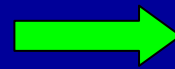
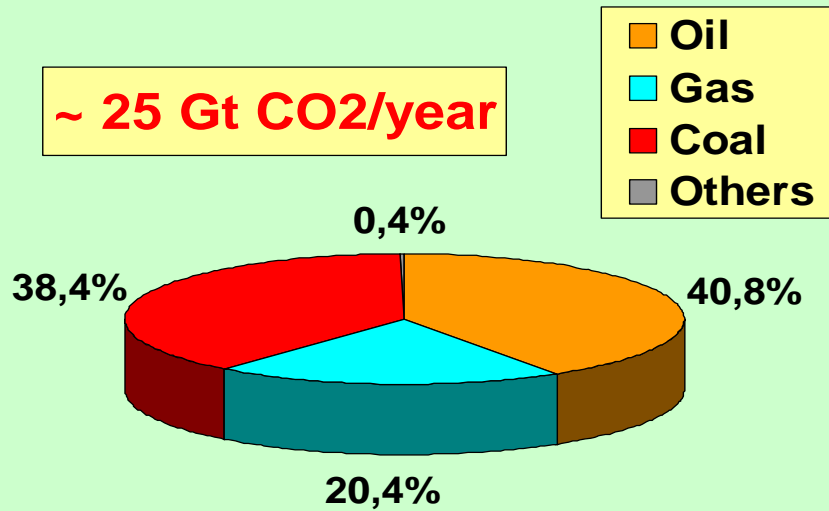


Reducing CO₂ Emissions from Land Transportation : Engine Design Consideration

Dominique HERRIER
IFP

Mains sources of anthropogenic CO₂ emissions

~ 25 Gt CO₂/year



Most of the CO₂ emissions are coming from the dominant primary energy vectors

Source : International Energy Agency
(Key World Energy Statistics 2005)

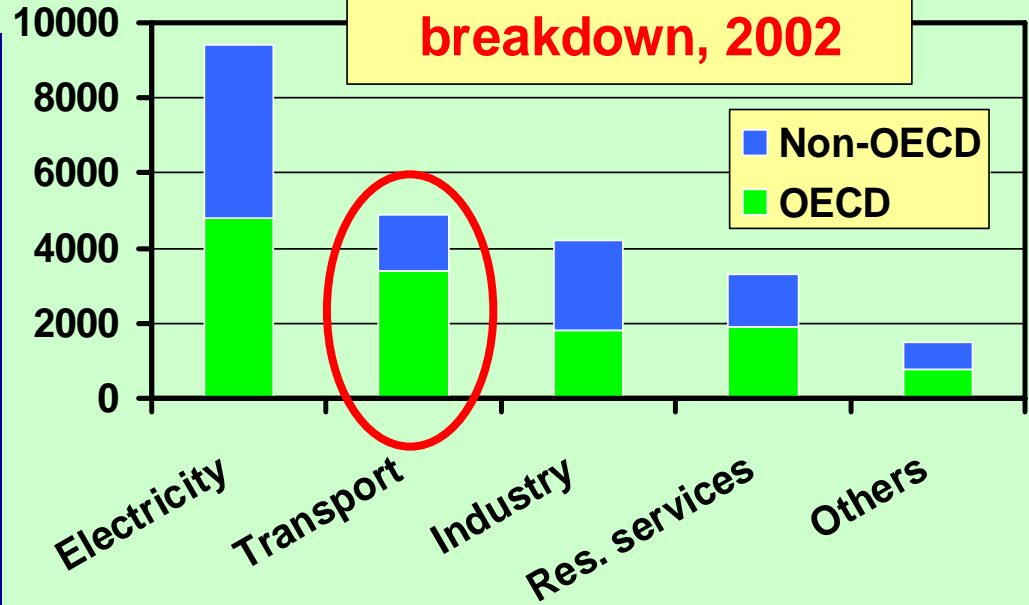
Electricity production and transport weigh heavily in the world CO₂ emissions balance



By 2030, transport sector will see its CO₂ balance rises ~ 80%

Mt CO₂

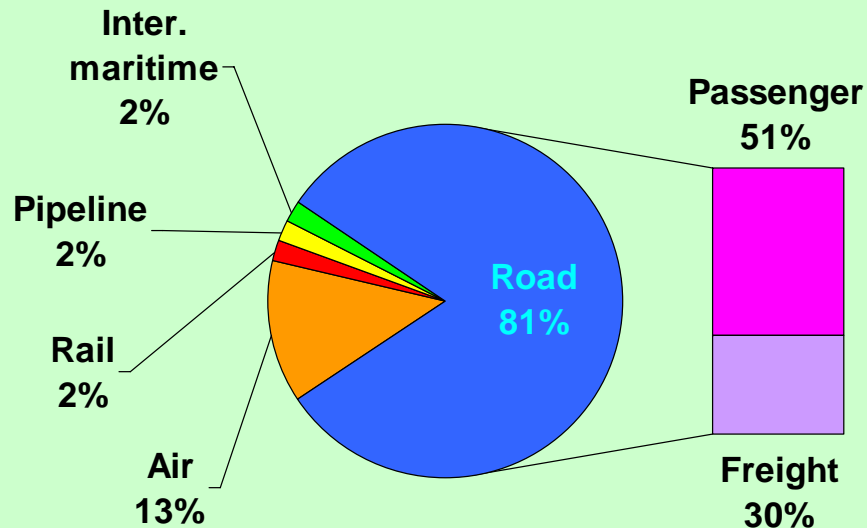
World CO₂ emissions breakdown, 2002



Source : IEA - World Energy Outlook 2004

Road transport sector & petroleum product consumption (CO₂ emissions)

