Light and Ultralight electric vehicles

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Today electrical vehicles are again considered seriously. However, one is not yet used to their performance. An overview is given in what one can expect from electric vehicles, ranging from electric bicycles to the electrical SUV.

Special attention is given to the possibility of ultralight electric cars and the elbev concept, "Ecologic Low Budget Electric Vehicle". Together with high efficiency power plants, a CO_2 emissions of about 10gr/km could be obtained.

***Index Terms*—Electric, Vehicle, Ecologic, Environmental Factors, Power conversion**

I. Introduction

First a historical note is given. In the beginning of private transport, the electricity was in competition with fuel powered vehicles. For example, the first car that reached more than 100km/h was electric, it reached 105km/h at Achères in the south of Paris (Fig.1)[1]. It was a Belgian, named Camille Jenatzy in 1899. His car got its name as it was a bit capricious :"La Jamais Contente". It had two independent motors on the rear wheels. It had no mechanical brakes, but did brake while reversing the two direct drive 25kW motors. He also made other vehicles like a beer truck, which made the distance Wieze to Brussels (32km) at 5km/h (Fig 2)[2]. It was mainly intended for advertising.
Also in 1899-1904 there was an electric tramway on batteries in Ghent "de accutram"[3].

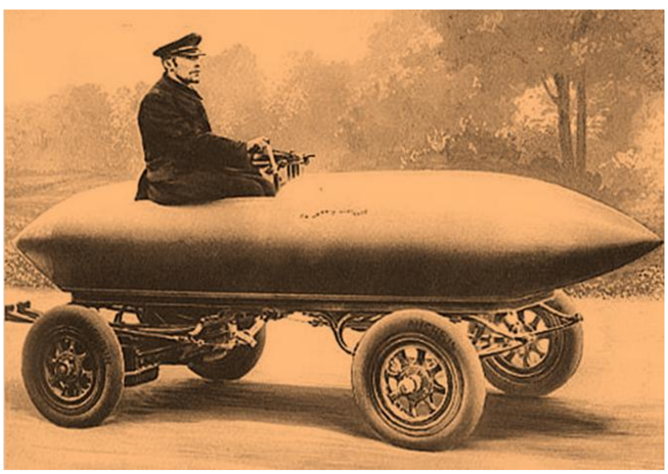

Fig 1. "La Jamais Contente", [1], 1899 Camille Jenatzy first 105.88km/h , electric, 1450kg where the batteries are 50%., 50kW in two motors.
100 cells of Lead-acid batteries. "

II. Mechanical needs

The load of the vehicle is mainly tire friction and aerodynamic friction. The braking of kinetic energy and the potential energy going downhill could be recovered. This could be in a mechanical, electrical or using compressed air. The recovery of kinetic energy recovery system "KERS" was common in formula 1. [4]

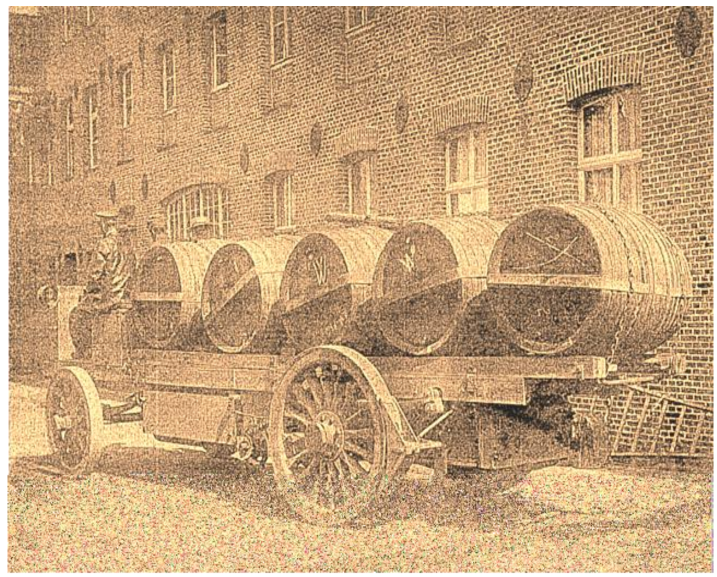

Fig 2. "Beer truck" Wieze, about 1905, Camille Jenatzy. [2]

