6.3 Hybridization and Electric Vehicles

6.3.1 Hybridization and Electric Vehicles (1/2)

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In this first part we will discuss vehicle electrification, and more specifically the case of electric vehicles.

Vehicle drivetrain system choice

What type of drivetrain ? Vehicle powertrains can be summarized as follows : first of all, energy storage is required on board, then an energy transformer, that ensures the production of mechanical energy, necessary to the motion of the vehicle. If we now consider a conventional engine (Figure 6.3), first we have a fuel tank, which provides the energy reserve required for motion, for the range of the vehicle, then a thermal engine that produces mechanical energy, that provides the power necessary for the dynamics of the vehicle. Recharging the energy is done very simply, as the storage system is an open tank, it is simply filled with fuel to recharge the vehicle and recover its full range. This system has the disadvantage of emitting local nuisance, notably pollutant exhaust emissions, and sound emissions due to the operation of the thermal engine.

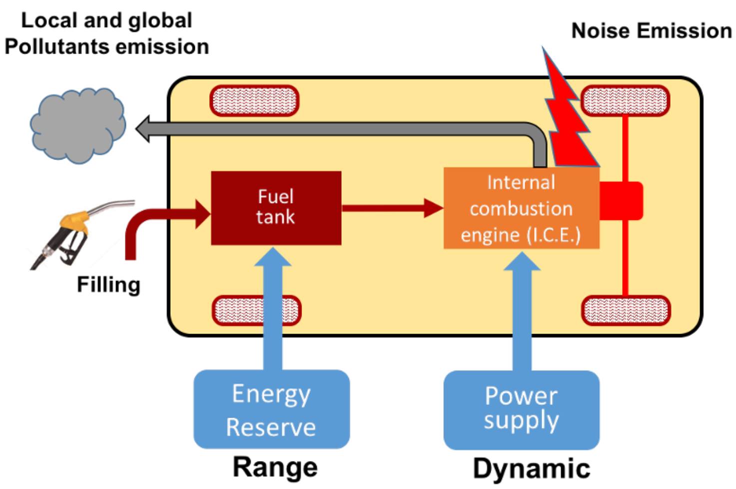

FIGURE 6.3 – Conventional drivetrain vehicle

If we now consider an electric vehicle (Figure 6.4), according to the same principle, on-board energy storage is provided by a battery, with the particularity that the battery provides both the storage of energy and the supply of power. It powers an electric machine, which provides the mechanical energy required by the wheels. Note that this system is reversible, energy can be recovered from the braking of the vehicle. This vehicle has the advantage of emitting no local pollutants, and only extremely low noise levels in urban use. Recharging the vehicle is done differently, the battery is a closed system, and the recharging system consists of an electric charger that reinjects power into the battery during recharge. Taking into account the balance of this vehicle then requires a total life-cycle approach, since there is production of electricity, therefore decentralization of pollutant emission to where the electricity is produced.