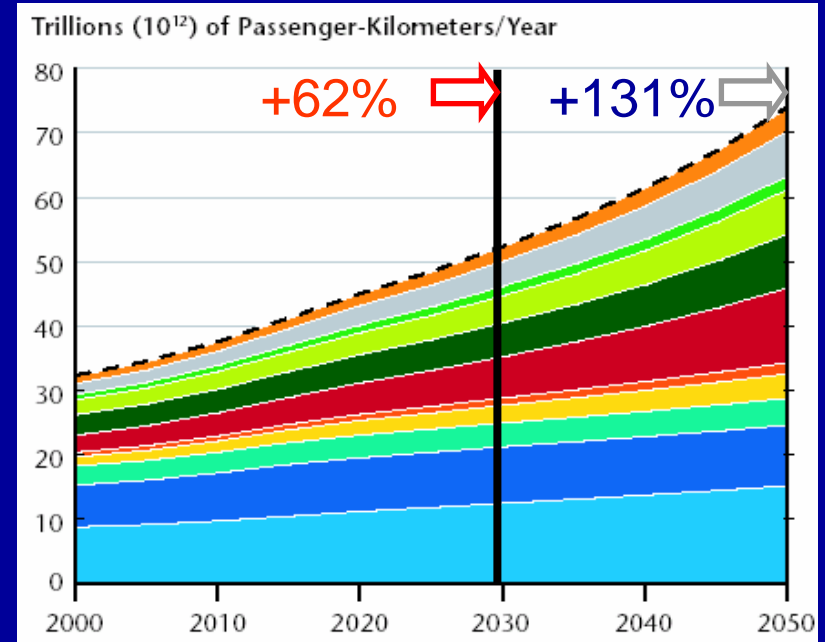
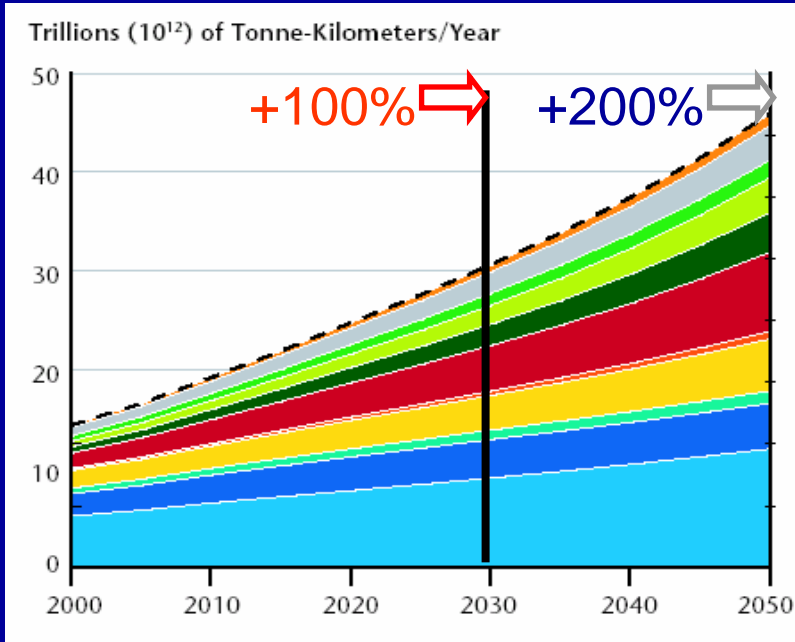
Energy consumption breakdown for the transport sector, 2001



Road transport accounts for an even higher percentage of energy consumption and is still the most energy-intensive mode of transport

