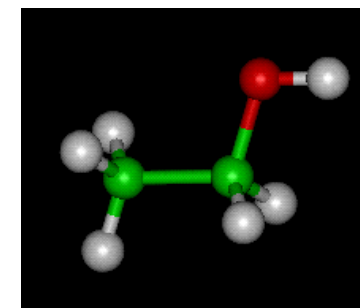


Ethanol Blending- EXX Challenges & Opportunities



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Contents

- FFV Cases at Brazil and North America
- Opportunities & Challenges
- Mitigation
- Summary & Conclusion

Doubts on Ethanol Blended fuel?

Truth or Rumours



image ref: Open-source Google: Toyota



From sugar cane to vehicle CO₂ emission – Brazilian history

Opportunities



Sugar cane
= since 1532 =



1975: Proalcool E100
2003: Flex Fuel E22...E100



Sugar
= since 1533 =



Caipirinha
= since 1918 =

Recipe

- ✓ 1 sliced lime
- ✓ 1 sugar spoon
- ✓ 50 ml of cachaça
- ✓ Ice

Ethanol biofuel business model

The ethanol fuel history in Brazil

- 1973:** Brazilian government started incentives for the production of fuel ethanol due to oil crisis.
- 1975:** Proalcool, The National Ethanol Program, was created to encouraged the production of ethanol and to establish a policy for automotive fuels.
- 1979:** The first vehicle moved with ethanol was launched in Brazil (and in the world as serial production). Fiat 147: 1.3L, carbureted, 62cv and 11,5mkgf.
- 1986:** It was also the peak for Proalcool, when 96% of new cars sold in Brazil used ethanol fuel.

Ethanol biofuel business model

The ethanol fuel history in Brazil

Na Europa eu sou o campeão da Fórmula Ford. Aqui eu dirijo um Corcel II álcool, o campeão da economia.

FORD CORCEL II

Ford merchandise in 1980s:

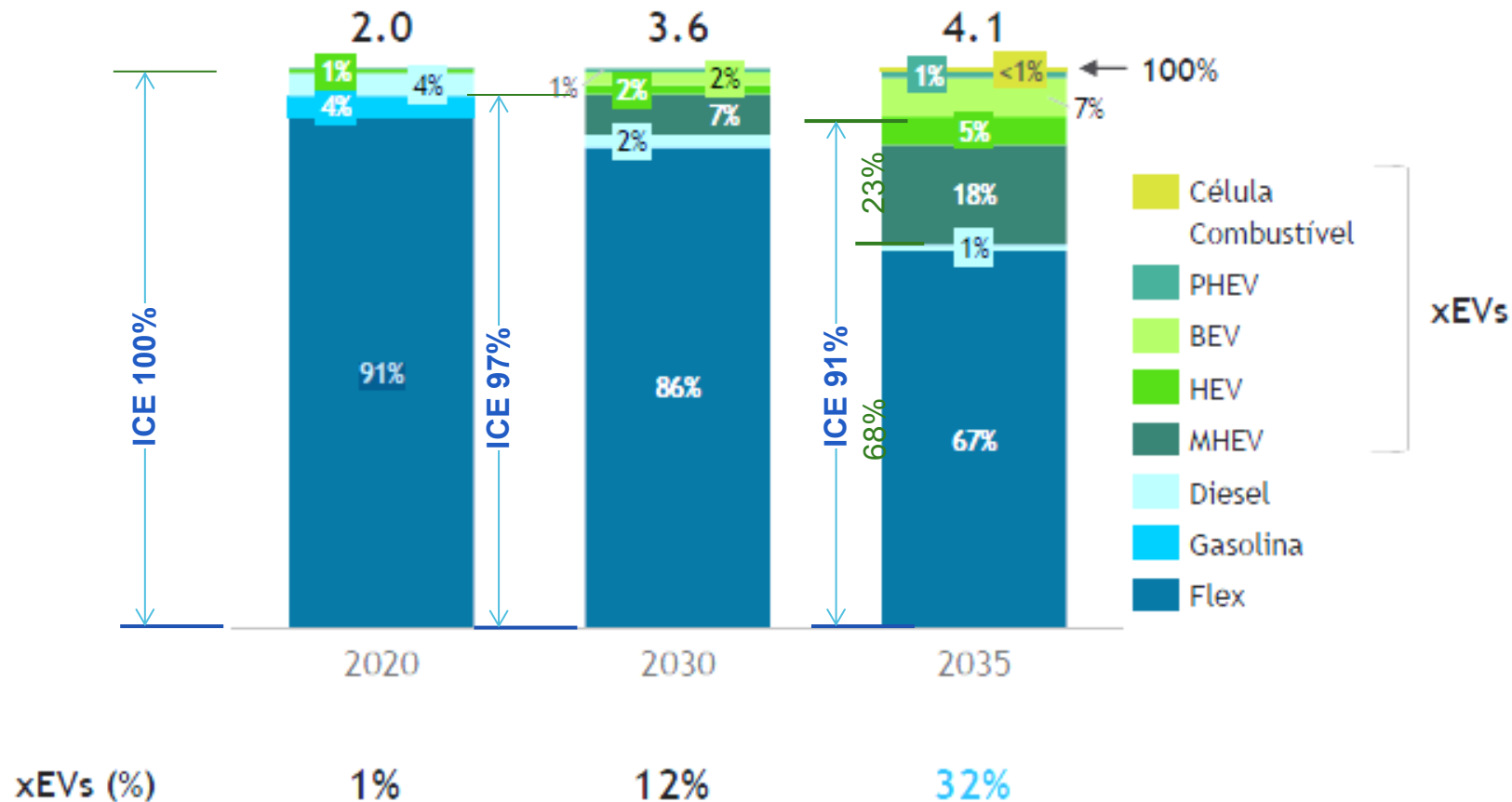
“In Europe I am the Formula Ford Champion. Here I drive a (Ford) Corcel II ethanol, the fuel economy champion.”