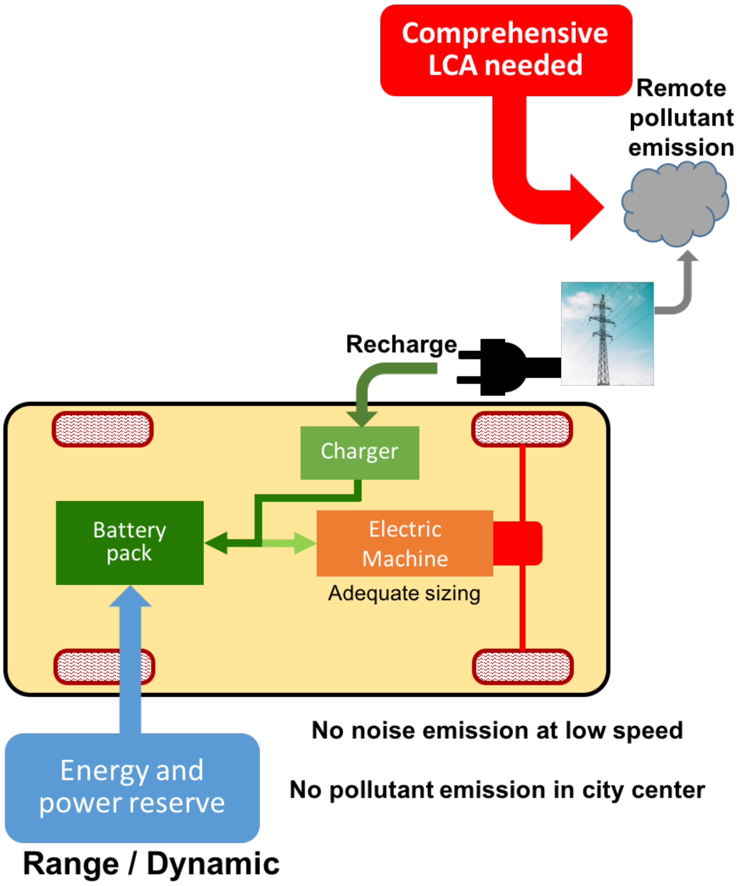

FIGURE 6.4 – Electric drivetrain vehicle

Issues regarding on board energy storage Let us now compare thermal and electric vehicles in terms of on-board energy (Figure 6.5). We have on this synthetic diagram first a conventional thermal vehicle, with a 45-liter tank, and we see that the range of this vehicle is approximately 1 000 km, and a very interesting factor, a very short recharging time, since the fuel pump hose represents a power of approximately 1 megawatt, and you see that in a few minutes, 2-4 minutes, the conventional vehicle can be fully recharged.

Characteristics		Conventional vehicle	Urban/ Suburban EV type	Sport / premium EV type
Fuel tank capacity	L	42		
Storage mass	Kg	~35	~310	~620
Total energy	kWh	400	~40 [1]	~81 [1]
Usable mechanical energy	kWh	~60 [2]	~32 [3]	~65 [3]
In use range	Km	~900	~320	~400
Charge duration (> 5 MW)	min	~4		
Charge duration @ 3.7 kW	h		~10	~20
Charge duration @ 7 kW	h		~4.5 [4]	~10 [4]
Charge duration @ 22 kW	h		~1.5 [4]	~3 [4]
		~65 kW, ~1000 kg	~65 kW, ~1500 kg Main vehicle characteristics	> 250 kW, > 2000 kg

1 : Pack energy density estimation : ~130 Wh/kg
2 : Average ICE efficiency estimation: 15%,
3 : Average El drivetrain efficiency estimation : 90%, SOC range estimation 90%
4 : Charge at 80% SOC

FIGURE 6.5 – Some elements of comparison

For both electric vehicles shown to the right in Figure 6.5, you see that the storage masses are larger, however the ranges are much lower, and an aggravating factor, recharging time is much longer, as it is linked to the power available from the network, and we see that we can increase this power, but this comes with many problems concerning the electric network and the cost of recharging. We see that recharging electric vehicles takes approximately one hour, compared to a few minutes for thermal vehicles.

Example of the Renault Zoé Taking a closer look at an electric vehicle, here we have the Renault Zoé, produced by Renault, which has the particularity of having been designed from the start as an electric vehicle, with a battery highly integrated into the vehicle body, an electric machine designed and produced by Renault, and battery assembly also carried out by Renault. It is interesting to note that the performances of this vehicle are constantly improving, as you can see, year to year, the energy content of the battery has increased, thus increasing the range, which is now 300 km in real use, with perspectives beyond 2020 of ranges over 400 km. It is currently the best-selling vehicle in France and in Europe.

Range and power consumption and regenerative braking

EVs energy consumption influencing factors It is important to note that for electric vehicles, range and power consumption, which are directly linked, are closely linked to the use made of the vehicle. Diagram 6.6 shows various cycles of use, listed by average speed in increasing order. We see that power consumption, and therefore range, have an optimum for speeds around 20-30 km/h, then deteriorate significantly at high speeds, due to many losses, of aerodynamic notably. They also degrade at low speeds, at which transmission losses occur, notably via the auxiliaries.

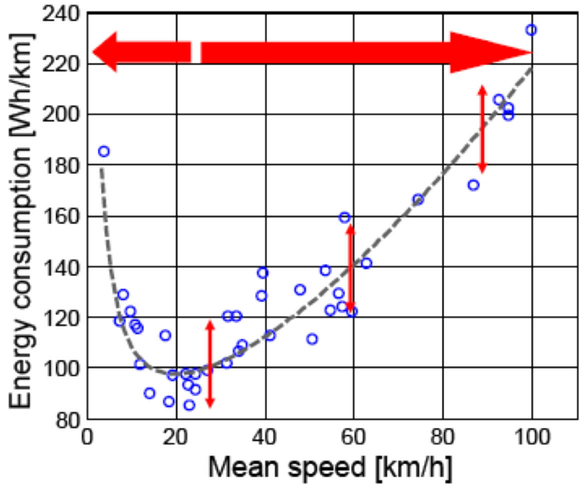

FIGURE 6.6 – Influence of EV operating conditions

Another point to note is the consumption of the auxiliaries, that must notably provide electric vehicles with heat for the heating system, and with cold for the air conditioning. We see on diagram 6.7, with the same axes as previously, the importance of the power absorbed by this on-board network, which can lead to range losses of 15 to 40% in urban driving, which is significant.

