L16a) Motors: a hybrid biofuel – electricity car. Viable?

Advanced School on the Present and Future of Bioenergy

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October 13, 2014

Summary

1. Hybrid vehicles and their role
2. Hybrid ethanol-electricity vehicles
3. Hybrid biodiesel-electricity vehicles
4. Where is the focus?
5. Concluding remarks

1. Hybrid vehicles and their role

Hybrid vehicle: the power can come from (at least) two different energy storages: chemical energy from fuels, electric energy from batteries, compressed air, kinetic energy stored, etc.

Hybrid electric vehicles (HEV): mechanical power to move the vehicle can go from an electric motor or an internal combustion engine, or both. The electric energy (even if stored in batteries) comes from an onboard electric generator moved by the internal combustion engine.

The concept can be adopted not only for passenger cars, but also by trucks and buses. It is very common for rail transport!

1. Hybrid vehicles and their role

Rail transport: diesel-electric hybrids
The movement of the wheels comes from electric motors; the electricity is generated by a diesel engine

1. Hybrid vehicles and their role

HEV for passenger cars:

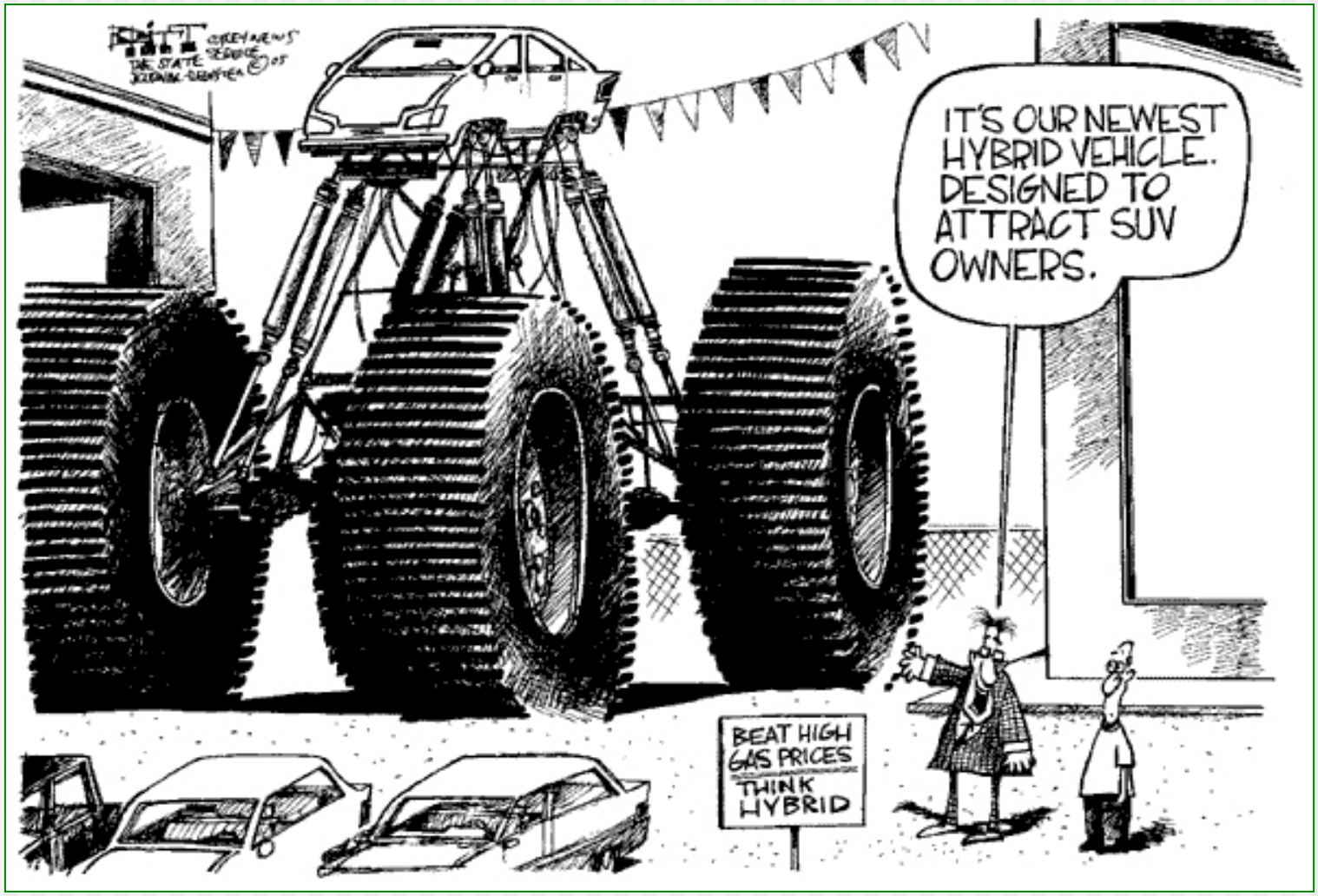
Advantages

- **Extended range, similar to gasoline engines**
- **Reduced pollutants emissions (transient operation of the internal combustion engine)**
- **Reduced CO2 emissions (more km/l)**
- **Can adopt an optimized engine and/or new technologies**
- **Can take electricity from the grid**

Disadvantages:

- **Vehicle weight and cost**
- **Complexity (maintenance)**
- **Trends → reproduce traditional designs**

1. Hybrid vehicles and their role



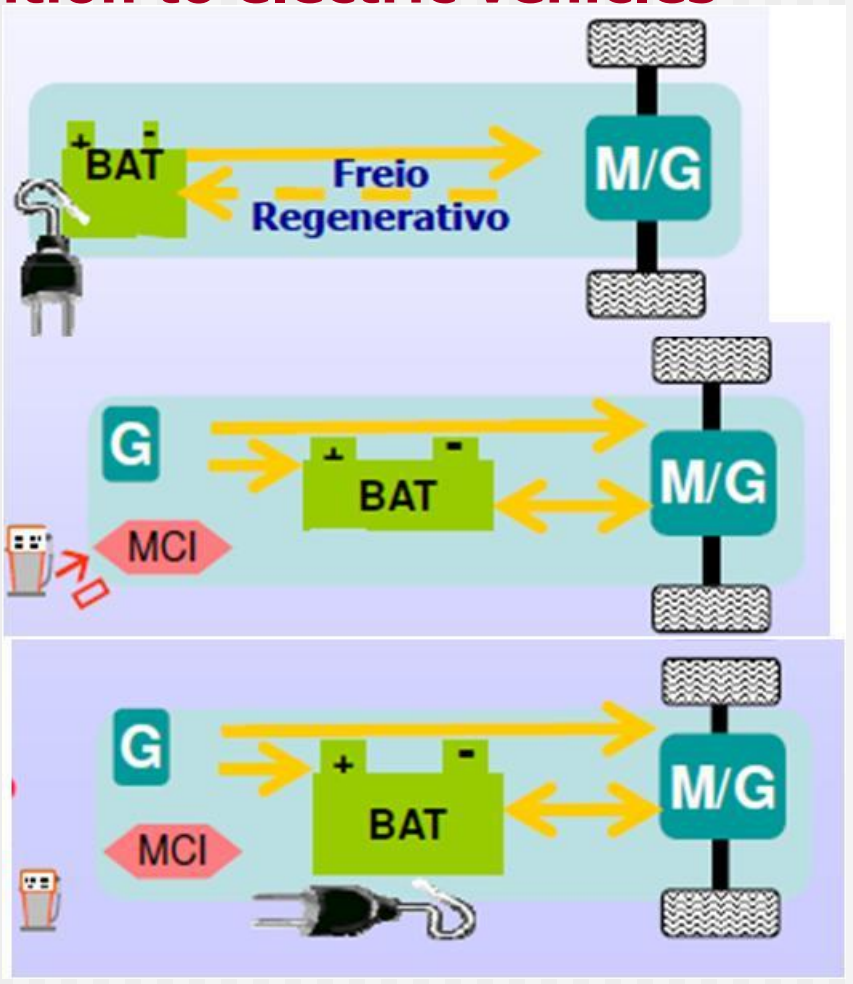
1. Hybrid vehicles and their role

Hybrid electric vehicles: transition to electric vehicles

Electric vehicle: the electric energy from batteries; low range; needs connection to the grid for recharge.