Also keeping the motor running at standstill is not very useful, and the worst this is that we got used to it.
So, the real mechanical losses may be the tire friction and the aerodynamic friction, which is quite independent of the drive system. Very different results can be found depending on the vehicle. In the car also 300W auxiliaries have been considered. Table 1 shows a few parameters for diverse vehicles. The tire friction in competition vehicles like Energy 5 is very low (Fig 5), but the lifetime of those tires is also too short for a common use. The tire friction loss is much dependent on the weight of the vehicle. The air friction cross section area is definitely lower for single person vehicles. Electric cars can better finish also the bottom side of the vehicle, which results in lower air friction.
We see that a car, *Wc* , needs a lot of mechanical energy (Fig3), but we will see that the mechanical required energy is still low compared to the fuel consumption.
A bike, *Wb* (electric or not) is OK, but due to the bad drag coefficient, it performs not so well at high speed.
The proposed elbev, *WL* (ecologic, low budget electric vehicle) performs well, but not so good as the human powered

Wq. Indeed, in human powered vehicles, important efforts were done to reduce weight. But it is a compromise with safety.

TABLE I
PARAMETERS OF VARIOUS VEHICLES

type	curve	M [kg] Curb + use	Fc [./.]	S [m^2]	Cx
Car (Brava)	Wc	1200+100	0.008	2	0.3
E-bike	Wb	25+85	0.006	0.5	0.8
Quest	Wq	39+85	0.005	0.47	0.22
Energy5	We	60+55	0.002	0.254	0.136
Elbev	WL	100+100	0.008	0.3	0.4

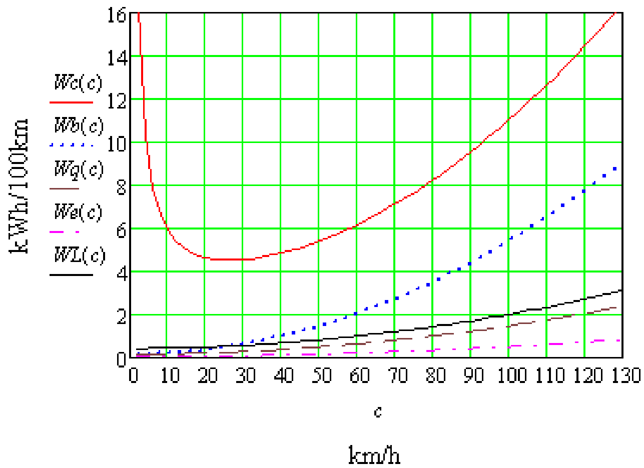

Fig. 3: Mechanical energy needs depending on speed for various vehicles.

One can verify that a car of 1300kg (driver included) keeps a constant speed at 20m/s (72km/h) at a slope of 1.8%. This corresponds to 6.38 kWh/100km, which is almost on the curve, this test was done at a concrete road surface and no wind, and tires inflated at 2.6 bar

Fig. 4: Mango "quest" human powered vehicle type "velomobiel" (*Wq*) [5]

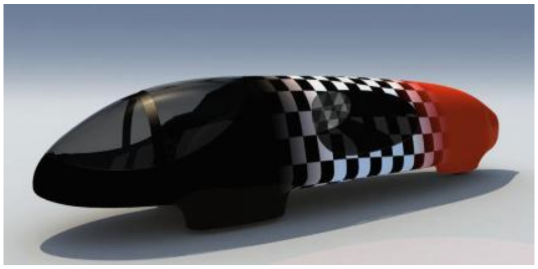

Fig. 5: Energy 5, design for eco marathon competition on electricity (*We*) [6]

The best are the eco marathon designs *We*., but they are not safe in traffic and are made for persons of 55kg.

