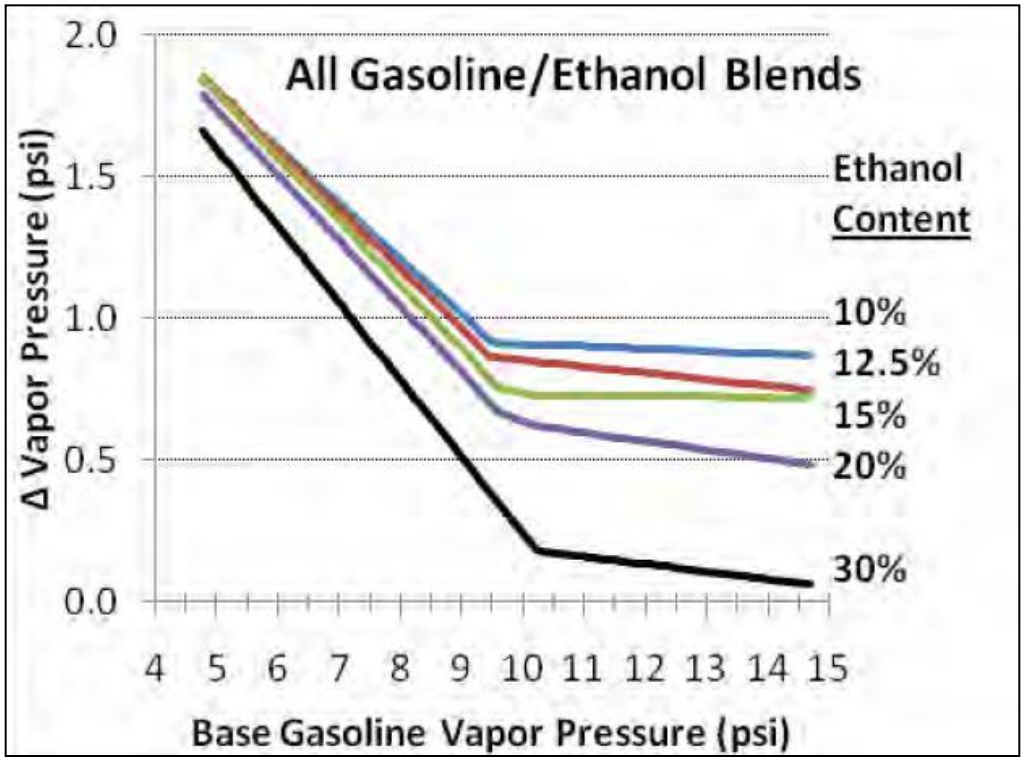
LOW & MID-LEVEL "SPLASH BLENDED"



Source: "Determination of the Potential Property Ranges of Mid-Level Ethanol Blends" – Final Report - American Petroleum Institute, April/2010

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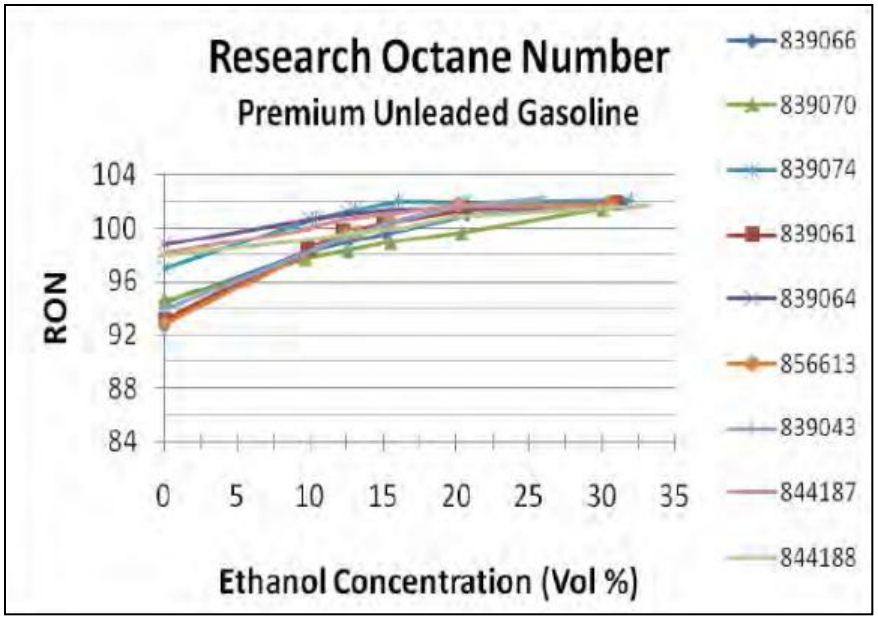