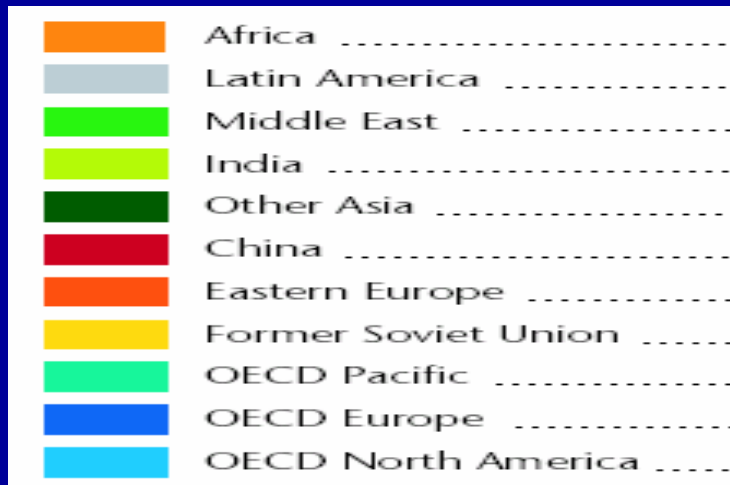
Source : IEA and IFP estimates

Transport demand will strongly grow in the next decades



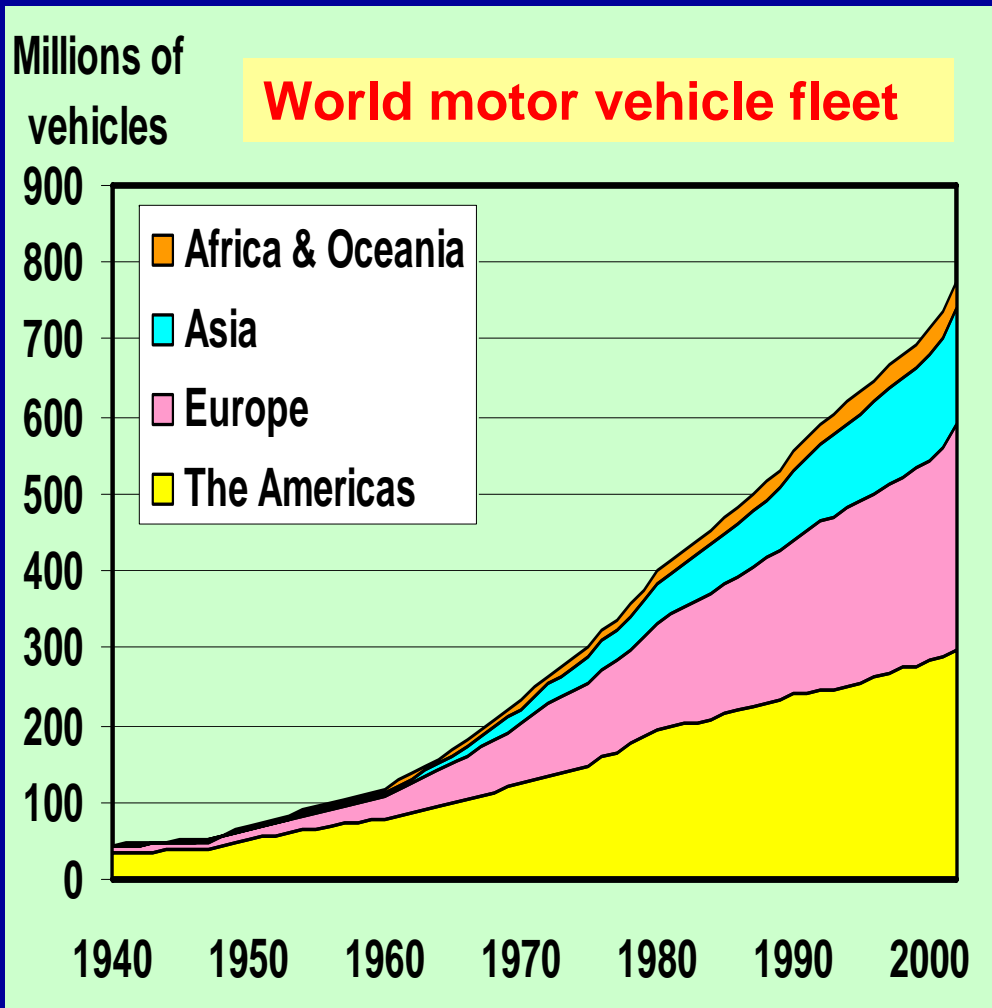
Freight

Passengers



Source : World Business Council for Sustainable Development (WBCSD) - The Sustainable Mobility Project, 2004

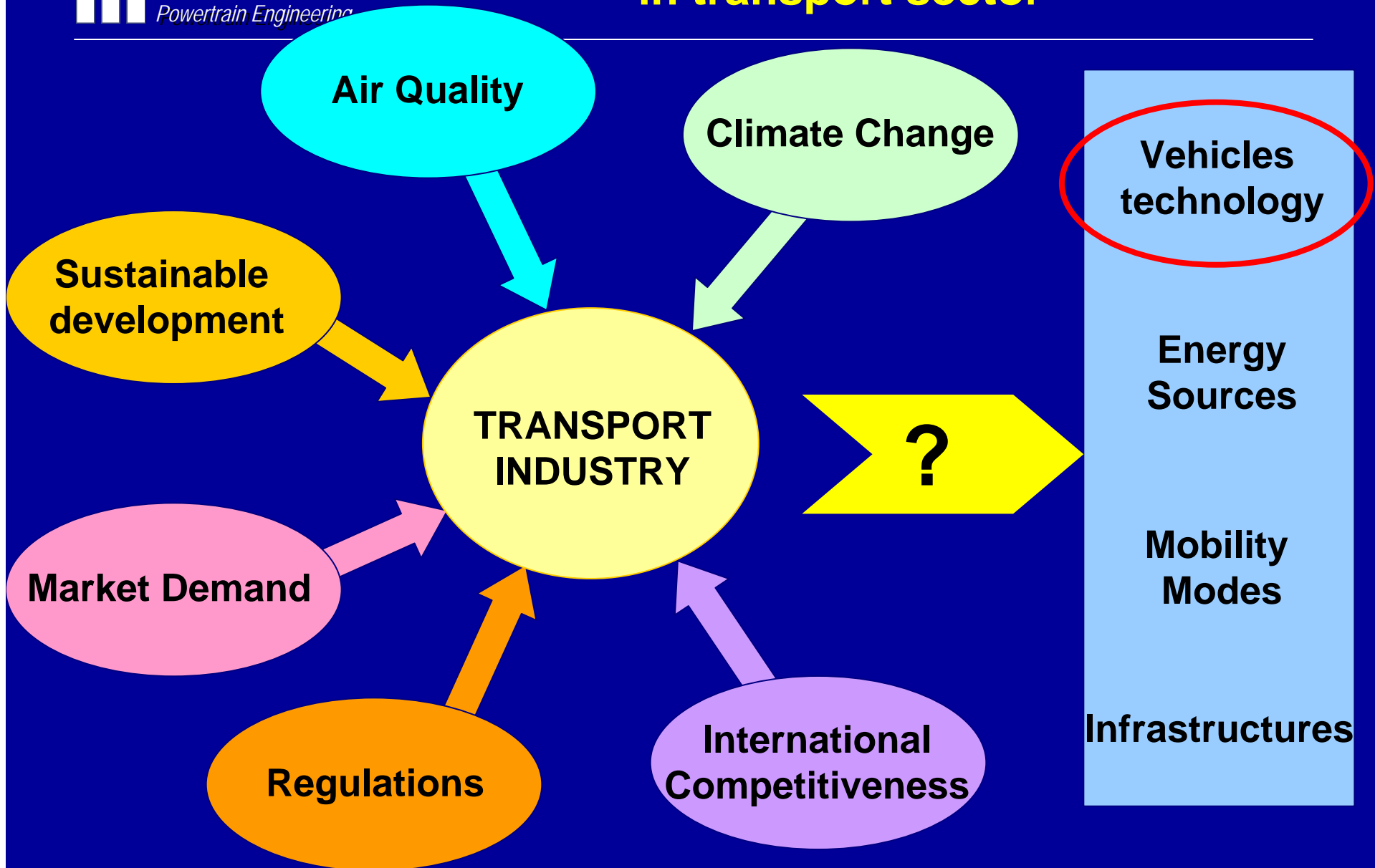
World private car fleet has more than tripled in 30 years



