif	
Public research				CAR, IFPEN,	
International Organisations					
Agencies				ADEME, EAFO	
Favourable buyers	Transport companies		Brazilians ?	Delivery companies, Island inhabitants, car urban rentals, taxis fleets,	
media	Traditional automotive magazine				
"social networks"					
NGO	Automobile Clubs,	LowCVP,	LowCVP,	IEDC, ICCT, LowCVP, Transport&Environment (50 organisations),	

consortium				- Electrification Coalition: (2009) Nissan, FedEX, General Electric, Johnson Controls-Saft, Fisker, A123 systems, Ener 1, Coda Energy, - USABC (Chrysler, Ford, GM)	- Hydrogen Council (2017): previous carmakers +Air Liquide, Alstom, Anglo American,, ENGIE,, Kawasaki, Royal Dutch Shell, The Linde Group, Total, Plastic Omnium - JV JXTG Nippon Oil&Energy, Toyota to expand station network
Engineers associations and schools	SAE			SAE	

What can be the sustainability of the NEVs coalition in China? The Chinese State, many provinces and metropolitan areas have constantly reaffirmed and strengthened, plan by plan, their choice for NEVs, for three main reasons: pollution, oil dependency, will to became quickly automotive leader country. But investigative work has to be done on the process of drawing up plans and on their implementation by the actors concerned.

There are in China a "spontaneous" NEVs production and market of two and three wheelers and of low speed four wheelers. 25 millions of electric bicycles are sold each year. In 2016, 500.000 low speed electric personal vehicles and 2 millions of low speed electric commercial and agricultural vehicles were bought. This context and the actors of this context participate to the EVs coalition. Electric Kwid of Renault is destined to a part of this market.

Can a political upheaval, always possible, change the choices made so far, as in USA? Or are choices constrained in China to such an extent that they cannot be modified? For the moment, and subject to the investigations to be done, the coalition for NEVs seems reinforcing in China.

2.4. Macroeconomic and political decisions to generalize the chosen solution have been taken by some countries, but it is too early for many others

The fourth condition makes it possible to complete the construction of alternative vehicles market by:
- a constant distribution of a part of national income to large social groups to be able to continue to buy new cars
- a synchronisation of all it is necessary to use practically the new means of transport
- eventually, subsidies to help the purchase of the first alternative cars, necessary more expensive at the beginning, before that the economies of scale allows to decrease the cost of production

Is there a risk to create an artificial temporary EVs market? The petrol car market is also strongly subsidised! In France, it was 15 times more subsidized than the electric vehicle market in 2016. The OECD has estimated at $ 160 billions support for the thermal vehicle in OECD countries and some other major countries, in 2014 [7].

That said, State and local incentives and restrictions on ICE vehicles traffic are important to explain the differences of EV sales between countries during the last years. But, they are not enough to explain all the cases. For example, Germany has practically no subsidies and nevertheless the sales of EV are close to French sales which are subsidized to 20-25% of the purchase price.

China is one of the countries fulfilling the fourth condition … but not totally. There are uncertainties about the Chinese growth model by investments and the political capacity to change it in growth model by consumption. The subsidies policy for the purchase of electric vehicles is sometimes applied or modified by brutal administrative decisions that disrupt the market. Nevertheless, this not prevented the take-off of NEVs sales since 2014. 500.000 were bought in 2016. Sales took off while the price per liter of gasoline at the pump was halved and the prestige of conventional cars is always highest. The probable reason of the take off is simply the offer. The curves of sales and of number of models on the market are the same. We observe the same thing in Europe and USA.

The World that Changed the Machine

The most important of this work is the proposed method (that can be further perfected), more than the necessarily provisional conclusion on the future. Provisional because, if we have identified some social processes that lead to choice a particular technical solution, some others are certainly to include and can lead to a little different conclusion. But to respond strictly to the question about the future of automobile, we had to document at least the four conditions of possibility of a "second automobile revolution" in each country and world region.

At this point, the question of the universalization of a new type of powertrain, as petrol ICE in the past, is open. The following process can be imagined in the case of EVs:
- China and India market obliged the carmakers to invest massively in EV vehicles, by increasing minima of EV sales
- Fast curves crossing price/performance of EVs
- Fear of traditional car builders to lose their commercial and technical leadership
- The offer of full range of powertrains too expensive
- Competition by Chinese and Indian carmakers on American and European markets
- Increasing costs of petrol vehicles to respect anti-pollution standard. Stop of ICE renewal (as recently Diesel engine by Volvo)
- Fall of resale price of petrol vehicle
- and so on…

The previous process is possible in the case of "rupture scenario". But "the diversity scenario" remains still possible. We have to wait few more years to decide between these two scenarios.

The "possibility conditions method" allows us to test all the scenarios of the future that we can imagine, as we did for the "resilience scenario". It has shown that it is not necessarily the most technically or socially satisfactory solution that prevails. It is a contribution to the construction of a more general theory of technical change and innovation. A social science approach is absolutely necessary to overcome the technological determinism that is so frequently adopted. The future lasts a long time: against the impatience of contemporary analysts.

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