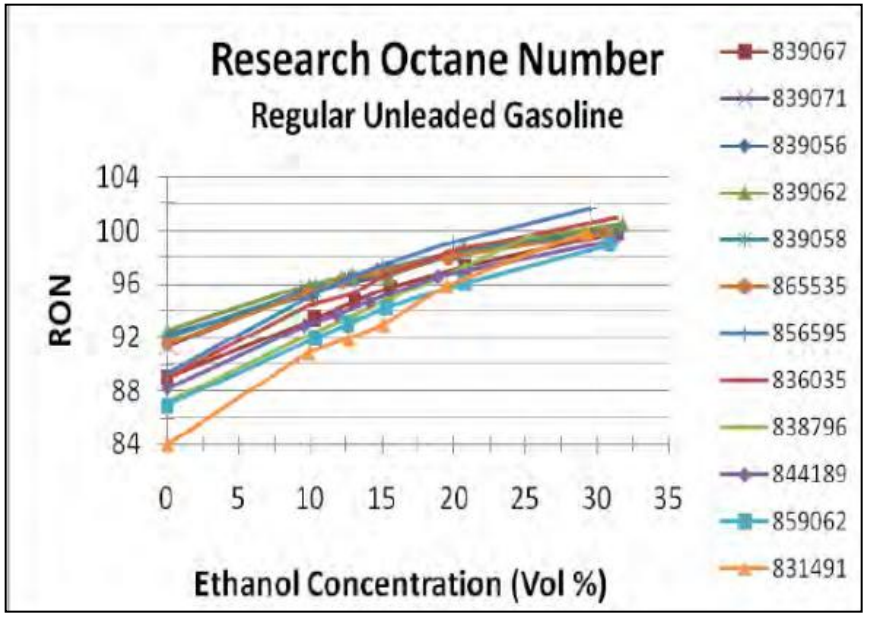

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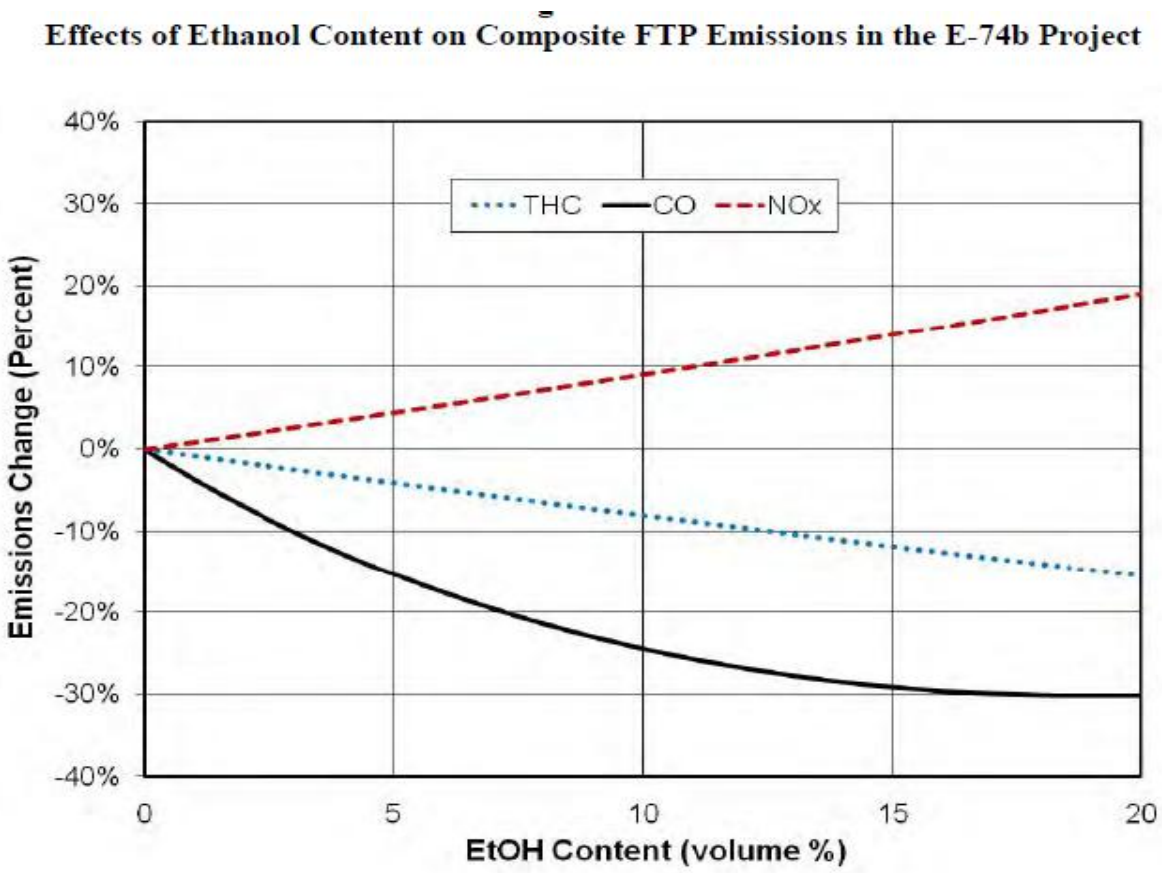
LOW & MID-LEVEL BLEND: EXHAUST EMISSIONS



Used cars emissions: Tier 1; NLEV, LEV and ULEV; Tier 2 Bin 9 and Tier 2 Bin 5.