Hybrid electric vehicles (HEV): Fuel engine produces electricity and excess electricity can be stored in batteries. High range

Plug-in Hybrid electric vehicles (PHEV): Batteries can also be connected to the grid



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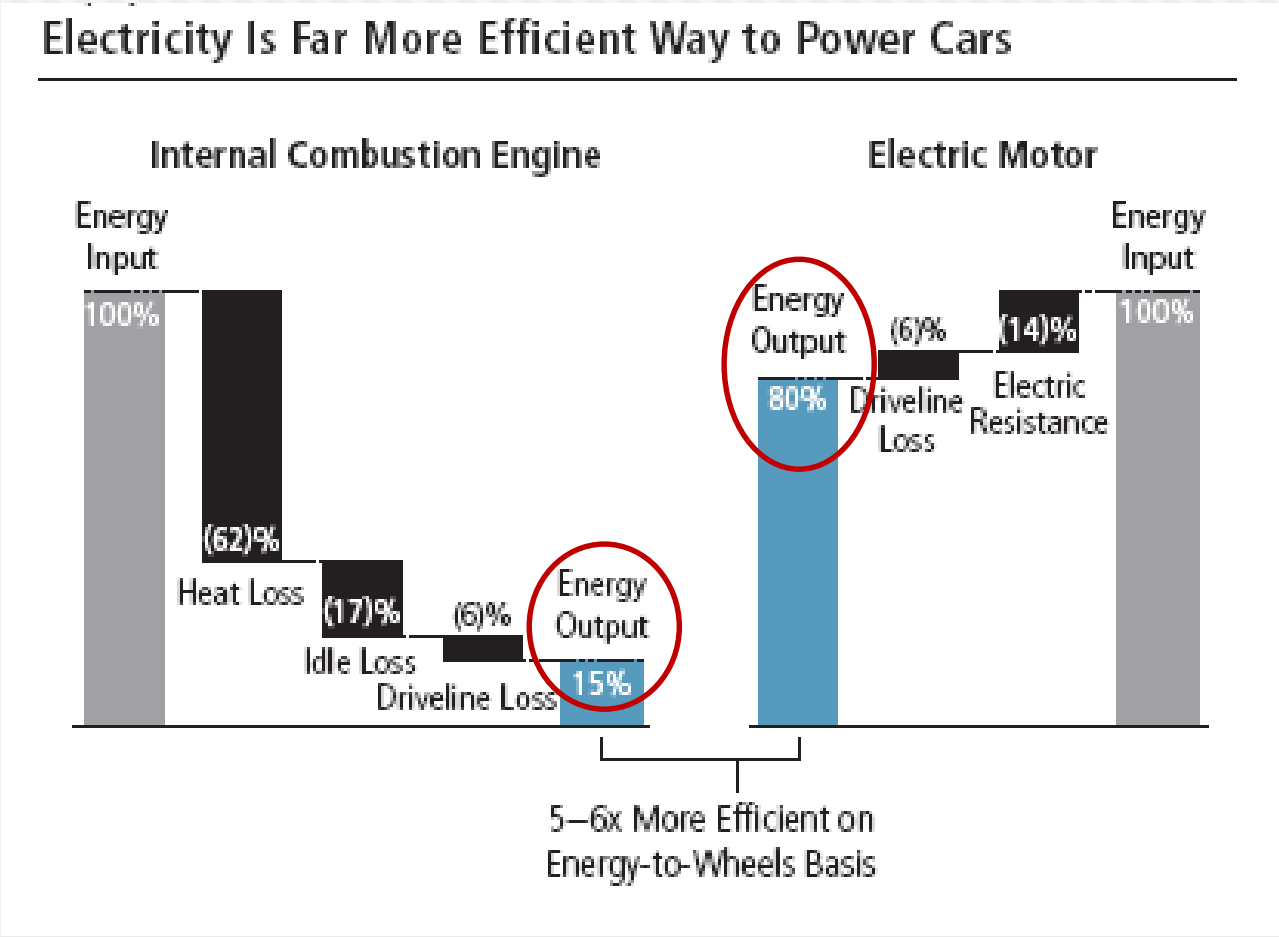
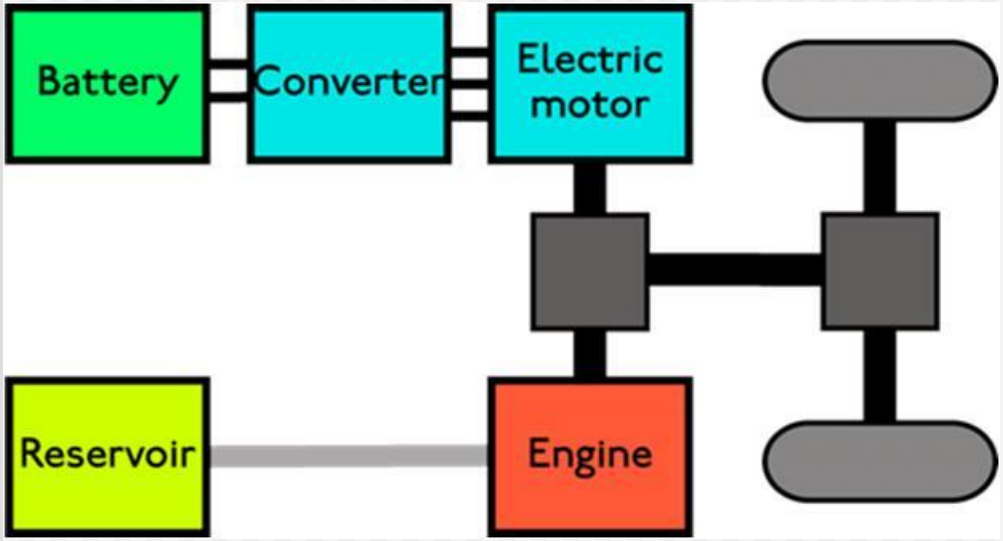


ICE → HEV → PHEV → BEV/FCEV

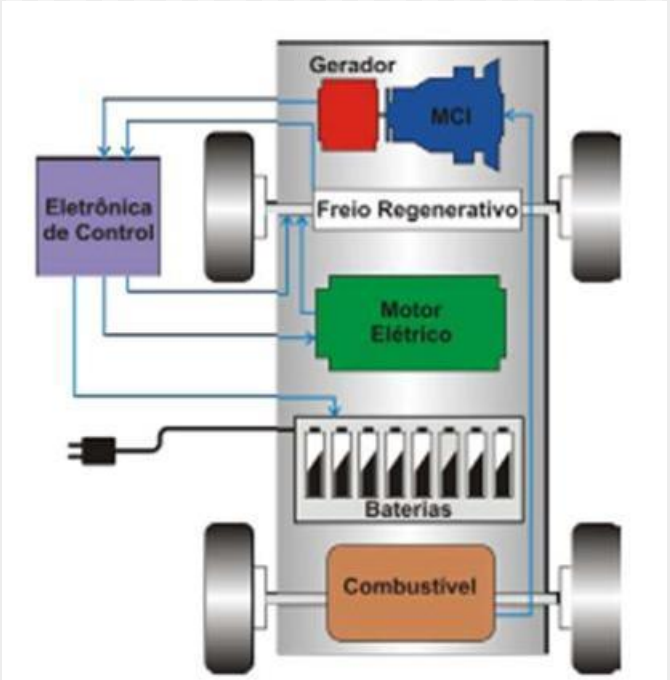
1. Hybrid vehicles and their role

HEV → two concepts: series and parallel

Parallel: electric motor AND/OR fuel engine can move the wheels



Series: only electric motor moves the wheels



1. Hybrid vehicles and their role

Parallel HEV → different levels of hybridization

Fuel Efficiency Rises with Ratio of Electric to Total Power

	Electric to Total Power	Fuel Economy Benefit	Representative Model
Conventional Vehicle	2%	Baseline	NA
Weak Hybrid	5–10%	5–20%	GMC Sierra
Mild Hybrid	10–30%	20–50%	Honda Civic Hybrid
Full Hybrid	30–50%	20–80%	Toyota Prius

Source: National Renewable Energy Laboratory, Dr. Menahem Anderman, Advanced Automotive Battery Conference (AABC), The New York Times, Car & Truck Test Monthly Buying Guide *and AllianceBernstein*

2. Hybrid ethanol – electricity vehicles

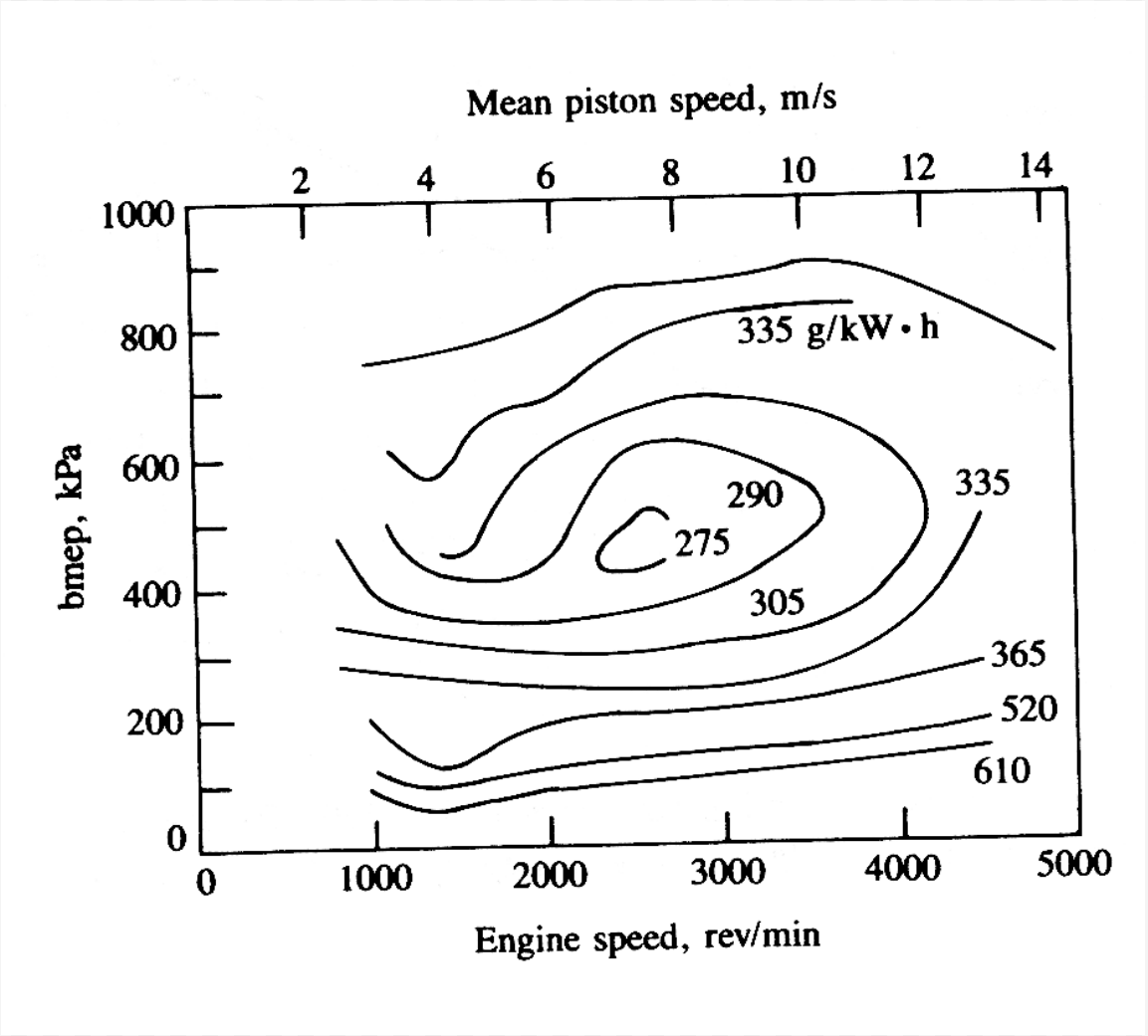
Parallel HEV: how to optimize the engine?

