6.3.2 Hybridization and Electric Vehicles (2/2)

Author : *François Badin, IFPEN*

In this second part, we will focus on the different types of hybrid vehicles.

Hybrid drivetrain

Following the same principle, hybrid powertrains include a conventional thermal engine and a fuel tank, as previously, to which is associated an electric engine, and a battery with a limited size, to limit problems related to the cost of the on-board battery. Notice also that these vehicles do not require external charging of the battery, which also eliminates all constraints related to the vehicle charging infrastructure. However, these hybrid vehicles produce local pollutant emissions, due to the use of the thermal engine, as well as, to a lesser extent, noise emissions, also due to the use of the thermal engine.

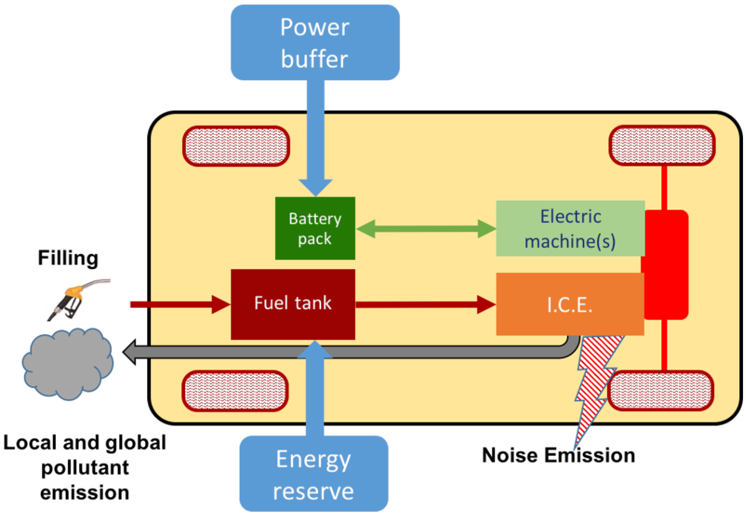

FIGURE 6.10 – Hybrid drivetrain vehicle

Note here that the functions have been separated. The energy reserve is still provided by the fuel tank, and the battery, limited in energy in this solution, is used as a power buffer instead of a power and energy reserve as in the all-electric vehicle.
This hybrid powertrain enables us to seek to achieve synergy between the two engines, electric and thermal, as well as to optimize more or less extensively the performance of the thermal engine, notably with the stop-start system, i.e. engine shutdown at idle, the help provided to the thermal engine by the electric engine, or boost mode, and to a lesser extent, the possibility to drive the vehicle over short distances without using the thermal engine, in all-electric mode. Besides, this system also enables the vehicle to recover energy from braking, like electric vehicles.
As we just saw, hybridization significantly improves the operating conditions of the thermal engine. This is shown on the two diagrams of Figure 6.11, where we see the operating range of a thermal engine in a hybrid vehicle, for urban and extra-urban use, and we see that in both cases the hybrid system maintains the thermal engine

around its maximum efficiency area, i.e. it notably lowers fuel consumption in urban use, and all the low-efficiency use phases of the thermal engine, specific to urban use, have been replaced by all-electric use phases. The consumption gain is therefore very significant in urban areas, thanks to the hybridization of the thermal engine.