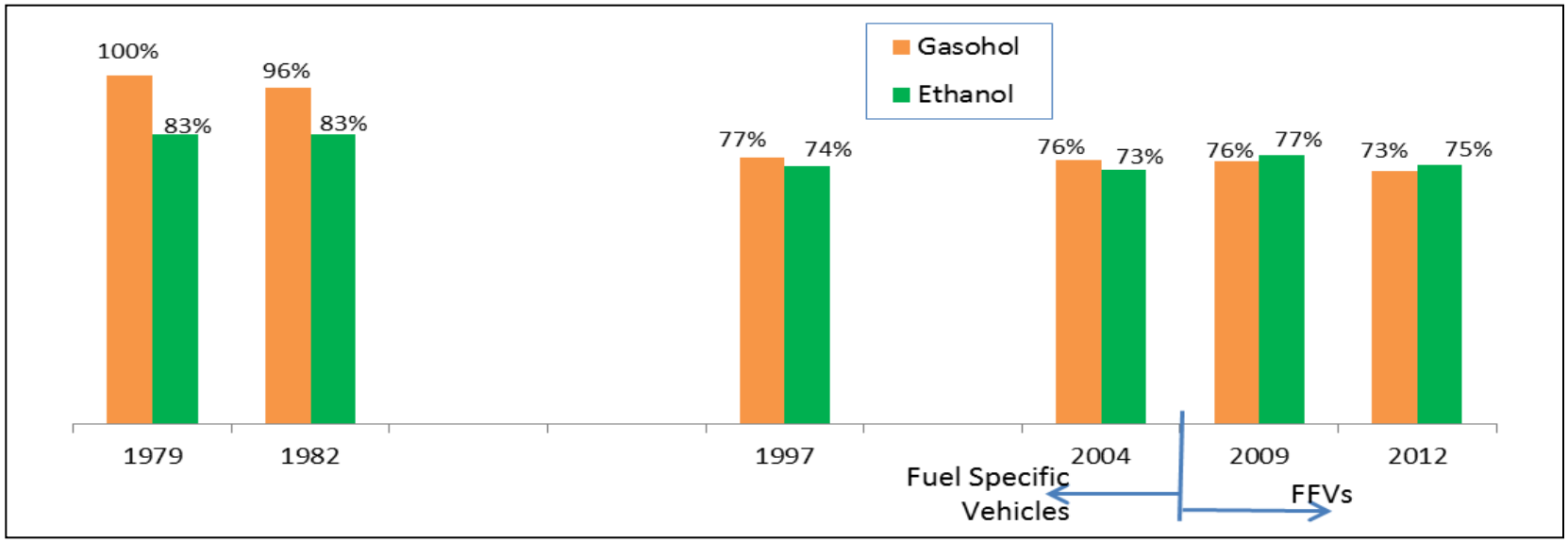
Fuel consumption (L/km) increases about 2,5% for each 10% blend.

Source: “Effects of Vapor Pressure, Oxygen Content, and Temperature on CO Exhaust Emissions” – CRC May/2009

STRAIGHT ETHANOL AND FLEX FUEL VEHICLES

- Brazil, the US and Sweden use high-level blends of ethanol in dedicated or FFVs (E85 in the U.S. and Sweden and E100 Hydrous in Brazil);
- Responsible for about 17% of world-wide ethanol consumption, mainly in Brazil;
- Brazil has produced 5.6 million straight ethanol vehicles from 1979 till 2005 and from 2003 to nowadays more than 20 million FFVs;
- U.S. has produced more than 14 million FFVs, since the 1990's. Fuel economy data show that FFVs on E85 have about 3% better fuel energy efficiency (km/MJ) than with E10; bigger models have larger advantage;

ENERGY CONSUMPTION BY BRAZILIAN CARS



Nigro, F.; Swarcz, A. "Ethanol as Fuel" in book "Ethanol and Bioelectricity: Sugarcane in the Future of the Energy Matrix"; – UNICA, 2010

- **1979 – Development emphasis was totally on fuel economy (Rc 7.5 → 11:1, full-load lean mixture, intake air heating, poor drivability)**
- **1985 – Torque gain → engine down-speeding (Rc 8.5 → 12:1, materials compatibility, lean mixture, equal performance)**
- **1997 – 3 way-catalyst (λ = 1, Rc 10 → 13:1, torque gain → performance bonus)**

MOVING FROM NEAT ETHANOL TO FFVs IN BRAZIL

- The arrival of electronic control of spark timing and fuel metering allowed for the engines to become adaptable to different fuels.
- After great changes in the energy price ratio of ethanol and gasoline have occurred, the vehicle consumers were eager to have the possibility to choose the fuel at every fill up, instead of every time they would buy a new car.
- The automotive industry benefitted from the unification of ethanol and gasoline production lines.
- One technology of local use was replaced by another with possibilities of global application.