- **For weak hybrids → there is little to do**
- **Example of the needed power and the available power in an internal combustion engine:**
  - **Power required to 100 km/h → ~20 kW**
  - **Max. power of the engine: 80 kW**
  - **Excess power: to accelerate and uphill operation**
- **For full hybrids → engine can have smaller power and can be optimized to a better efficiency operational profile. Extra power comes from the electric motor, which drains the stored energy in the batteries.**
- **To take advantage of parallel hybrids → smart and precise control**

2. Hybrid ethanol – electricity vehicles

Bsfc is an inverse measure of the efficiency for a given operating point

There are strategies to maintain the engine close to the small BSFC. For very low loads, stop the engine and use the energy of batteries



2. Hybrid ethanol – electricity vehicles

Series HEV: how to optimize the engine?

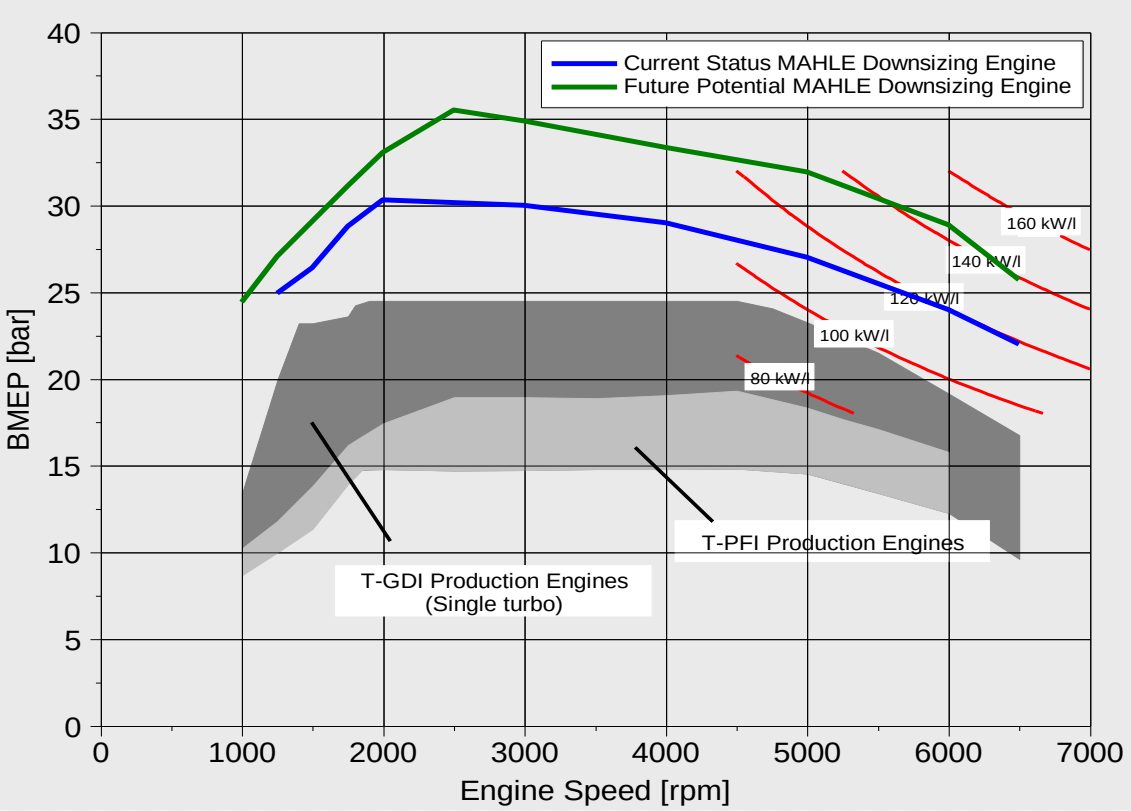
Apart from strategies adopted for parallel HEV:

- **Develop simpler engines (soft transients, reduced speed range, reduced load range)**
- **Downsizing: smaller displacement, turbocharger, EGR → reduced weight and size for a given power**
- **Engine can have a smaller power (batteries assist high loads)**
- **Operation in the lean region (higher efficiency)**
- **Load control with variable intake valve**
- **All these characteristics make ethanol a good choice**

2. Hybrid ethanol – electricity vehicles

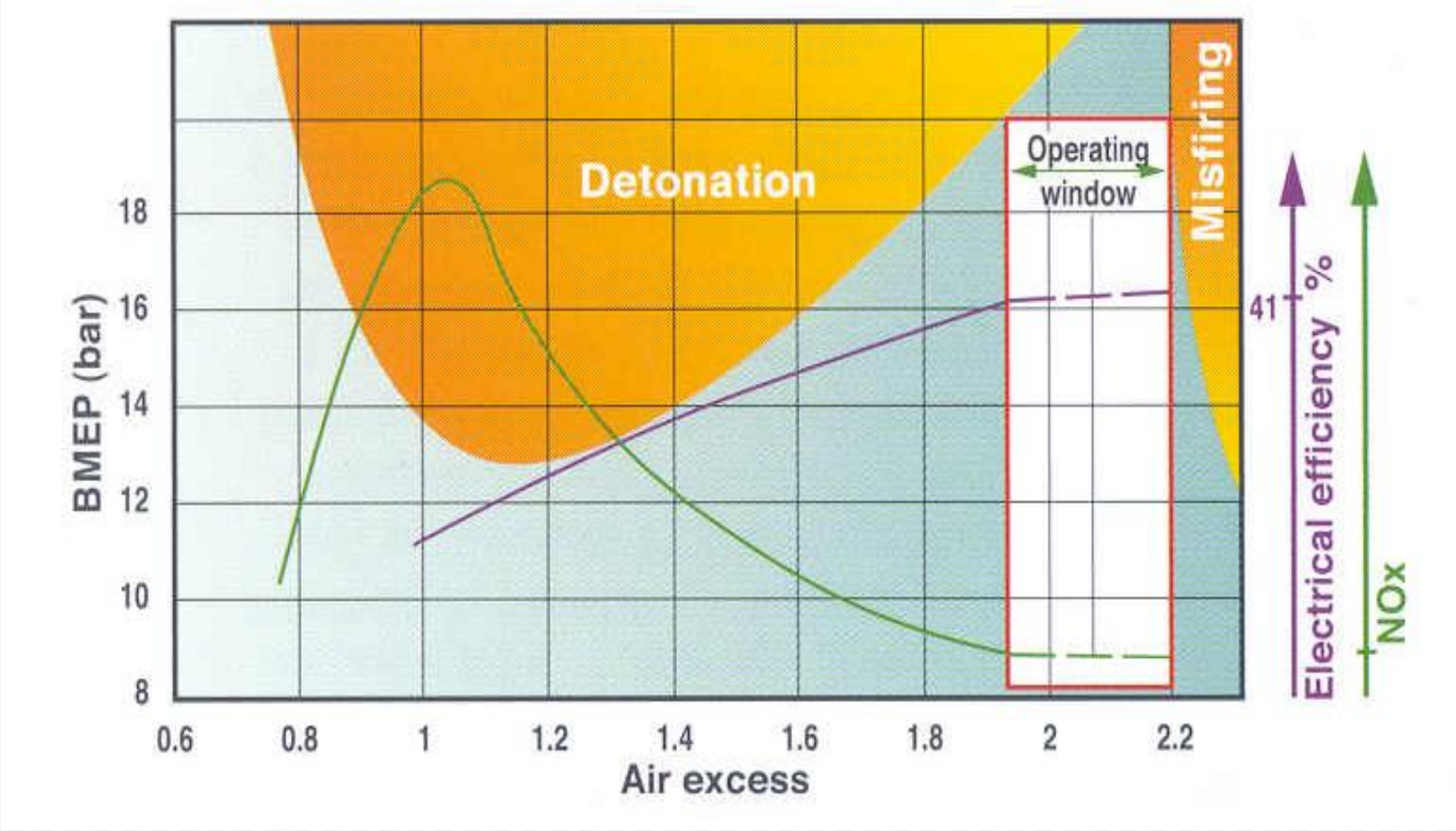
Downsizing: higher power for a given displacement

Engine with small weight and size



2. Hybrid ethanol – electricity vehicles

Lean operation – constant engine speed



3. Hybrid biodiesel – electricity vehicles

Compression ignition engines are far more efficient than spark ignition engines.