600 M private cars and
200 M light trucks
registered in the world

By 2030, the non-OECD
motor vehicle fleet will
triple and the world fleet
will double, reaching
nearly 1.3 billion vehicles

Rapid changes are expected in transport sector



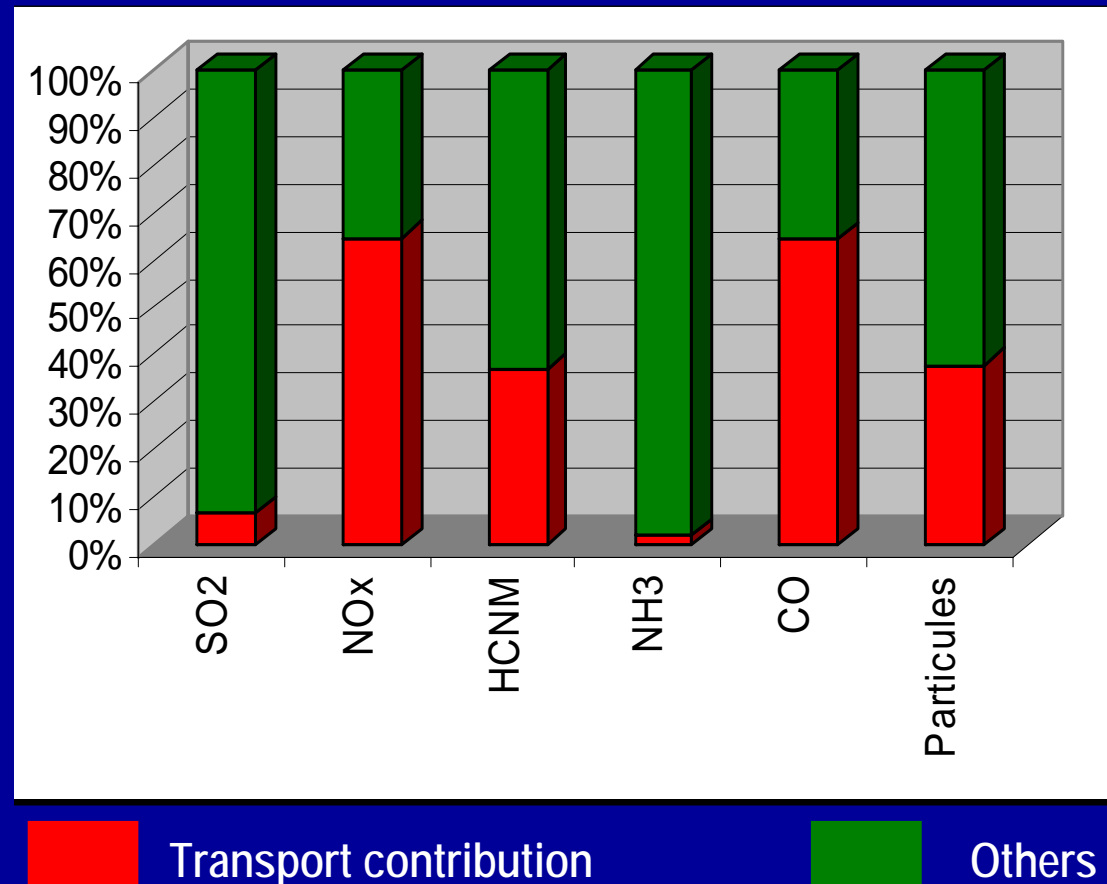
Many questions arise for the future in relation with the powertrain evolution

- Which major powertrain technologies will emerge ?
- Which fuel specifications will be requested to fit with these technologies ?
- Which energy sources will be used ?
- Which energy carriers : liquid fuels, electricity, hydrogen, ...?
- What time schedule ?
- Merging or diversification of engine and fuels technologies ?