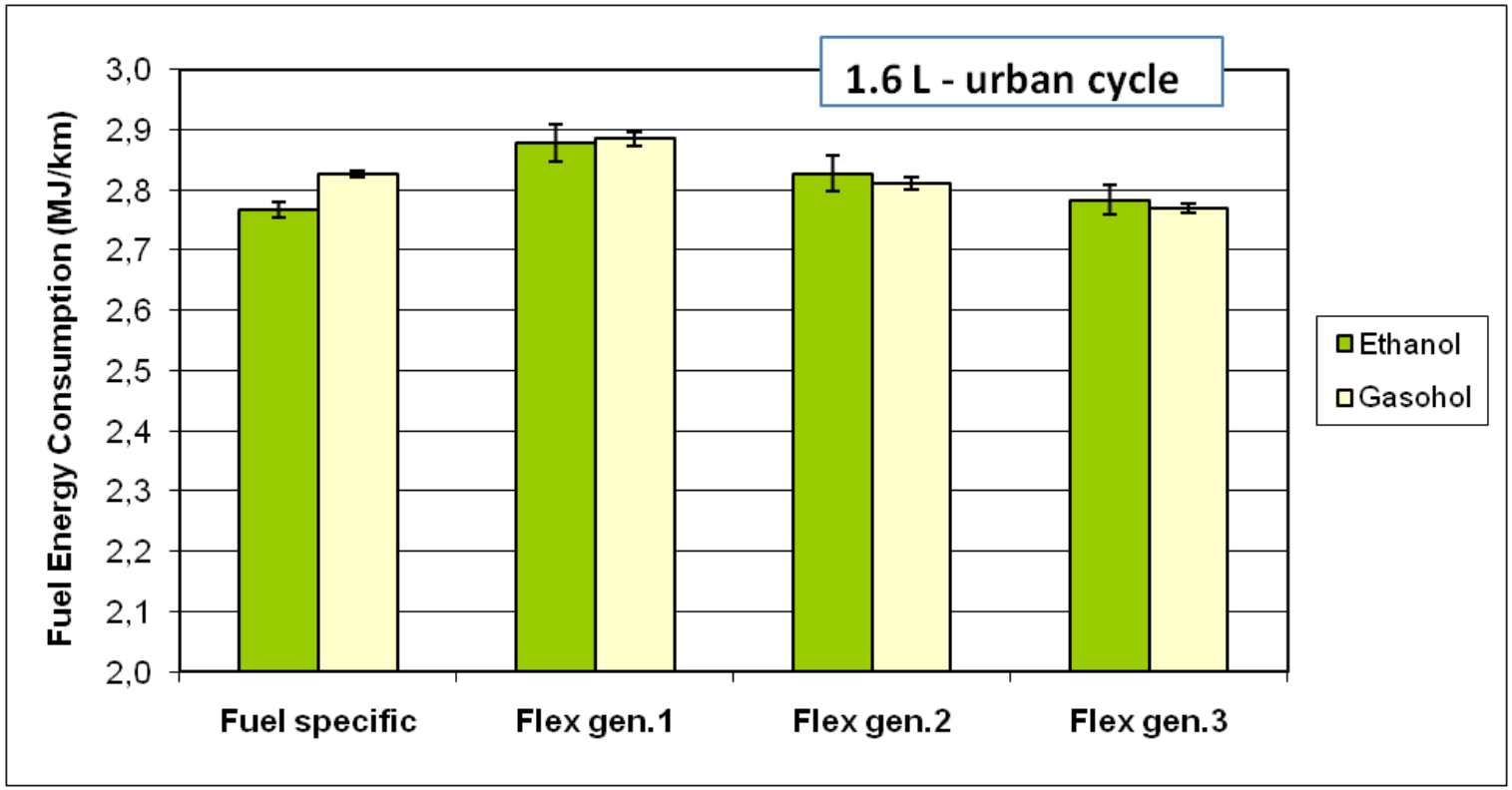
FFVs EVOLUTION IN BRAZIL (Volkswagen View)

Km/L

Generation	For Sale Since	Engine Compression Ratio	Engine Power	Engine Torque	Fuel Efficiency	Gasoline Injection Cold Start System
1st	2003	10,1 ~ 10,8	2,1% Higher w/ Ethanol	2,1% Higher w/ Ethanol	25% ~ 35% Lower w/ Ethanol	Yes
2nd	2006	10,8 ~ 13,0	4,4% Higher w/ Ethanol	3,2% Higher w/ Ethanol	25% ~ 35% Lower w/ Ethanol	Yes
3rd	2008	11,0 ~ 13,0	5,6% Higher w/ Ethanol	9,3% Higher w/ Ethanol	25% ~ 30% Lower w/ Ethanol	Yes
4th	2009	11,0 ~ 13,0	5,6% Higher w/ Ethanol	9,3% Higher w/ Ethanol	25% ~ 30% Lower w/ Ethanol	No E-Flex System

Joseph, H. “New Advances on Flex Fuel Technology” Ethanol Summit , 2009

PROGRESSION OF FUEL CONSUMPTION OF FFVs (data on single model)