However, their weight and size are bigger;

Biodiesel (B20) was employed with success in locomotives in Brazil. To be noted: the engine of the locomotive are not subject to the emission limits as engines dedicated to road transport → the is no after-treatment and the biodiesel reduces somewhat the pollutant emissions, specially particulate matter and unburned hydrocarbons.

There are some VEH diesel, for heavy-duty operation (trucks and buses)

3. Hybrid biodiesel – electricity vehicles

Beyond the passenger car:

There is a Brazilian company which produces electric and hybrid buses for urban transportation: Eletra

For daily trucks (Isuzu)...

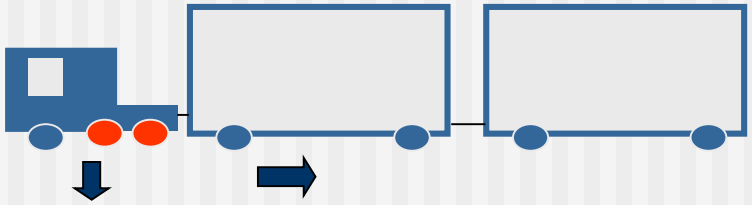
...and urban buses

3. Hybrid biodiesel – electricity vehicles

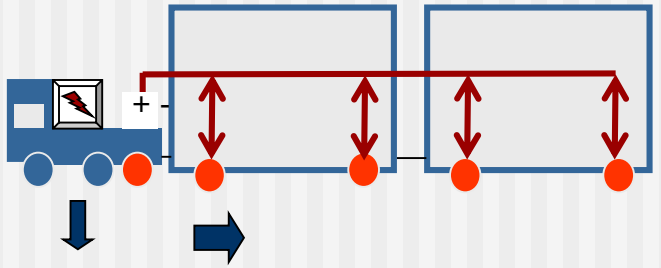
Proposition (J.B. Hollanda):

For big trucks, with very heavy-duty – as in the sugar cane transportation → hybrid engines (series)
High torque at low speed
Engine in (near) steady-state
Ethanol fueled engine

Conventional



Proposal CVA



Passive wheel Active wheeel
Hybrid engine - ethanol etanol

4. Where is the focus?

There are three possible targets to be obtained with VEH:

1. **Local emissions of pollutants (CO, HC, NOx, PM)**
2. **GHG emissions (CO2 from fossil fuels)**
3. **Increase in efficiency of the transport service (MJ/km)**

IMPORTANT:

To optimize for one target does not mean to optimize the other two!

For example: to optimize the efficiency for spark ignition engines means to exceed the local emissions (the catalyst must operate with near stoichiometric mixtures and the best efficiencies occur for lean mixtures)

4. Where is the focus?

The importance of fuel economy

4. Where is the focus?

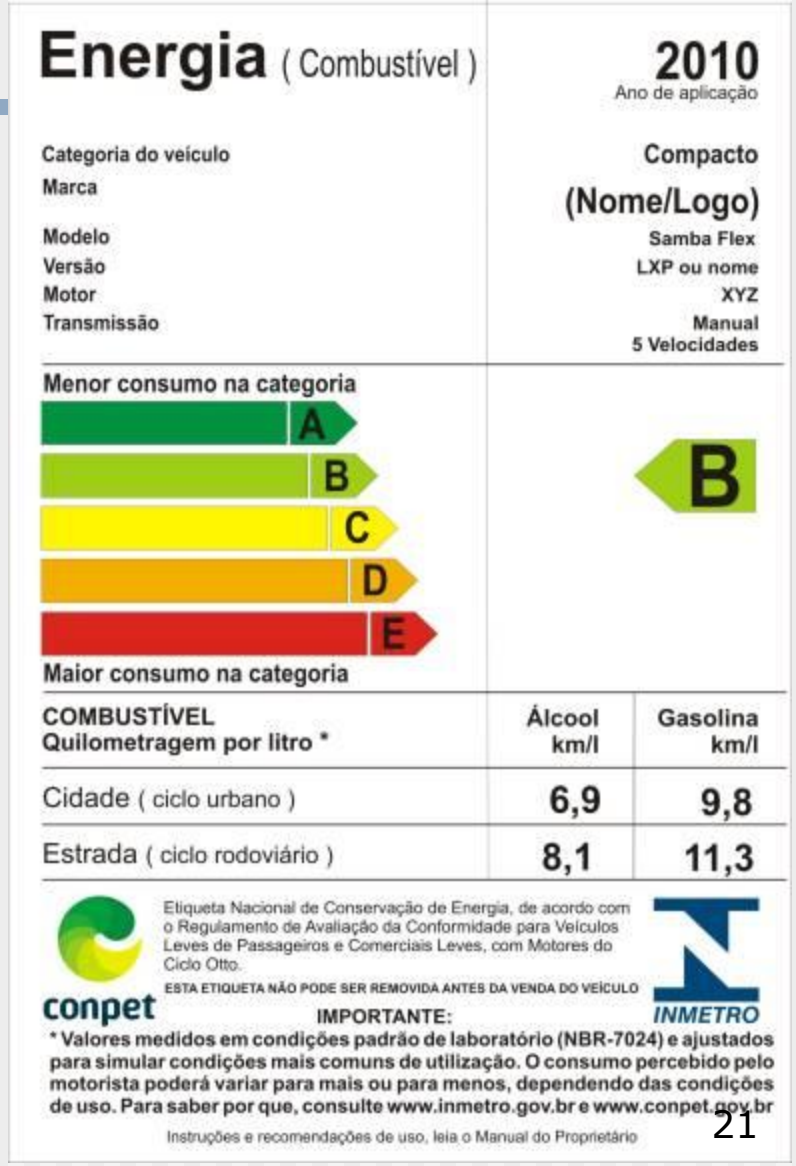
For fossil fuels there is a direct connection among efficiency and CO2 emissions

An increase in the engine efficiency means a reduction in the CO2 emissions

Brasil has a Program for Vehicle Efficiency, dedicated to passenger cars

The label is obtained from the small energy use (MJ/km) in a standard test

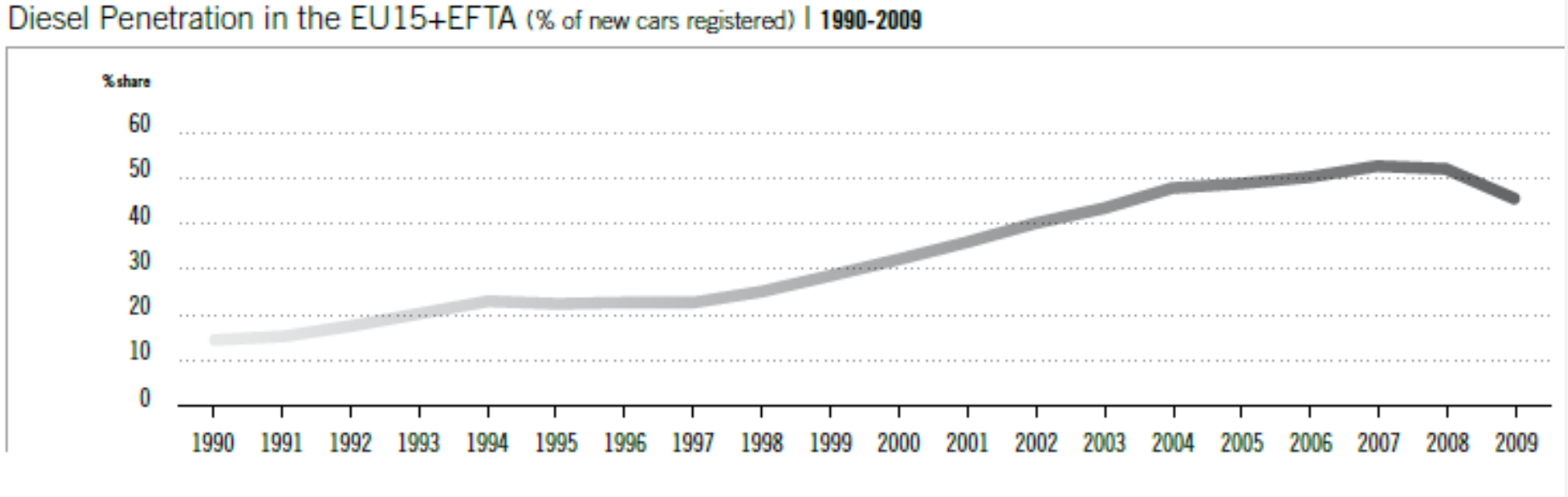
In 2012, the InovarAuto increased the scope of this Program, with tax reduction associated with an increase in the efficiency of the vehicles until 2017.



4. Where is the focus?

The European Union defined targets to an increase in the efficiency of vehicles, pointing to a reduction in the CO2 emissions. The target is 130 g/km of CO2 by 2020.

The first effect: diesel penetration in passenger cars → local emissions...