Table II gives an impression of what we consider as light and ultralight. It is clear that non covered vehicles attain easier a low weight, but the diver is directly exposed to climate, and the air friction is high.

TABLE II
SOME IDEA OF LIGHT AND ULTRALIGHT VEHICLES

	Ultralight [kg/person]	Light [kg/person]	Normal [kg/person]
Elektric bike Weight/person	<20	<25	30
Non-covered 3-4 wheel Electric vehicle	<60	<120	200
Covered 3-4 wheel	<100	<200	300

III. "ELBEV" ECOLOGIC LOW BUDGET ELECTRIC VEHICLE

The idea was that a big part of the mechanic needs in short distances in the city is due to the tire friction. This can be lowered by lowering the weight of the vehicle. Also if the cross section can be reduced, the aerodynamic friction can be reduced. Also the battery weight reduces if the total weight reduces.

So the compromise was to design a single person electric vehicle. But a lot of people use a car with a single person in it for commuting. And a single person vehicle is always 100% filled…

The actual state of the art allows making electric motors of high power to weight ratio. Also batteries of the Lithium family allow a high energy/weight ratio. But if a similar effort is done for the mechanics, very light vehicles can be made. A reasonable compromise with safety can be obtained while putting the chassis at the side, not at the bottom.

The target specifications of the "elbev" are:

- Single person (for the moment)

Curb weight 80-100 kg

Three wheel: two driven front wheels, one back

Max Speed range 70-80km/h

Gradability >=20%
Acceleration: about 0-50km/h 8 seconds
Consumption country side 2kWh/100km
Consumption city 3kWh/100km
Battery type (Li-Mn or Li-PO4)
Battery Voltage about 100V
Intended drive: front wheel 2x4kW peak , 2x 1.5kW average motor weight 1.55kg/motor, a special designed gear.
Elements as safety, avoiding 12V battery….

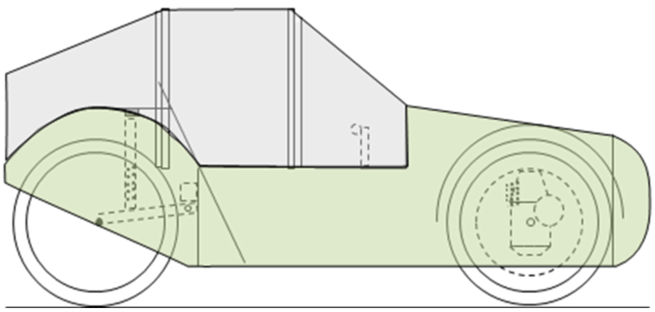

Fig. 6: elbev, side impression

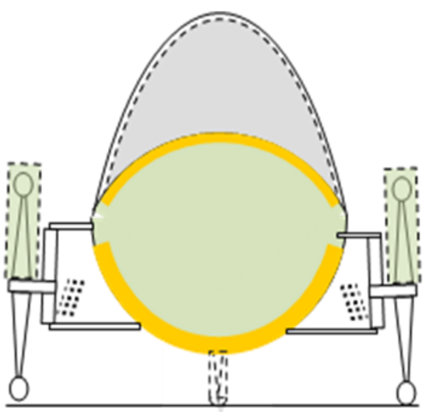

Fig. 7: Elbev, front impression, cross section.

In ultralight vehicles, every component should have two or more functions. The chassis must be at the side for side impact protection. The heat losses of the converter are used for heating. Thermal insulation also active for acoustics and may be for seating comfort. If two options are possible, the lightest should be chosen.
The vehicle is not too low for traffic safety (to see and be seen) and not too high for side wind sensitivity.
The "egg" form allows reducing the front area.
The yellow lines are the damping and thermal insulation inside.

In the electric vehicles a whole range between 1 and 25 is observed.