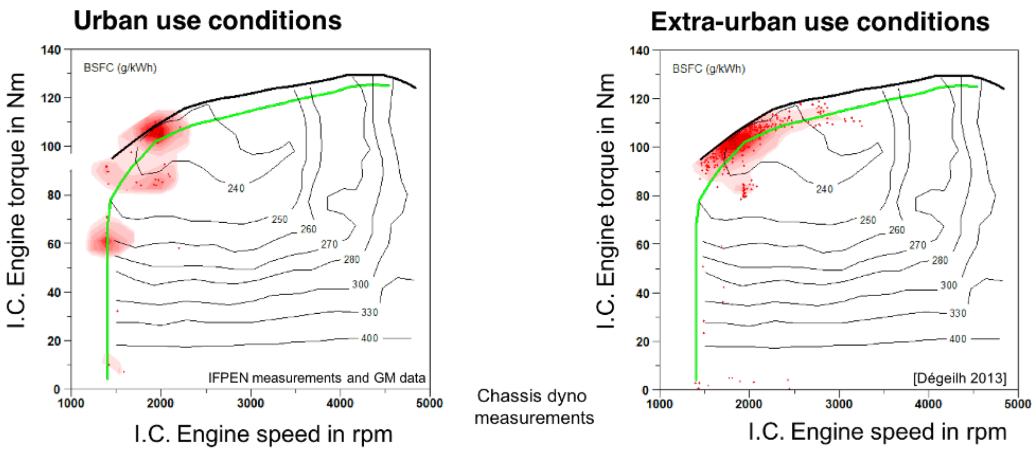

FIGURE 6.11 – Example of I.C. Engine operating region

Plug-in hybrid drivetrain

Intermediate all electric capacities between all electric vehicles and hybrid vehicles ones An evolution of hybridization consists in using a battery with an energy content intermediate between that of a hybrid vehicle and of an all-electric vehicle, as is in Figure 6.12.

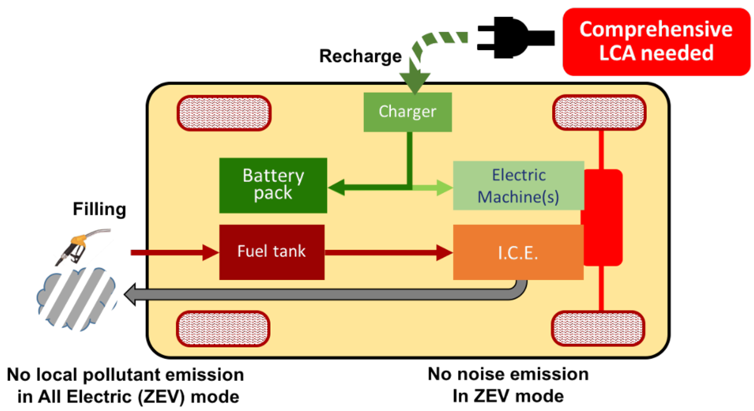

FIGURE 6.12 – Plug-in hybrid vehicle drivetrain

This brings two notable advantages, firstly, the vehicle can be used with significant electric ranges, from 20 to 60 kilometers, and secondly, the capacity of the on-board battery is sufficient for it to be recharged, as shown here, and the result is a rechargeable hybrid vehicle, characterized in that it uses two energy vectors, a hydrocarbon, and electricity. Therefore, this vehicle, like all-electric vehicles, requires a total life-cycle analysis taking into account the production of the required electric energy.

The advantages of this rechargeable hybrid vehicle are of course the same as those of hybrid vehicles, plus the extended all-electric mode, and the possibility to recharge the battery using the network.

A large variety of solutions Let us look at the solutions devised by manufacturers for the all-electric range of their rechargeable hybrid vehicles. On the diagram (Figure 6.13), that shows the dynamic power and the range of the vehicle, are represented various solutions implemented by manufacturers, and you can see that between Toyota's 2012 solution, which is the most restrictive, and BMW's on its i3 with its range extender, there are huge differences in the range that can be covered and in the dynamics of the vehicle in this all-electric mode.

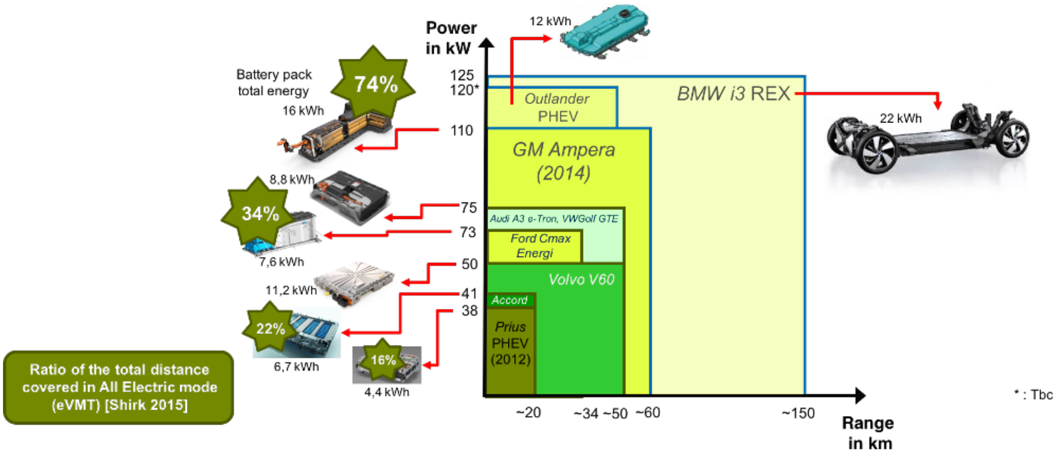

FIGURE 6.13 – All electric mode performances

High sensitivity of fuel consumption to vehicle use conditions Another particularity of hybrid vehicles is their consumption of two types of energy vectors. The overall consumption is a balance of these consumptions, and this balance depends heavily on the distance over which the vehicle is used between two recharges. As shown on diagram 6.14, , at the start, when the battery is full, the energy used is mostly electric, and as the distance between two recharges increases, more and more fuel is used, there is a transfer to the energy from the fuel.