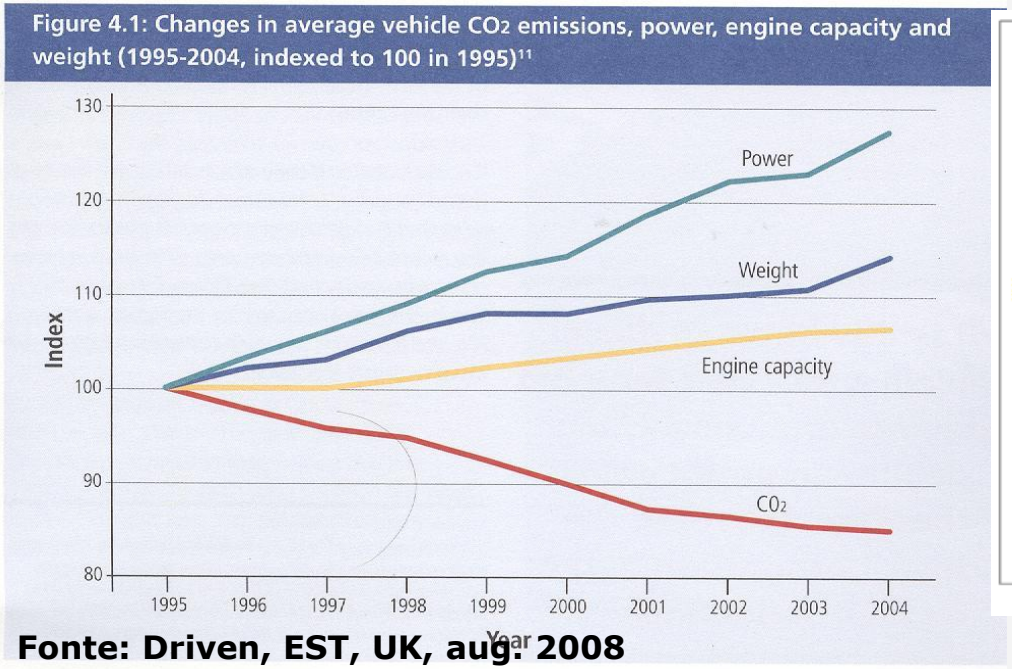


Fonte: ACEA 2010

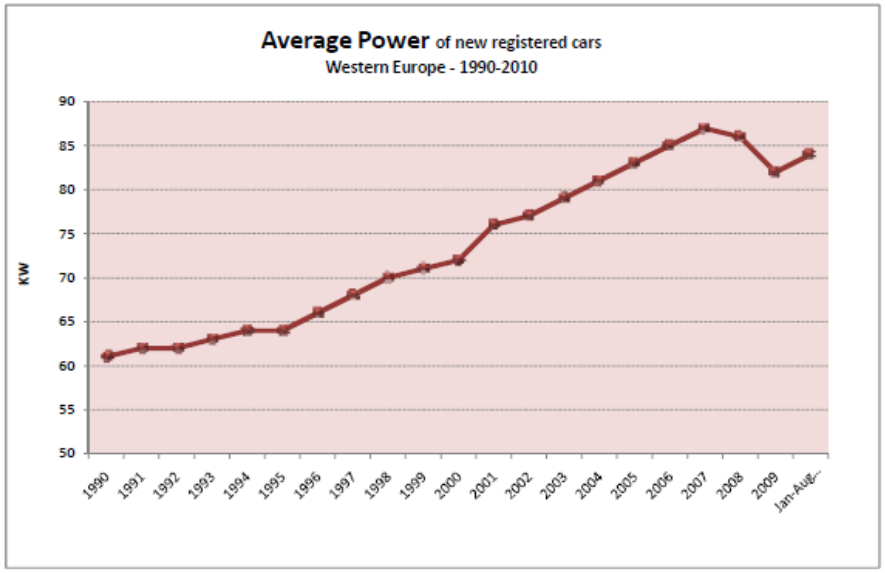
4. Where is the focus?

More advanced technology does not mean more environmentally friendly engines:

Power, weight and engine displacement increased in the last years, in UK. The same trend is observed for Western Europe



Fonte: Driven, EST, UK, aug. 2008



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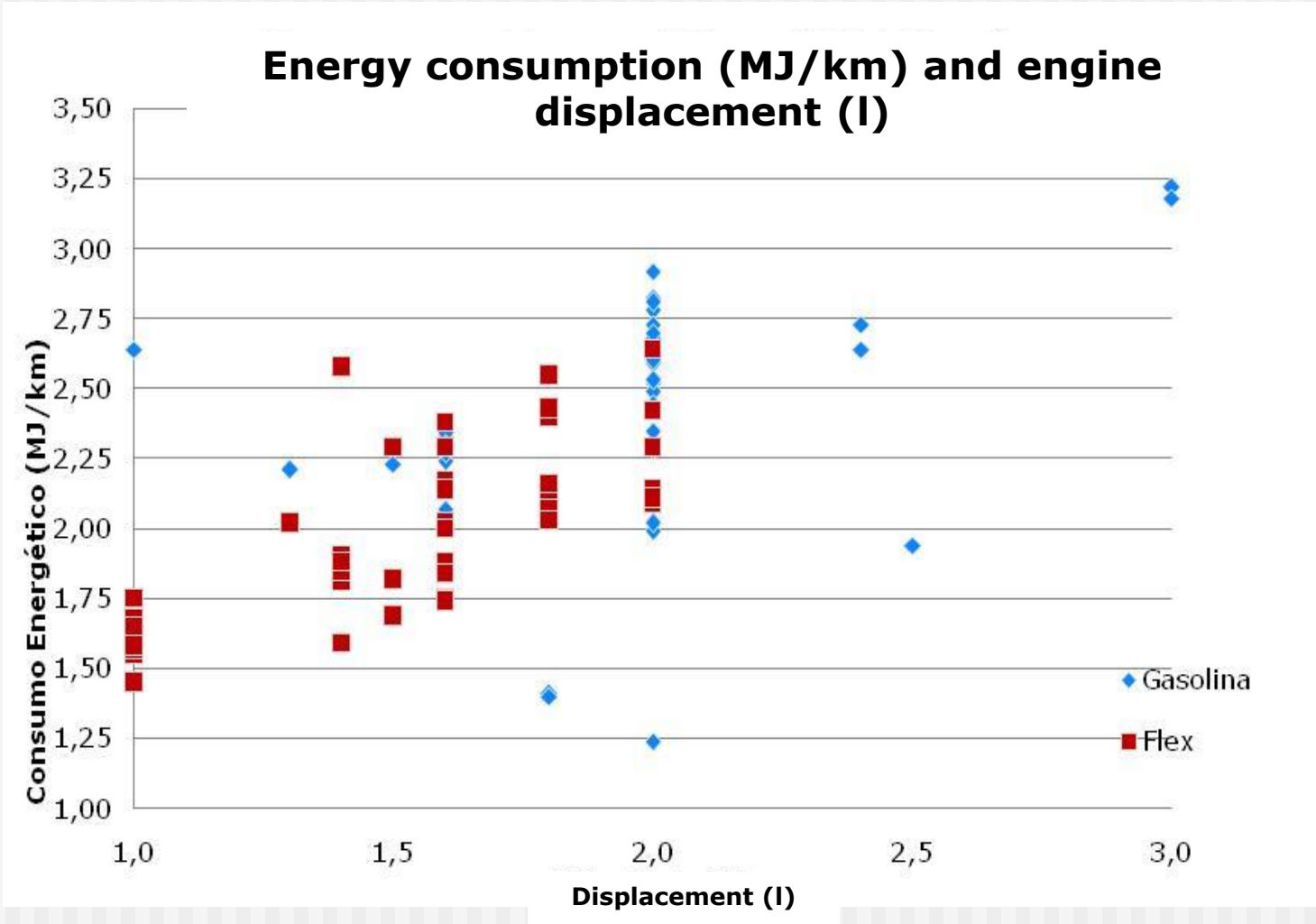