Data from "Reports on the Production Emission Values"- error bars refer to 95% confidence interval for the mean value. Production conformity requires testing of at least 0.2% of the vehicles.
Nigro F.& Szwarc A. – "O etanol como combustível" from the book "Etanol e Bioeletricidade"- UNICA -2010

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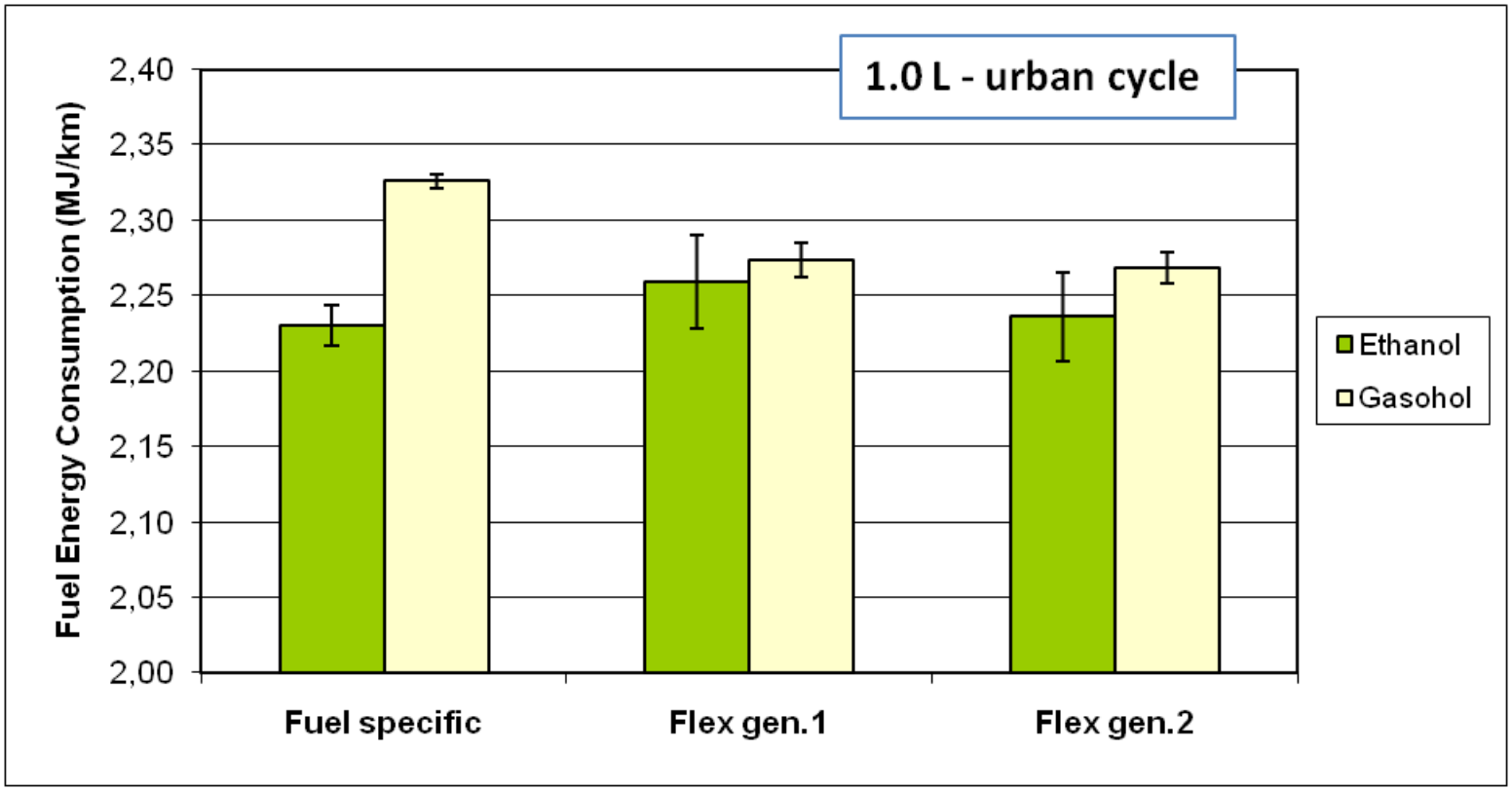