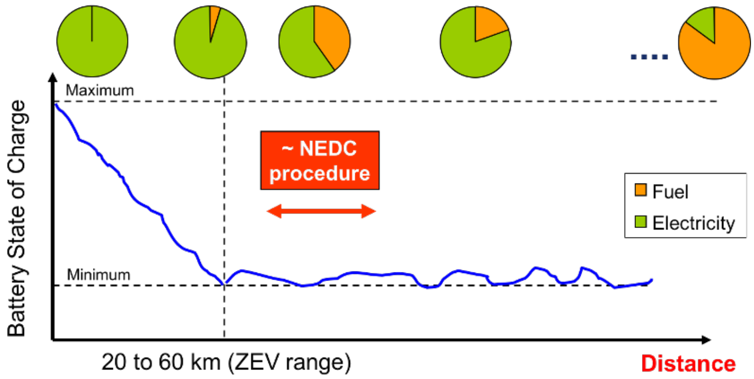

FIGURE 6.14 – Illustration of the variation in the ratio fuel consumption vs electricity consumption according to the distance covered between two battery charges

The current European Standard, although it will change very soon, places this shared consumption approximately at the center of Figure 6.14, and remarkably, in the statements of the manufacturers, you may have a rechargeable hybrid, such as this very large BMW sedan, which features a powerful 240 kW engine, and which, according to the standard, has a consumption of 2.5l/100km, reflective of this split between electricity and fuel. We can well imagine that this vehicle, when driven hundreds of kilometers without recharging the battery, has a consumption around 6 to 8l/100km, very different from the 2.5l/100km which corresponds to this vehicle's standardized test.

Synthesis of the main hybridization solutions

As we said earlier, we see on diagram 6.15 that hybrid engines represent a continuum of solutions, that bridge the gap between the conventional vehicle on one side, and the all-electric vehicle on the other side, with an increasing number of features, from the simplest vehicle with a stop-start system, to the most complex vehicle, closest to the electric vehicle, the range extender vehicle, such as the BMW i3.

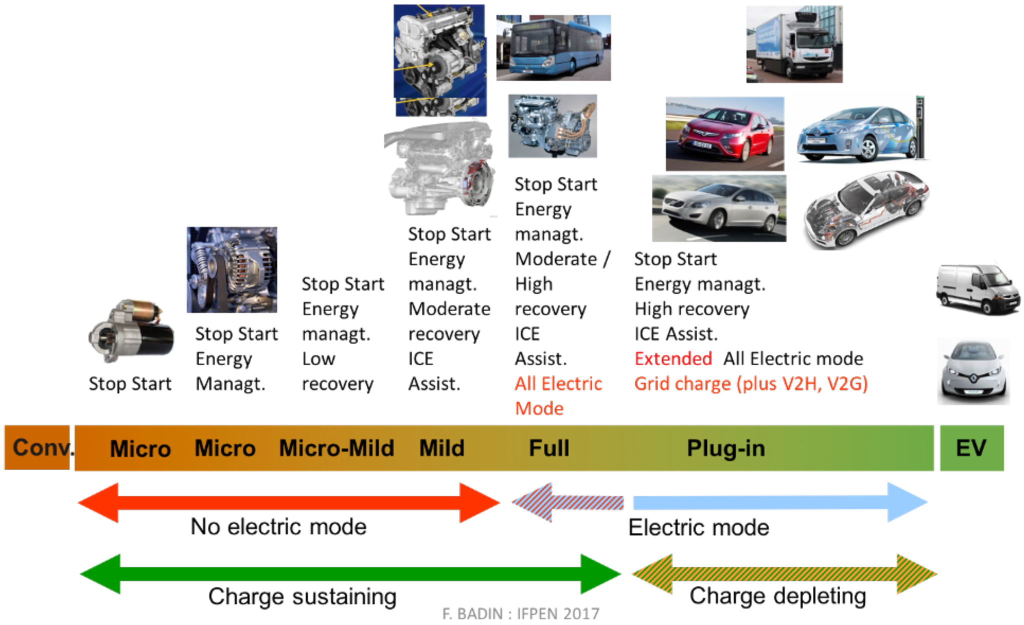

FIGURE 6.15 – Synthesis of the main hybridization solutions

Evolution of the Electrified vehicle market (EVs and PHEVs) Figure 6.16 gives the sales of electric and rechargeable hybrid vehicles in several countries over the last 6 years.