Road transport & air quality

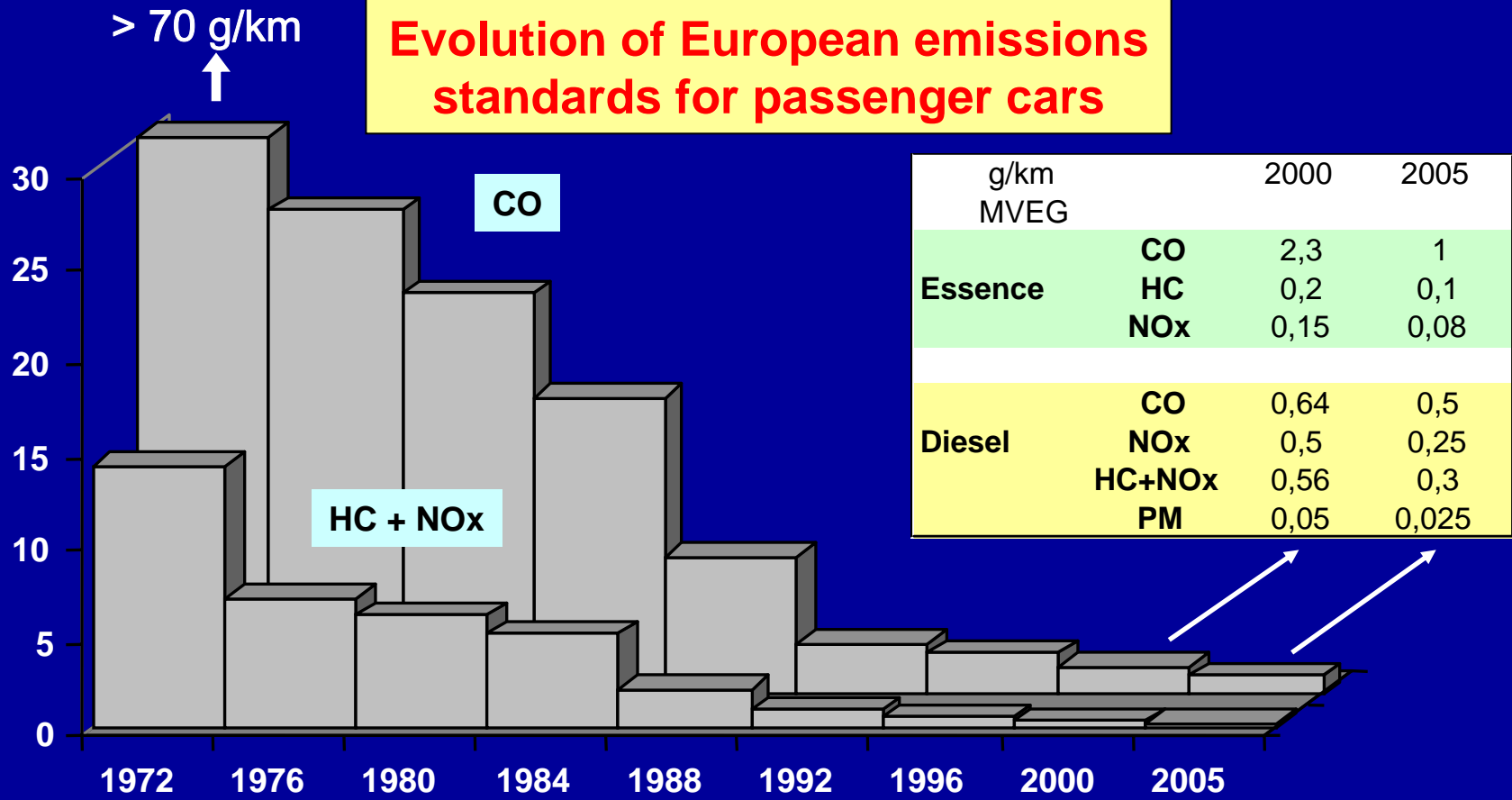
Road transport contribution to global pollutants emissions in the UE, 2001

The effect of these pollutants takes place at first at a local stage, and in particular in urban areas in the zones of dense and heavy traffic



Road transport & pollution regulations

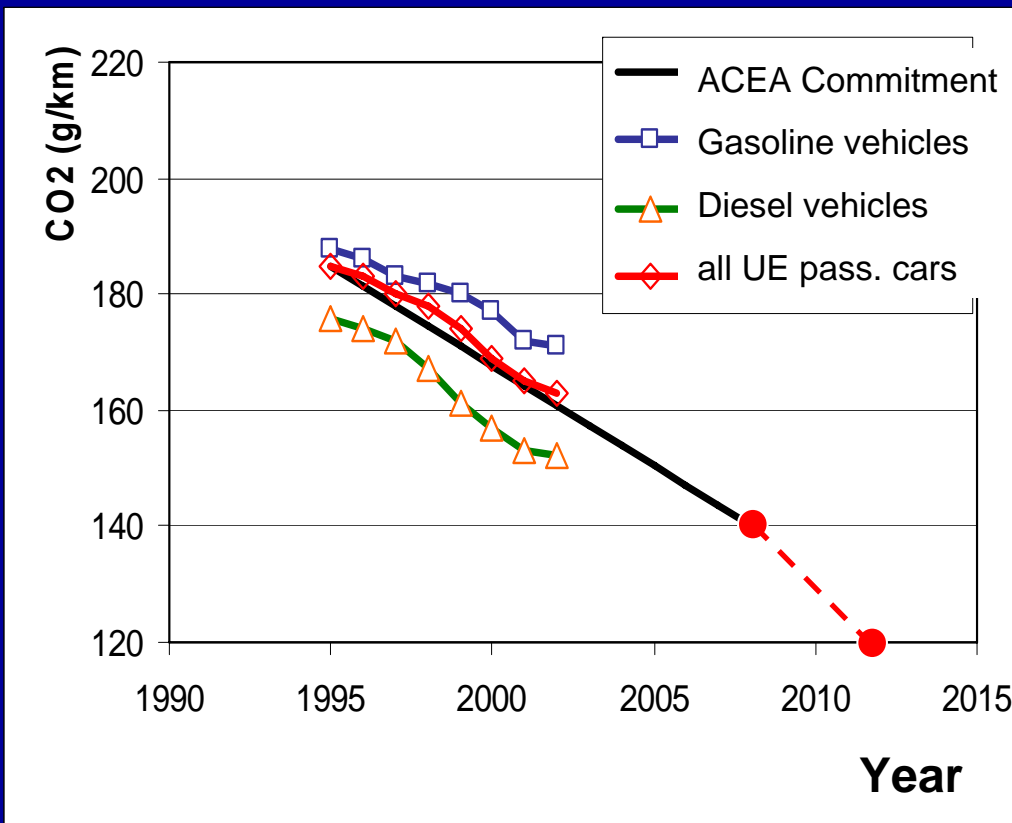
Evolution of European emissions standards for passenger cars



At request of the Public Authorities, the limits of emissions were reduced by a factor of 10 -100 within the last decades