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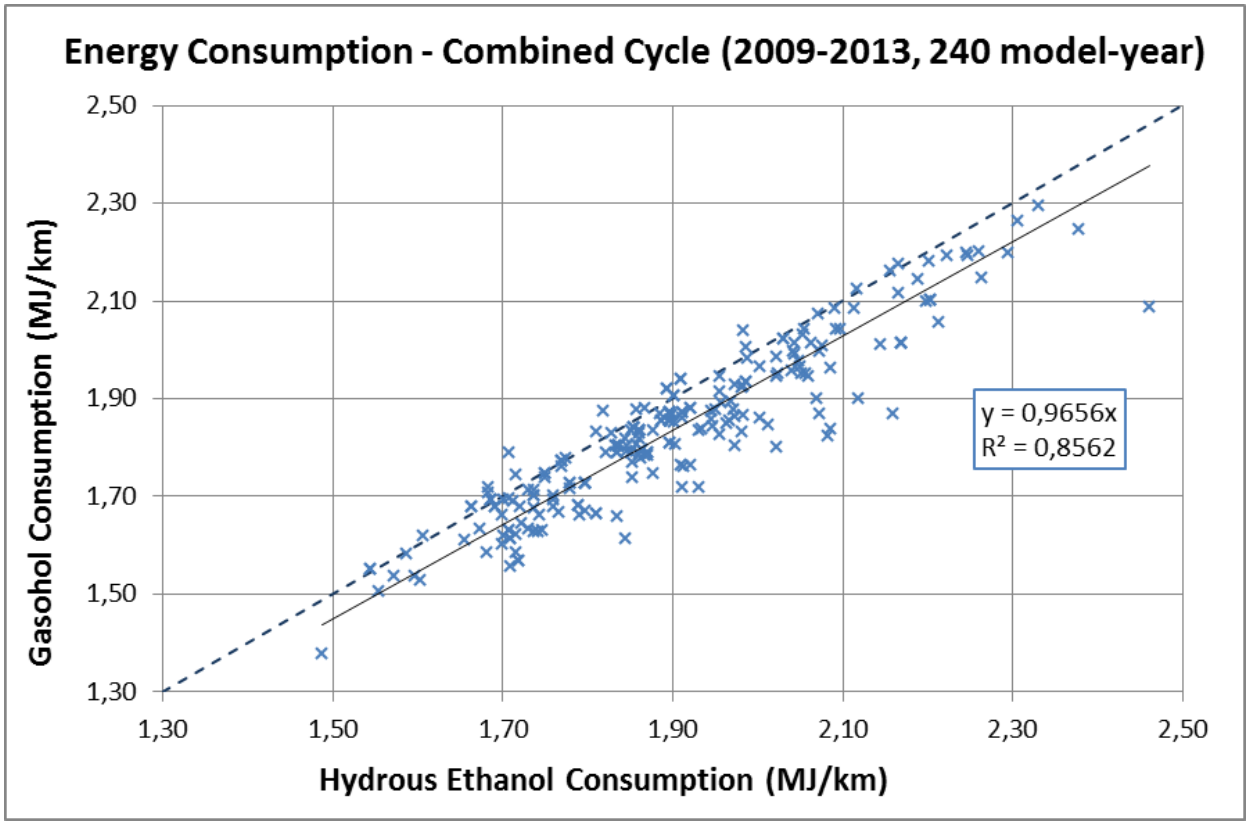
FLEX FUEL VEHICLES – ENERGY CONSUMPTION

Average energy consumption with ethanol is 3.4% higher than with gasohol in Brazilian FFVs



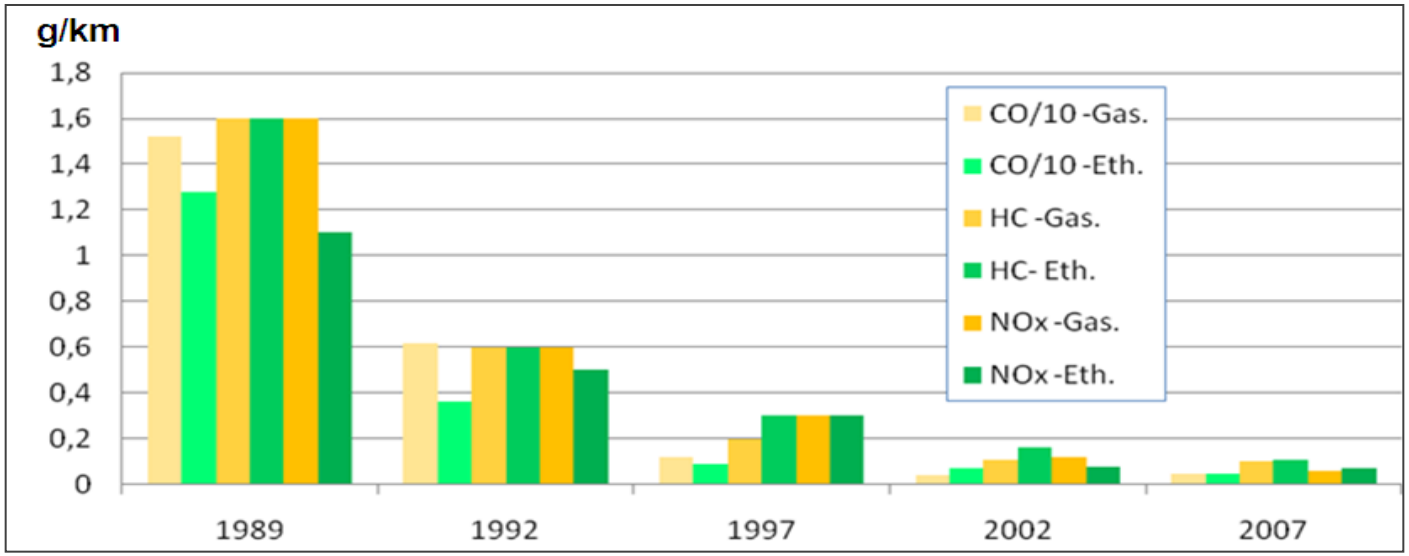
Original data from "Program Brasileiro de Etiquetagem Veicular", compiled and adapted by the author, 2014.