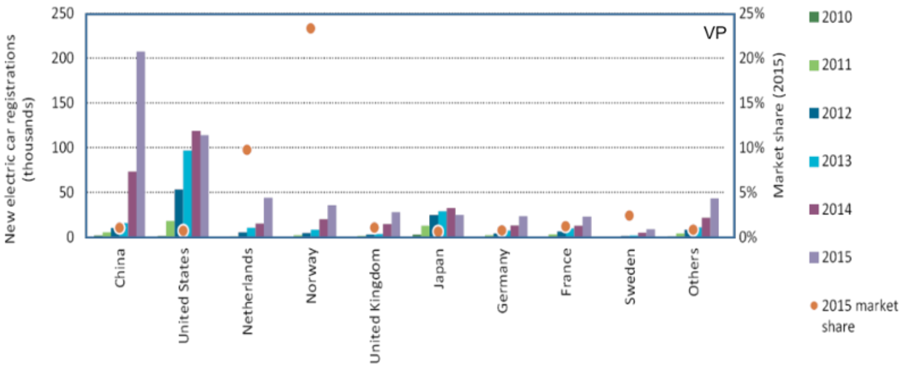

FIGURE 6.16 – Evolution of the Electrified vehicle market (EVs and PHEVs) (2015) - Source : IEA, Global EV Outlook 2016

We can see several things, first the increasing share of China among these countries, and we see that China has taken the lead for vehicle sales, with an extremely high growth rate and sales now greater than those of the United States.
Second interesting point, on the right axis of the chart, we see that for most countries, market penetration is around 1%, or slightly over 1%, except for two countries, Netherlands and Norway, two countries that do not have local manufacturers, and that have huge vehicle import taxes, and through these taxes, the governments manage to promote the purchase of these vehicles by significantly correcting the price differences. As you can see, this leads to significant differences in the penetration

rate of these vehicles in these countries, which are artificially due to a change of the huge import taxes on these vehicles.

Annual light-duty vehicles sales predictions Let us now look at future perspectives (Figure 6.17). Here we have sale volumes for several engine types until 2050, and we see that conventional vehicles tend to gradually disappear.

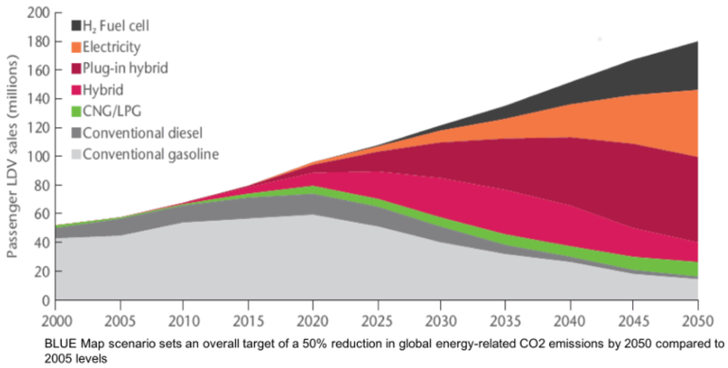

FIGURE 6.17 – Annual light-duty vehicles sales predictions - Source : IEA, 2011

In the lead we have hybrid vehicles, then gradually plug-in hybrids, and finally all-electric vehicles, and as a complement hydrogen fuel cell vehicles.

Conclusion

As a conclusion on these electric vehicles, note that we see a great number of technological solutions, and as we said there is a continuum of solutions that will enable us to switch gradually from conventional vehicles to all-electric vehicles, then one day to fuel cell vehicles.
There will be a range of solutions available on the market, and buyers will have to choose their solution, mostly based on how they will use their vehicle.
One last thing to note, for all vehicles that will use energy networks based on electricity and hydrogen, their development in the market will need to go hand in hand with the development of the electricity infrastructure and of the hydrogen distribution infrastructure required by these vehicles.