A big challenge for the reduction of CO₂ emissions

Evolution of CO₂ emissions of European passenger cars



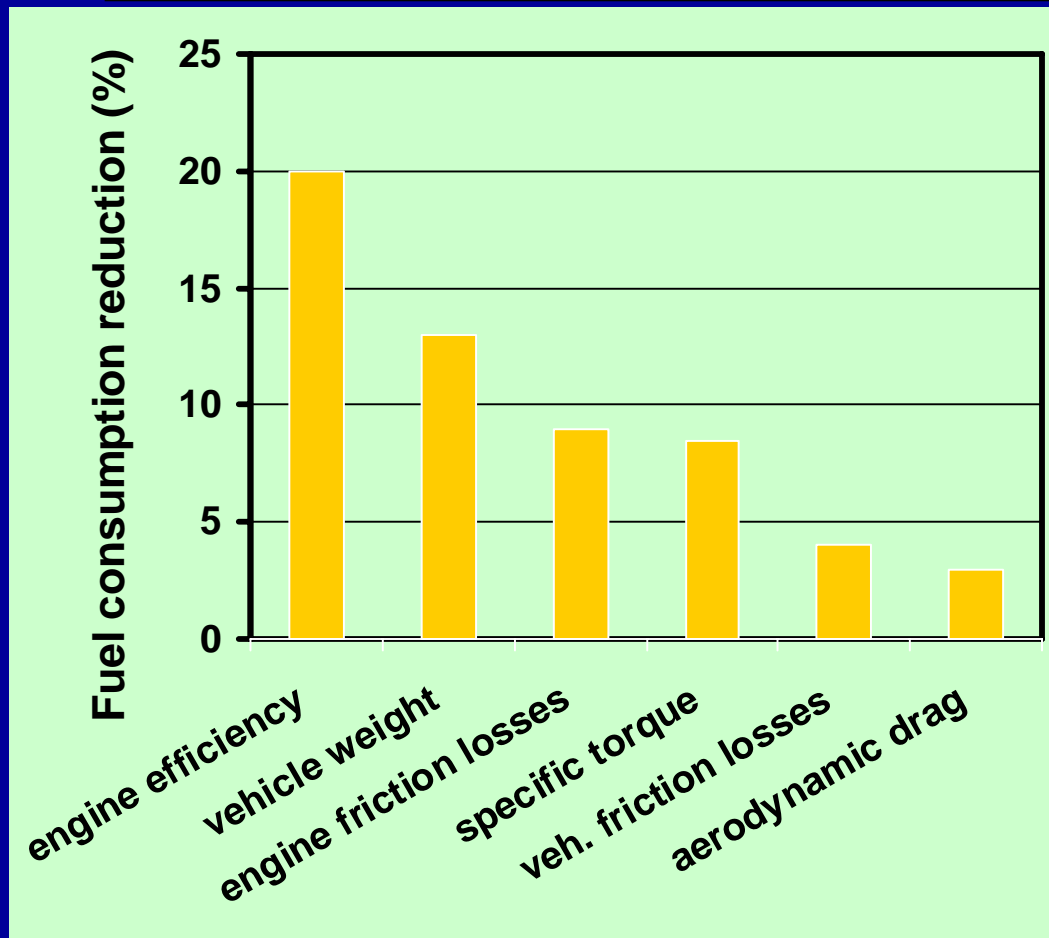
Improvement of the efficiency of gasoline and diesel engines



Large increase of diesel car penetration (particularly for the heaviest vehicles)

Engine efficiency is a key factor for vehicle fuel consumption reduction

Fuel consumption reduction of passenger cars : effect of a 20% improvement on each of the main controlling parameters



Standard European NMVEG driving cycle, characterized by a mixed urban and peri-urban travel



Significant reduction of the fuel consumption (CO₂) can be achieved by powertrain system improvements :

- engine efficiency
- specific torque and power (downsizing)
- optimization of the engine operating conditions with variable transmission, automatic gear box, hybrid systems, etc.

A large number of possible solutions to reduce CO₂ and pollutants emissions for engines and fuels

Conventional powertrain

- Port Fuel Injection Spark Ignition (PFI) or Direct Fuel Injection Spark Ignition Engines (DISI)
- Compression Ignition Engines (Diesel and HCCI)
- Manual or automatic transmission

Conventional fuels

- Derived from crude oil refining
- With oxygenate components and additives

Alternative powertrain

- Dedicated engines (CNG, GTL, DME,...)
- Electrical motor (batteries or Fuel Cell)
- Hybrid vehicles (IC engine and electrical motor)
- Advanced transmissions, CVT

Alternative fuels


- Gaseous fuels: LPG, CNG
- Synthetic fuels : DME, GTL, BTL, CTL, H₂
- Bio-fuels : ethanol, ETBE, MTBE, FAME, FAEE

- Local pollution
- GHG emissions
- Energy supply

Potential of gasoline engine technologies

Strength : SULEV capacity and moderate cost technology

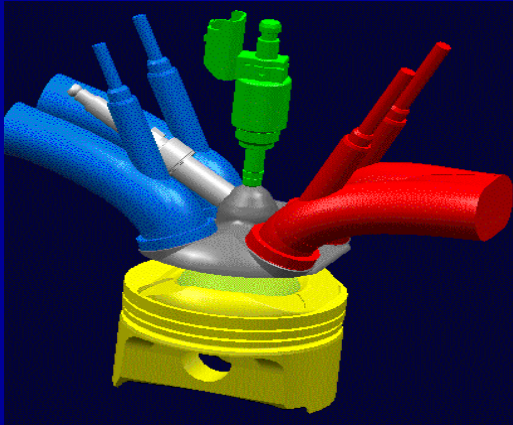
Weakness : About 20 % more CO₂ than today diesel

 **Expected evolutions : fill the gap with today diesel CO₂ emissions**

GASOLINE ENGINE (for the same vehicle weight and power)	Fuel consumption improvement *
Advanced combustion <ul style="list-style-type: none"> ▪ Direct injection (GDI), stratified charge combustion ▪ Auto-ignition Combustion (CAI) 	10 to 15 %
Variable Valve Actuation (VVA) <ul style="list-style-type: none"> ▪ Valves with variable timing (VVT) ▪ Intake valves with variable lift (VVL) ▪ Electromechanical valves ("camless") 	5 to 15 %
Turbo-charging and reduced capacity <ul style="list-style-type: none"> ▪ Indirect injection ▪ GDI + VVA ▪ GDI + VVA + variable compression ratio (VCR) 	10 to 30 %