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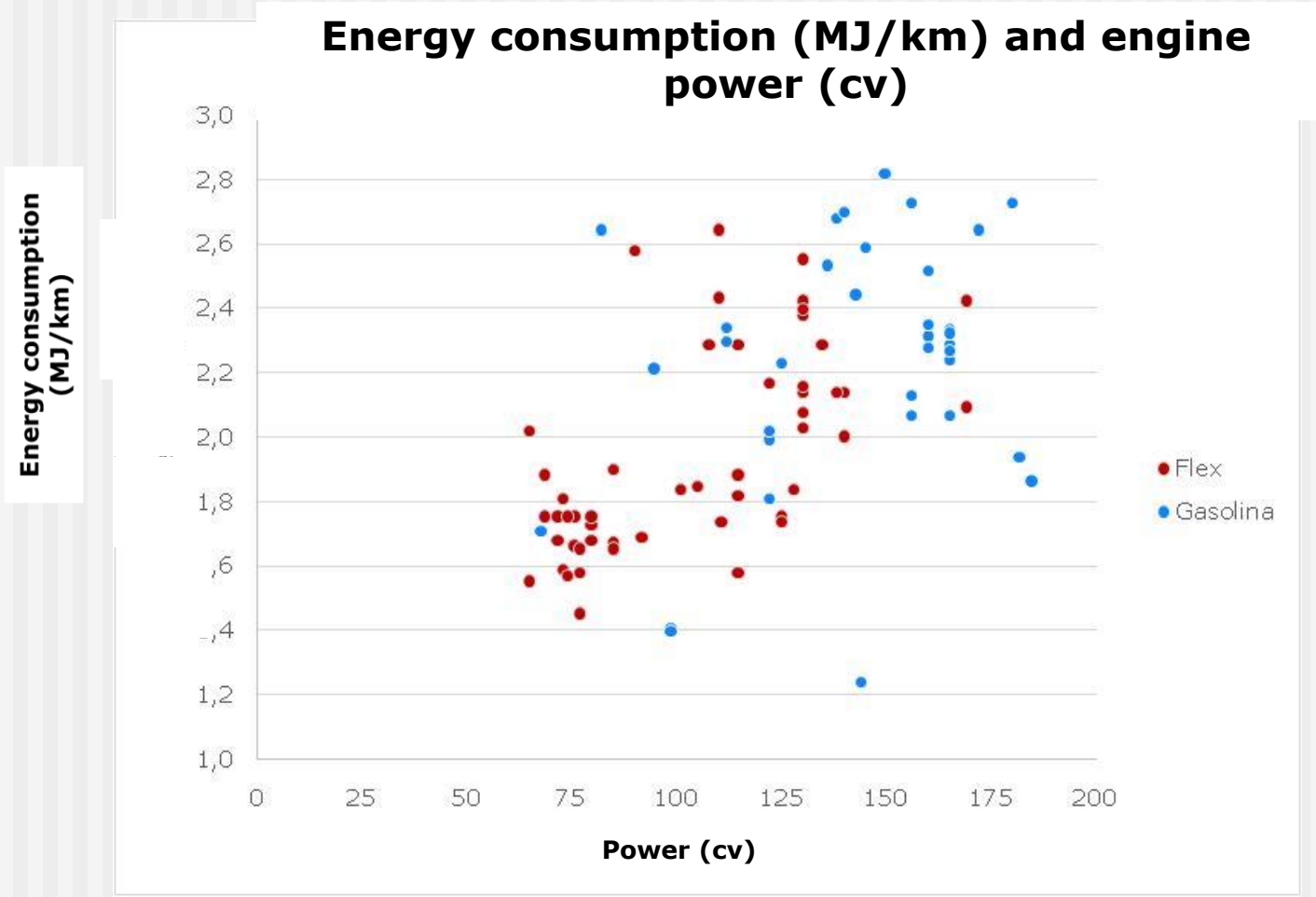

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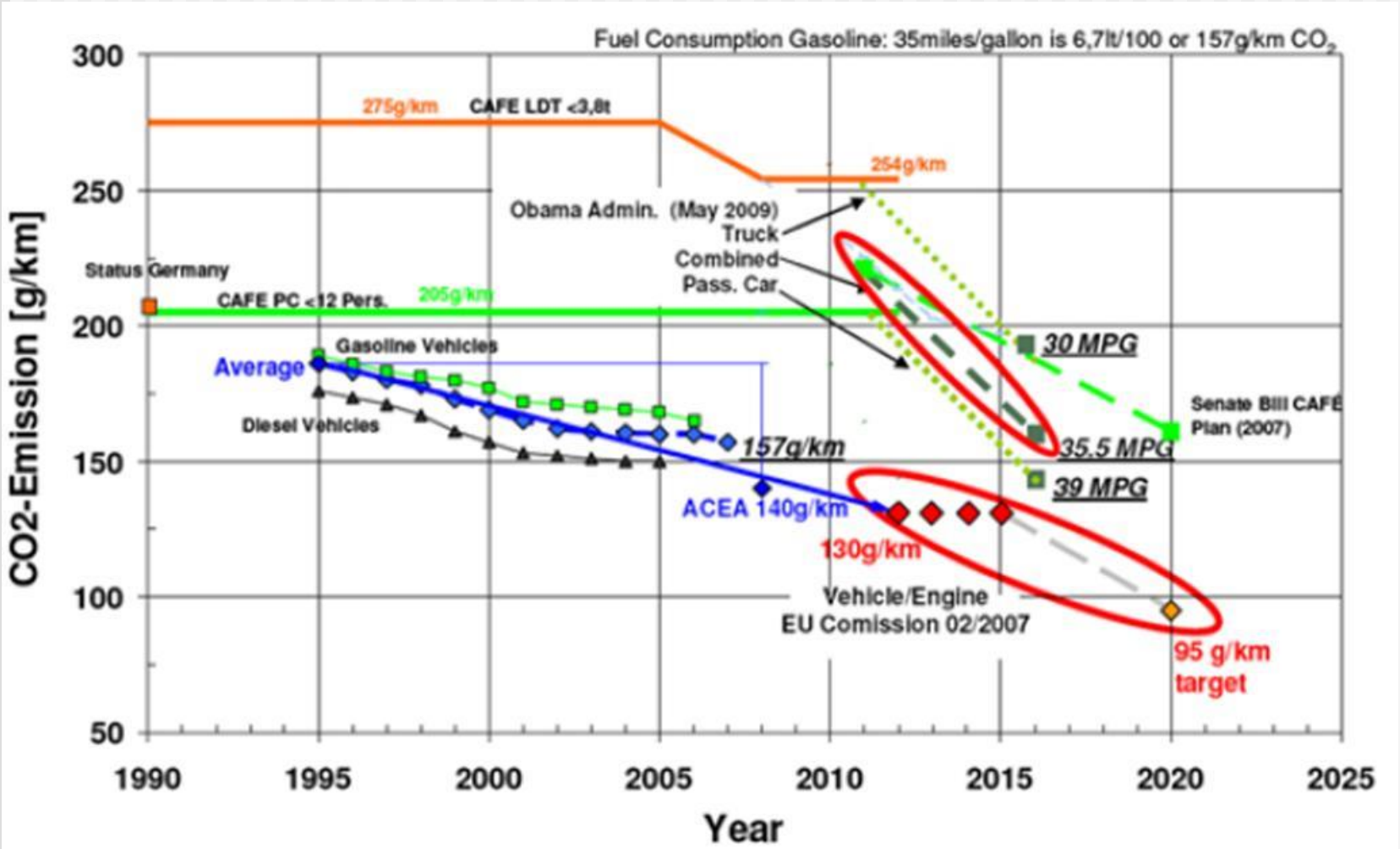
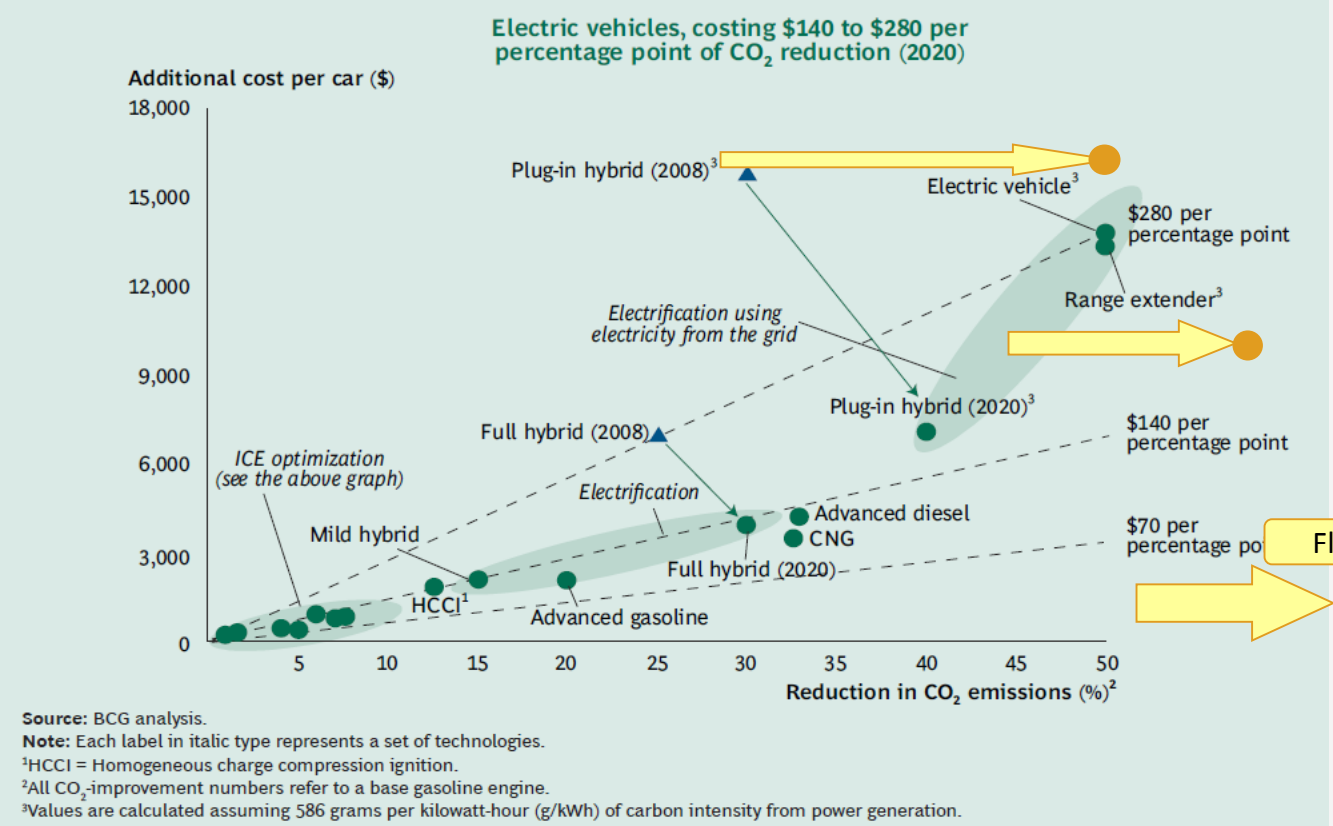