This is much wider than in conventional fuel vehicles as from motorbike (2-3Litres/100km) to an SUV 9 l/100km there is only a factor 4.

Fig. 8: electric mini-bike (23kg), [7]

Fig. 8: electric covered light vehicle (Ducati Free Dug, 240kg) [8]

Table III gives an overview of expected energy consumption for various electric vehicles.

TABLE III
COMPARISON OF WEIGHT AND CONSUMPTION

	kWh/100km At wall plug	Curb weight kg
Elektric bike	1 (+0.5 human)	20…30kg
elbev	2-3 (3 city)	80…100
Light high efficiency 4 person	10	800
Normal With high efficiency drive	15	1300
Heavy Normal efficiency	20	1800
Electric SUV	25	>2000

IV. EFFICIENCY OF CONVENTIONAL ENGINES

Usually one takes an efficiency for combustion engines in cars, of 35% for diesel, 30% for gasoline. However, these are maximal values

Practically, in actual good cars, (air + tire friction)/fuel, we get 12% for a diesel, (5liter/100km,1.8% equivalent slope, 1250kg) and 10% for gasoline (6 liter/100km, 1.8% equivalent slope, 1150kg).

But we can also discuss the "mobility efficiency". This is the efficiency x useful weight/total weight

For one person in a car one gets 0.96% diesel, 0.87% gasoline so typical <1%. From the engineering point of view, these figures are not to be proud of.

V. EFFICIENCY OF ELECTRIC VEHICLES

One can estimate the maximum efficiency of charger, battery, converter, motor= 95x90x96x90 = 74%

Practically, in real conditions 50% in high efficiency drives, <40% in average efficiency.

Some reasons are:

- Driving at very low speed on hills.
- The no load losses of the electric motor is not negligible compared to the friction
- The efficiency in acceleration and braking is also much lower than optimal..

Mobility efficiency:

For a normal vehicle for 50% and 100kg useful on total 1400kg total results in 3.57%

Ultralight: for 60% and 100kg useful on 200kg total results in 30%.

So an important improvement can be done if high efficiency electric vehicles are used, but even more if light electric vehicles are designed. Our today mobility has a very low efficiency if the motion of the real useful weight is considered compared to the energy in the consumed fuel.

Even if one considers that electricity is partly made by fossil fuel, the difference still remains.

VI. RENEWABLE AND GREEN HOUSE GAS ASPECTS

A yearly distance of ten thousand km at 3kWh/100km (city) corresponds to 300kWh. This is what 3m ^{2} photovoltaic panel can produce in the same year, even in the Belgian climate. But probably one will not store it over a half year, so still fossil fuels will be needed. One often takes an equivalent of 40% efficiency to recalculate to primary energy. In that case it corresponds to about 0.75 liter/100km, The CO2 production of one liter of gasoil is 2.36 kg of CO_2, or 17.7 gr CO_2/100km. However, today an electric efficiency of 70-80% could be reached using SOFC-GT (solid oxide fuel cells power plants with turbine) [7]. This technology is not practical to be on board of vehicles, but in can be used in medium size and large size power plants, the listed efficiency is not for today, but today a large penetration of electric vehicles is also not a fact today. But in that case, the equivalent CO_2 may be in the order of 10 gr/km. Today combined cycle gas power plants are installed with an efficiency between 55 and 60%, which is also significantly more than 40%.

We see that the resources of natural gas may last longer than petrol. So, it is probably better to convert first natural gas to electricity than compressing natural gas in vehicle tanks. Compressing gas takes also some 10% electrical energy. This electric energy is amply sufficient to drive an ultralight electric car.

VII. CONCLUSION

Electric vehicles use much less energy than comparable combustion engines. But light and ultralight do much better. The combination of solar cells or ultrahigh efficiency power plants could result in a very low CO_2 /km rating close to an indirect emission of 10gr/100km in variable traffic.

ACKNOWLEDGMENT

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