EXHAUST EMISSIONS OF E85 X GASOLINE (U.S.)

- **In the U.S.,Tier 1 FFVs running on E85, compared to similar non-FFVs running on gasoline, have shown 54% reduction of NOx, 27% of NMHCs, and 18% of CO;**
- **Tier 2 FFVs under similar conditions show, on average, 20% reductions in CO and no significant effect on NMOG emissions.**

U.S. EPA, Regulatory Impact Analysis: Renewable Fuel Standard Program 2007, EPA420-R-07-004 Washington, DC.
U.S. EPA, Renewable Fuel Standard Program (RFS2) Regulatory Impact Analysis, 2010: Washington.

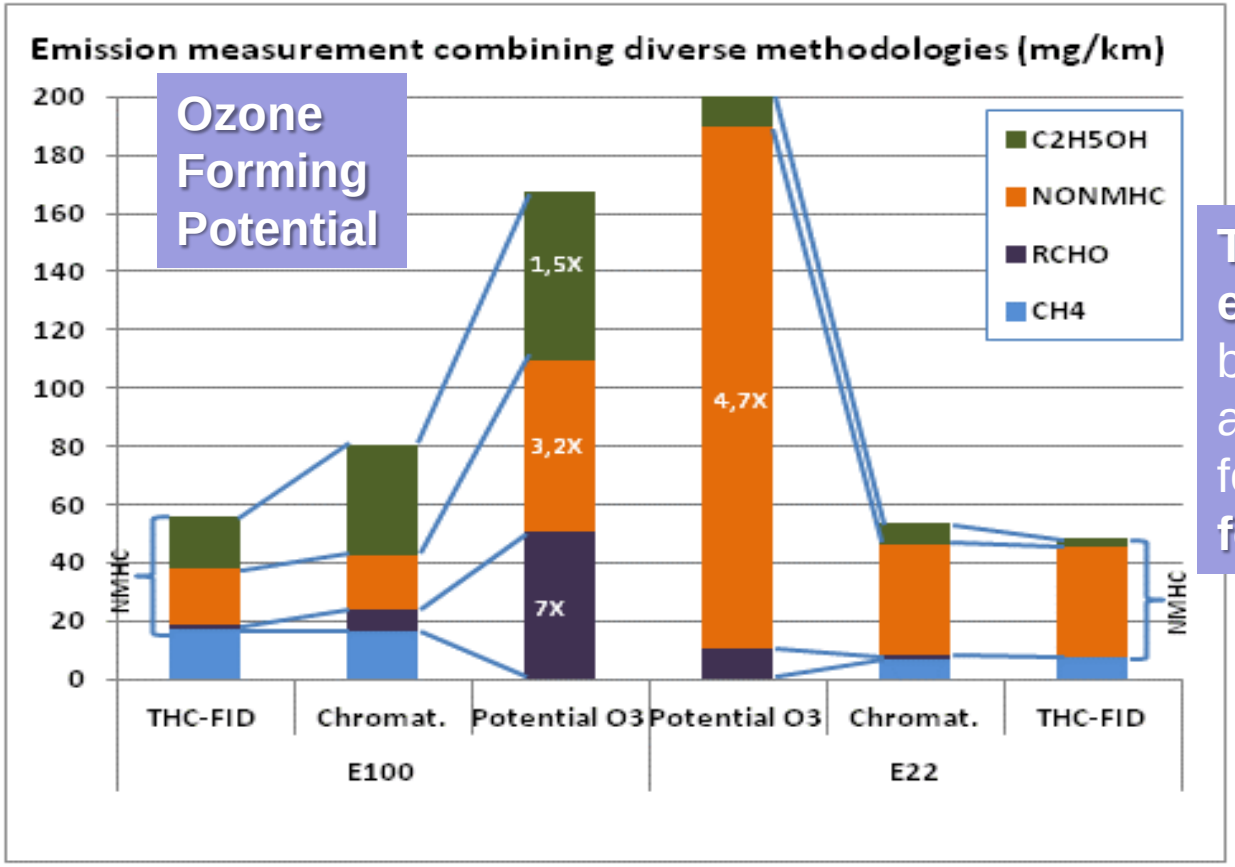
EXHAUST EMISSIONS OF E100H X E22 (BR)



Average data on new sold cars after Cetesb (Report of Air Quality in State of Sao Paulo (in Portuguese) – 2007

- **After the advent of 3 way-catalyst, ethanol lost lean-burn advantage (need of EGR)**
- **Cold phase of cycle dominates total emissions (R, D & I)**
- **Unburned ethanol is important for VOC emissions (ozone forming potential)**

EXHAUST VOC OF FFV ON GASOHOL & ETHANOL



Toxicity-weighted emissions (1,3 butadiene; benzene; acetaldehyde; formaldehyde) : **for E100 << for E22**