4. Where is the focus?

The cost to reduce CO2 → the role of biofuels and renewable electricity

If the question is CO2 → ethanol (from sugar cane) vehicles are the best

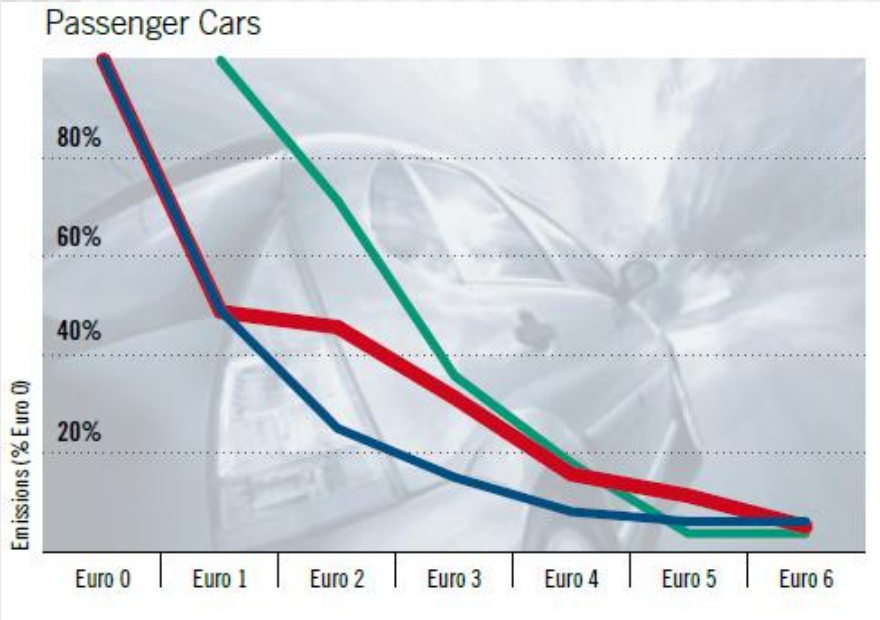


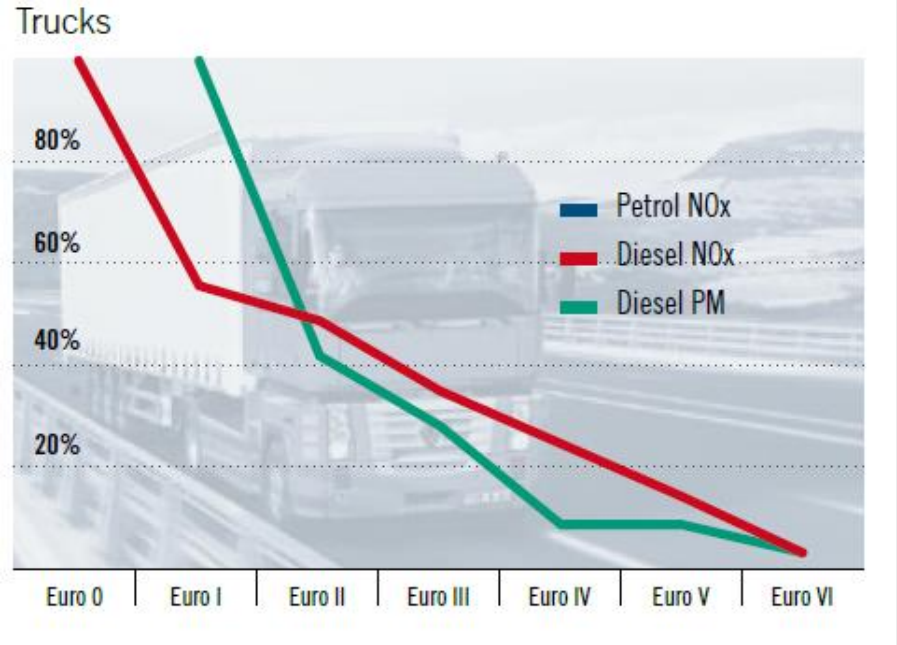
4. Where is the focus?

Local pollutant emissions: evolution in Europe

There is not much room for spectacular reductions

Smaller emissions limits will impact efficiency (and CO2 emissions) OR will require electric vehicles