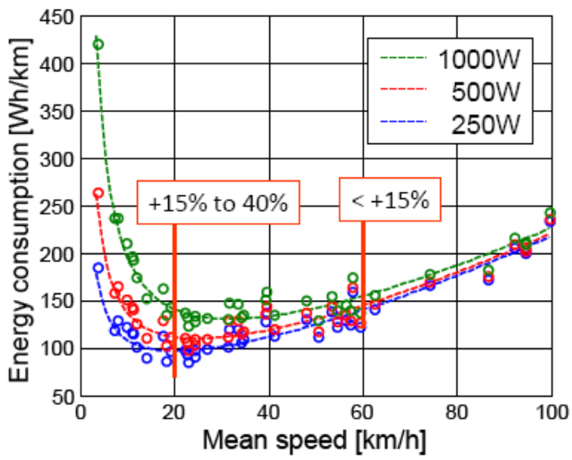

FIGURE 6.7 – Influence EV auxiliaries consumption

Braking energy recovery influence on EV range An important particularity of electric engines is regenerative braking. Diagram 6.8 shows the distribution of the energies corresponding to the forces that apply to a vehicle driving on a level road. There are two main dissipative forces, linked to aerodynamics and rolling, and a potential force that we try to recover during braking. You can see that in urban use the corresponding energy represents more than half of the energy required for motion. This is not the case in motorway use where aerodynamic losses predominate, and potential recovery is negligible, around 15%.

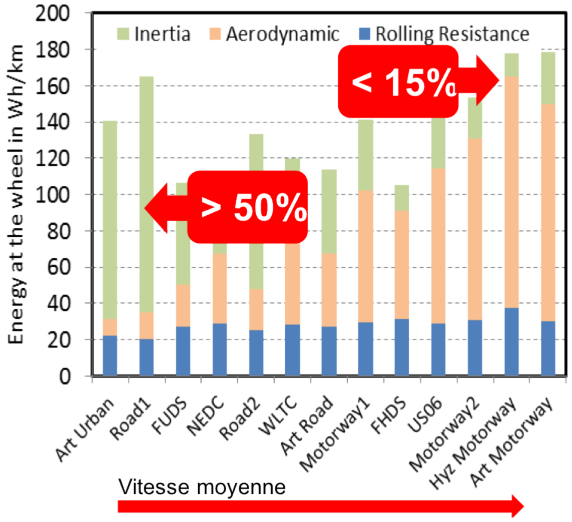

FIGURE 6.8 – Influence of vehicle use on recoverable energy potential - Source : EAFO, European Alternative Fuels Observatory

When we look at the influence of energy recovery during braking still as a function of use types (Figure 6.9), as shown here to the right, we see that it is very important in urban use, with gains up to 30-50% from the energy recovered during braking, and that as we said earlier its impact is lower for road or motorway cycles.

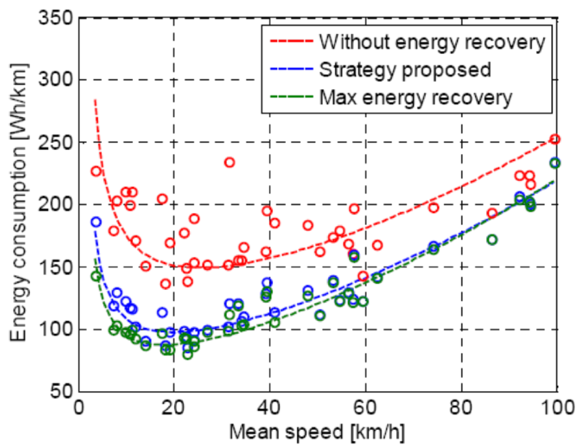

FIGURE 6.9 – Influence of braking energy recovery on energy consumption - Source : EAFO, European Alternative Fuels Observatory

The issue that we saw about the electric vehicle is essentially linked to the size of the battery that is required on board to ensure maximum range, which remains low and entails significant battery costs.
In the next part we will study hybrid powertrains, that we will present as a solution enabling the vehicle to retain all its capabilities, while eliminating, or avoiding as much as possible, the issue of the battery and of the cost linked to the battery on board the vehicle.