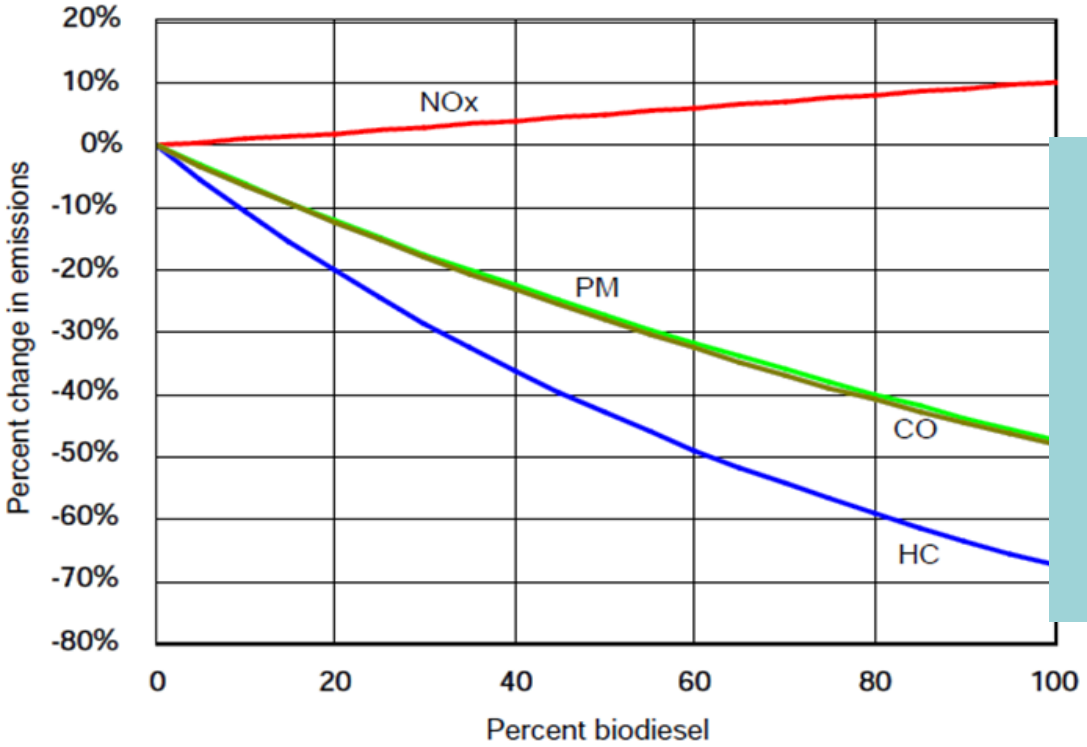
• Branco, G.M., Nigro, F. et al "Emission control of organic compounds based on their ozone forming potential" (in Portuguese) XXI SIMEA – São Paulo – August 2013

• Graner, L.; Garcia, I.S. & Joseph Jr, H. "Comparative qualification of non-methane hydrocarbons in the exhaust gas of a flex fuel vehicle fuelled by E22 and E100)" (in Portuguese) - XXI SIMEA – São Paulo – August 2013

BIODIESEL: LOW-LEVEL BLENDS

- More than 40 countries have policies to use low-level blends in transportation diesel (B2 up to B7);
- World-wide production was over 23 billion liters last year;
- Use of up to B20 is not uncommon in segregated fleets with specific diesel engine models;
- Biodiesel has to attend specifications like ASTM D 6751, EN 14.214 or ANP Resolution Nr. 45/2014;
- Dynamometer tests have shown a small increase in brake energy efficiency by using biodiesel (0.2% for B10);
- Transportation of biodiesel by multipurpose pipelines has caused some issues about contamination of jet fuel.

BIODIESEL: EFFECT ON EMISSIONS



In modern engines equipped with diesel particulate filters, diesel oxidation catalysts and NO_x emission control catalysts the effect on tailpipe emissions is negligeable

Sources: EPA Report “A Comprehensive Analysis of Biodiesel Impacts on Exhaust Emissions” , 2002;
Renewable Fuel Standard Program (RFS2) Regulatory Impact Analysis - Appendix A – EPA Feb/2010
Lammert, M.P., et al., Effect of B20 and Low Aromatic Diesel on Transit Bus NOx Emissions Over Driving Cycles with a Range of Kinetic Intensity. SAE International Journal of Fuels and Lubricants, 2012. **5**(3): p. 1345-1359.

RENEWABLE DIESEL

- It is a hydrocarbon frequently obtained from vegetable oils (Hydrotreated Vegetable Oils – HVO) or from several other fatty residues;
- Worldwide production, mainly in EU and U.S. was over 2.7 billion liters last year;
- In Brazil, Amyris is producing and testing “diesel de cana”, a farnesane obtained by microbial fermentation of sugars;
- Petrobras “Hbio” process was successfully demonstrated in Brazil 8 years ago;
- Production cost is higher than that of biodiesel, but there are advantages in terms of compatibility with on hand engines and distribution chains.

THANK YOU FOR YOUR ATTENTION

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