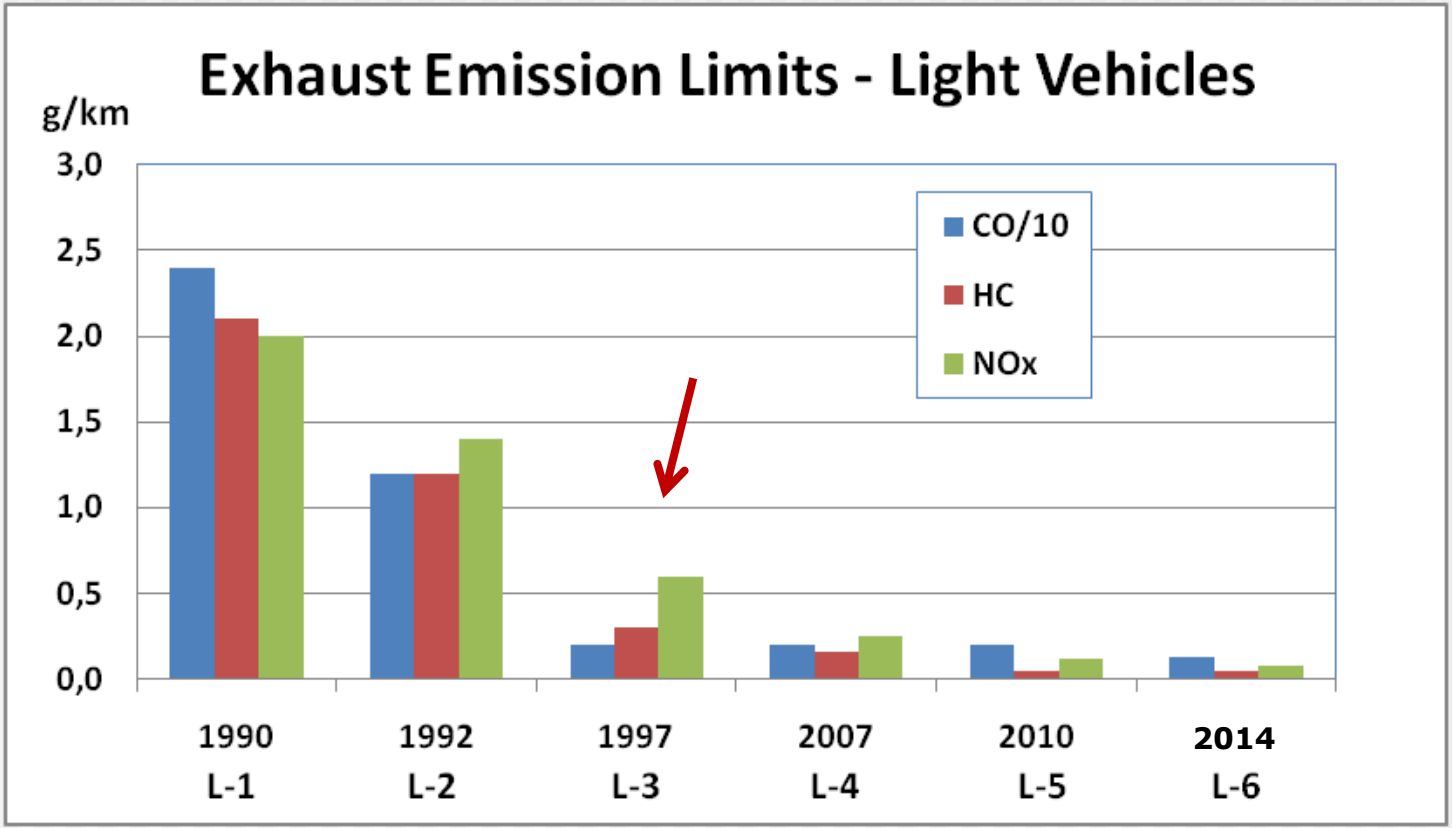
Fonte: ACEA 2010

4. Where is the focus?

Local pollutant emissions evolution in Brasil

Light duty vehicles – Proconve

Emission limits are the same irrespective of adopted fuel



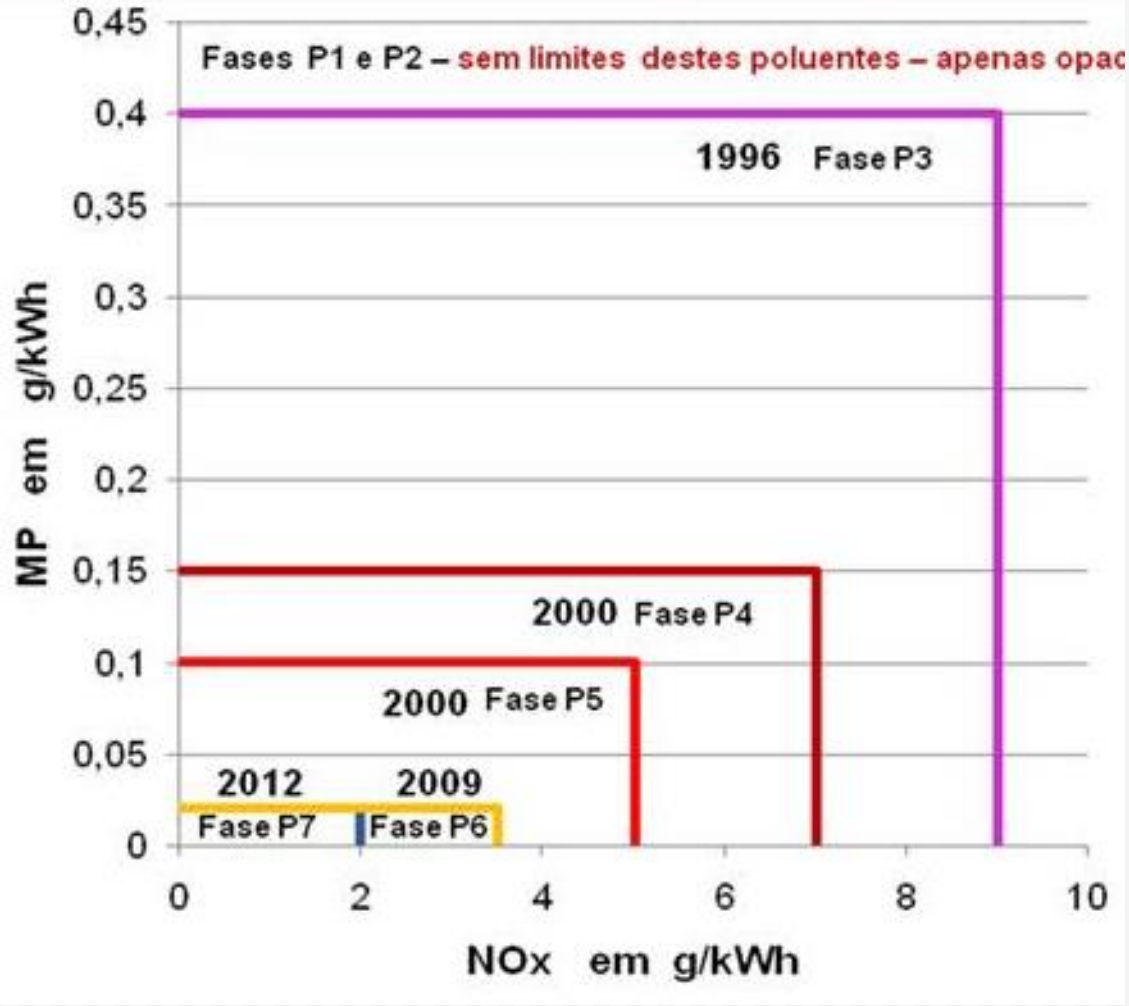
4. Where is the focus?

Local pollutant emissions evolution in Brasil:

Heavy-duty vehicles

Proconve

Shown only NOx and PM – the most difficult to deal – there is a trade-off among them



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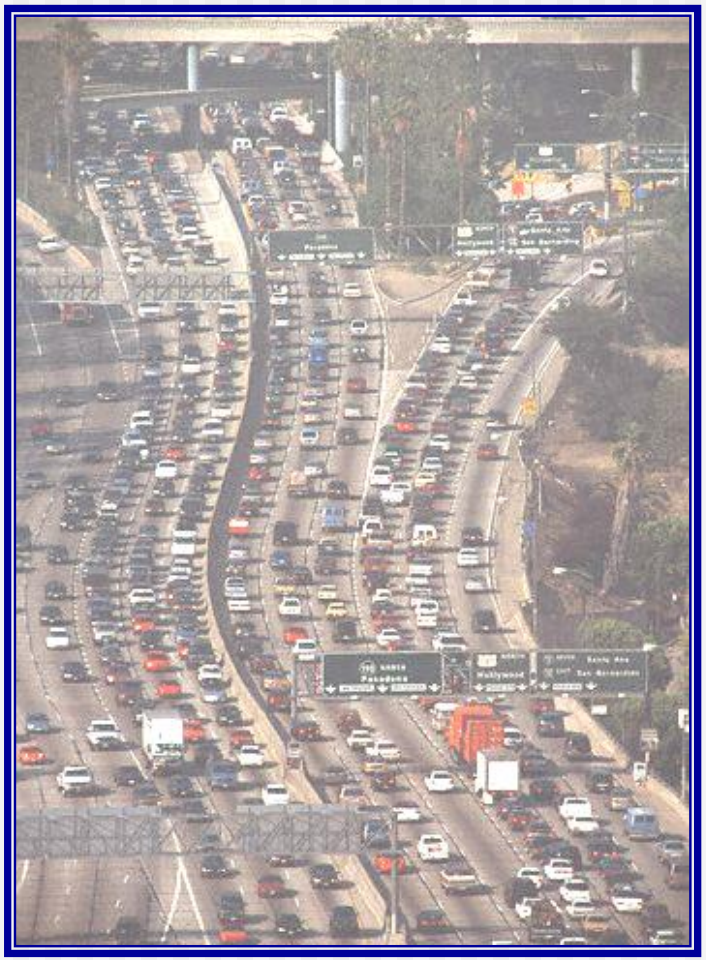
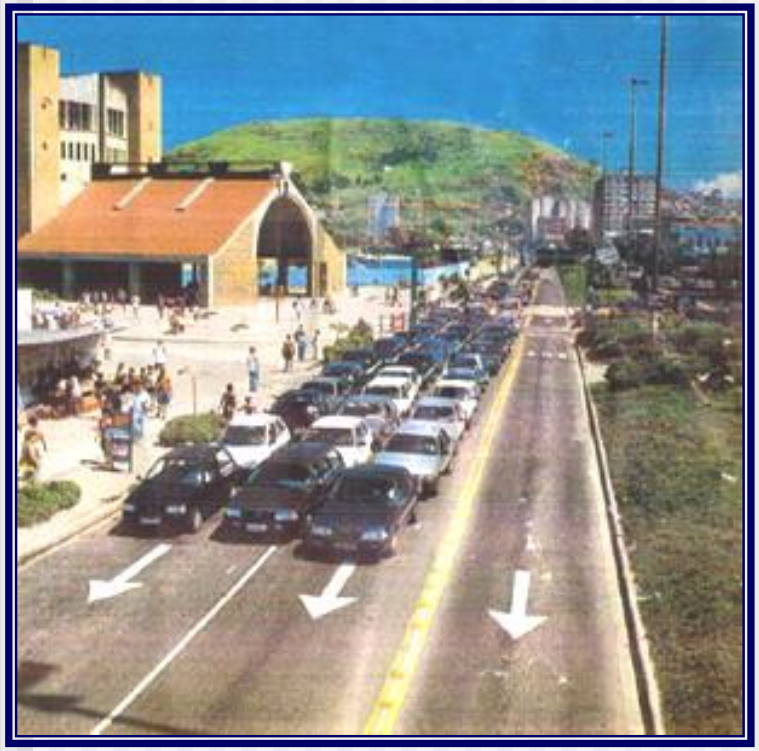
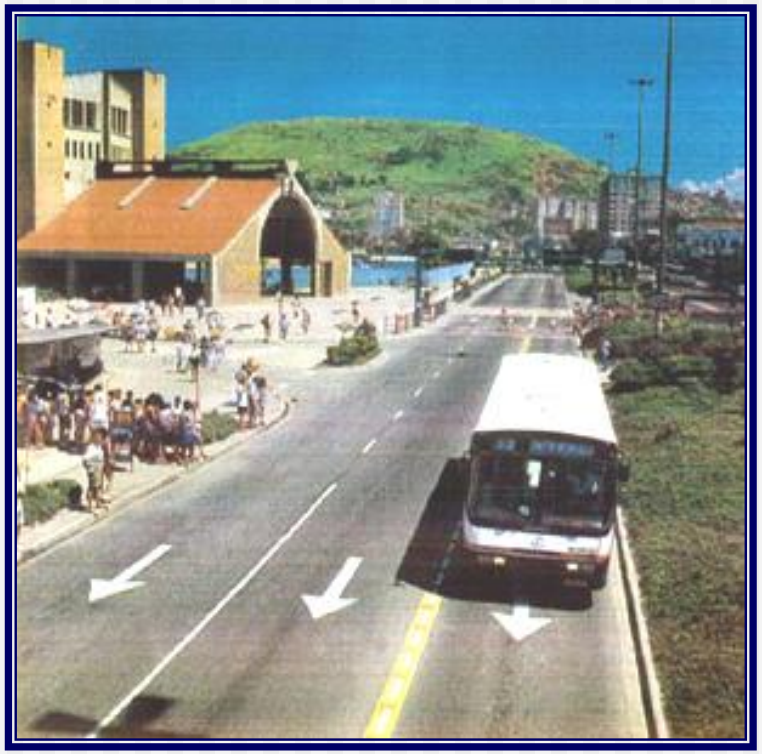


4. Where is the focus?

How to compare the emissions from passenger cars and public transportation?





4. Where is the focus?

If the focus is the local pollutant emissions: electric transportation → biofuels are not better than fossil fuels

5. Concluding remarks

Hybrid engines give a range compatible with traditional engines and much higher than obtained by electric vehicles

Ethanol fueled hybrid vehicles should be plug-in type and run as much as possible on electricity. This reduces the local emissions in cities and takes advantages of the renewable electric matrix in Brasil (~80%)

Gasoline fueled hybrid vehicles does not increase the efficiency (MJ/km) significantly, due to its high weight.

Heavy-duty hybrid vehicles which run on cities can reduce local pollutants – specially PM – even if they run on diesel engines.

5. Concluding remarks

There are some regulatory and political issues:

- **How to register unusual vehicles (Transit Code)**
- **How to define the Federal (IPI)**
- **How to define State taxes (ICMS and IPVA) for hybrid vehicles**
- **To define public policies with clear targets to be obtained: energy efficiency, local emissions or GHG emissions**

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