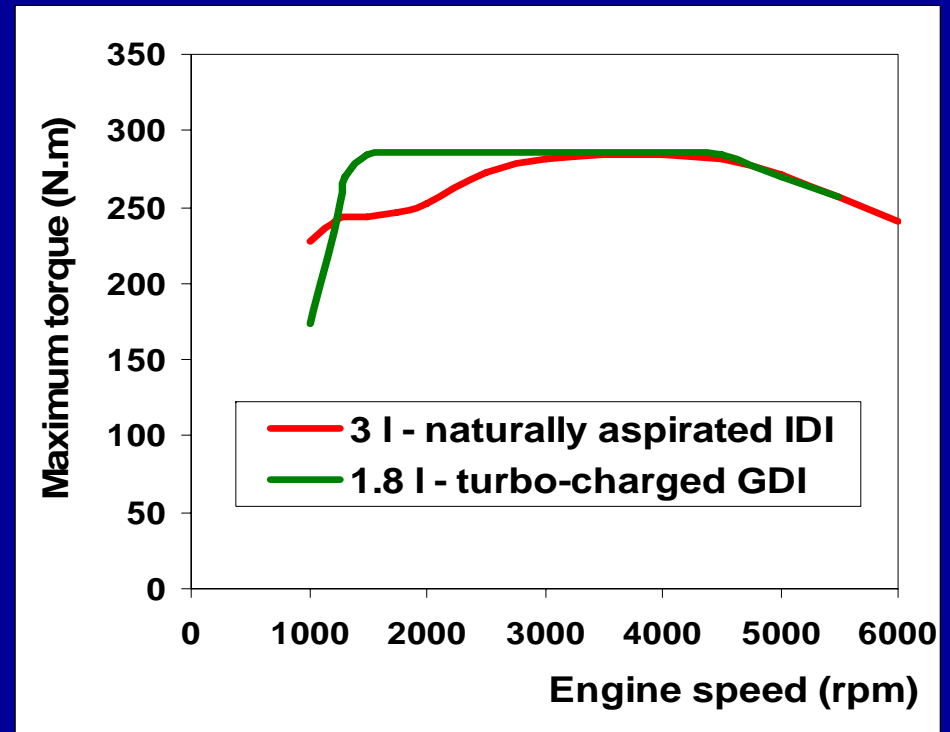
* by comparison to the gasoline standard motorcar combustion engine equipped with a 3W catalyst

The downsizing approach for SI engines



Performances of a 1.8 l downsized IFP prototype engine versus a 3 l marketed engine

- GDI concept
- Turbo-charging
- Valves with variable timing (intake and exhaust)



Improvement in fuel consumption : 20 to 25 % (urban driving cycle)

Potential of diesel engine technologies

Strength : very fuel efficient and well proven technology

Weakness : must reduce NO_x and particulates emissions

→ Expected evolutions : same NO_x and PM emissions as gasoline and slight fuel consumption improvement (5 to 10 %)

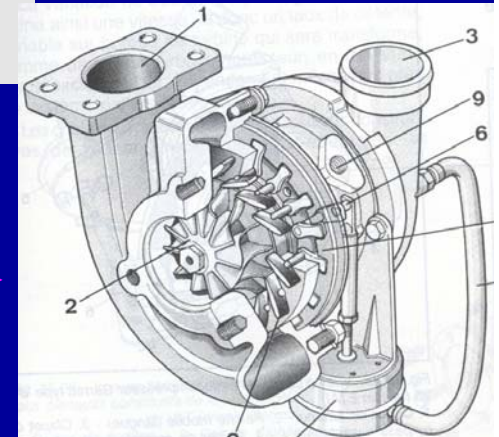
Development of small capacity engines with very high specific performances (80 kW/l – 200 Nm/l) → downsizing



Two key technologies

high pressure fuel injection systems (Common Rail)

turbo-charging (variable geometry, twin TC, ...)

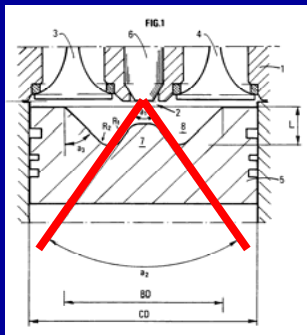


Diesel NO_x and particulates control by mean of HCCL combustion

Development of low temperature combustion processes to reduce drastically the production of NO_x and soot without fuel consumption penalty

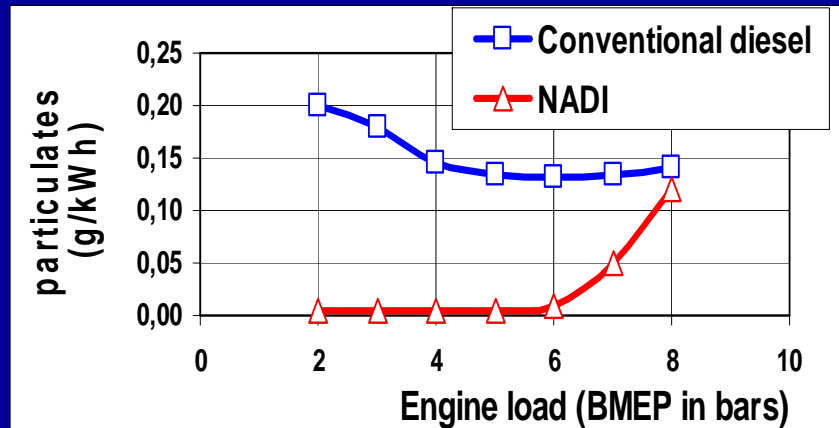
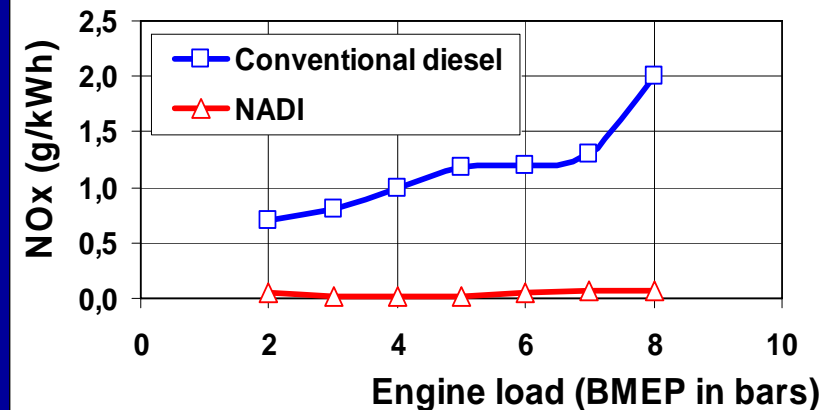
IFP NADI™ concept

"Narrow Angle Direct Injection"



NO_x divided by a factor of 10 to 50

Particulates divided by a factor of 5 to 10



Non conventional engines Hybrid vehicle

A very attractive way for CO₂ further reduction

Strength

- A progressive evolution is possible : light → mild → full hybrid
- A good balance between pollutants & CO₂ emissions
- An addition value for the client : low noise, high electric power onboard, automatic transmission, ...

Weakness

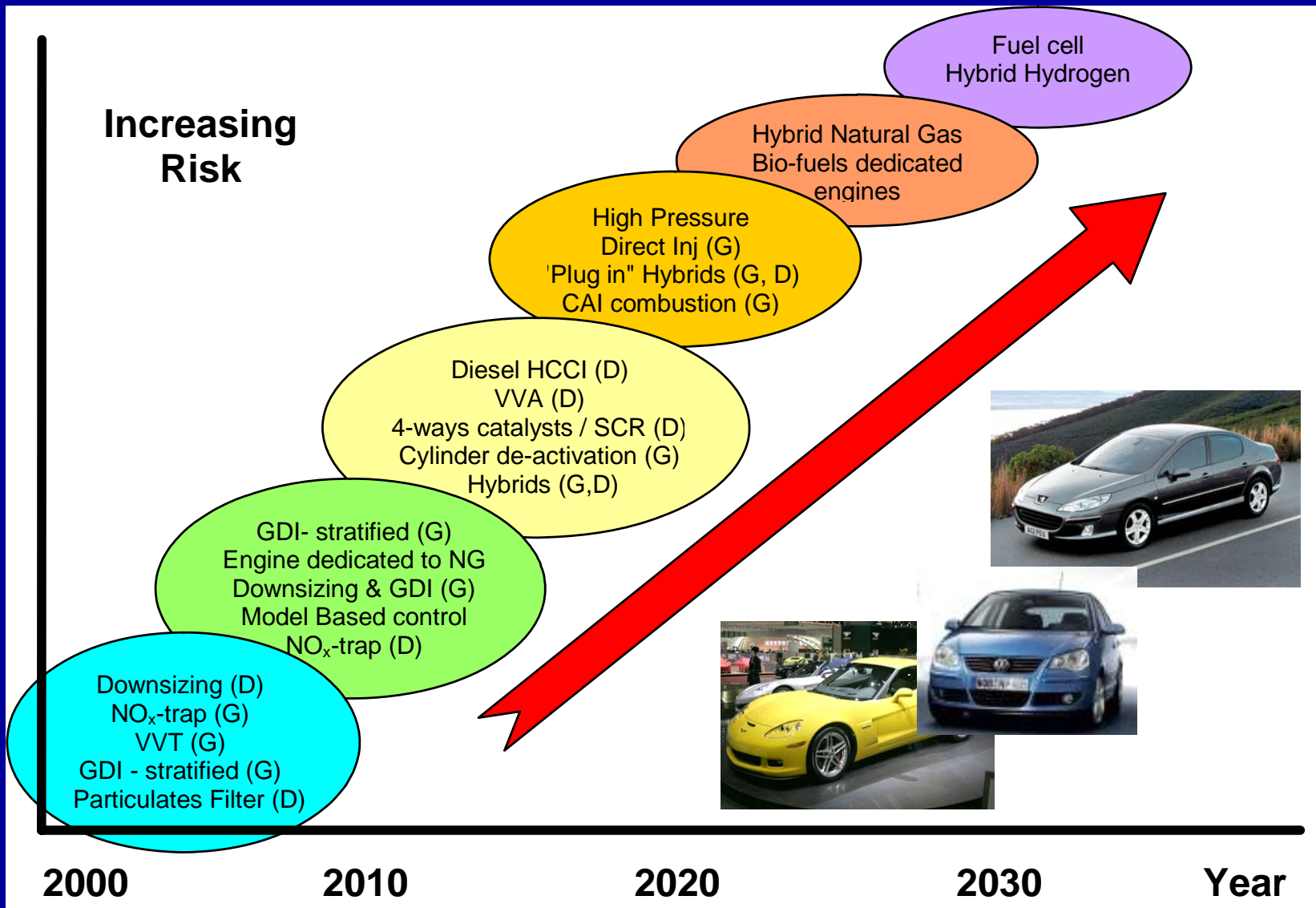
- Important cost : 2 systems for energy production and storage
- Complex system : energy management issue
- Efficient electric storage : cost, weight, reliability, ...

Non conventional engines Hybrid vehicle

The different steps of hybridization and their potential versus fuel consumption

Functions	Power of the electrical motor	Reduction of CO ₂ emissions
Stop of the internal combustion engine at idle ("Stop & Start")	~ 2 kW	~ 8 %
+ Recovery of the braking energy	~ 3 kW	~ 13 %
+ downsizing of the internal combustion engine and boost during acceleration	~ 10 kW	~ 30 %
+ full hybrid serie / parallel	~ 30 kW	~ 45 %

Passenger cars powertrain roadmap



Thank you for your attention