Ayrton Senna,

British and European Formula Ford champion in the 1980s.

Light Duty Vehicles Technologies

Annual sales perspective – million vehicles



ANFAVEA, 2021

Ethanol biofuel business model

Opportunities

USA Flex fuel Cars Market Segmentation by Fuel Type (in value %)

USA Flex fuel Cars Market
USA Flex fuel Cars Market Segmentation by Fuel Type



i ref: Ken Research Analysis

→ Increased Adoption of Flexible Fuel Vehicles (FFVs)

In 2024, there are over **22 million flexible fuel vehicles (FFVs)** operating in the United States, driving demand for flex-fuel cars. The governments push towards biofuels such as **E85** has contributed to this growth, with over **4,000 fueling stations** across the country now offering E85. This growing infrastructure is encouraging more consumers to adopt flex-fuel cars, enhancing market potential. Macroeconomic factors, such as stable gasoline prices, are further boosting consumer interest in more fuel-efficient and environment-friendly alternatives like flex-fuel vehicles.

→ Government Incentives for Biofuels

The U.S. governments **Renewable Fuel Standard (RFS)** mandates the blending of renewable fuels into the gasoline supply. In 2024, this initiative will inject approximately **36 billion gallons of biofuels** into the fuel market, increasing the appeal of flex-fuel cars. The availability of tax incentives for both manufacturers and consumers for producing and purchasing FFVs has driven substantial growth.

→ Economic Advantages of Ethanol-based Fuels

As of 2024, ethanol prices are about **50 cents lower per gallon** than conventional gasoline, making ethanol-based fuels a cost-effective choice for consumers. This economic benefit has made flex-fuel vehicles a financially viable option, leading to increased sales across the USA. Consumers in states with high agricultural output, such as **Iowa and Illinois**, have especially benefited from locally sourced ethanol, further pushing the growth of flex-fuel vehicles.

Ethanol biofuel business model

USA Flex fuel Cars Market Segmentation by Fuel Type (in value %)

USA Flex fuel Cars Market
USA Flex fuel Cars Market Segmentation by Fuel Type



i ref: Ken Research Analysis

Future Market Opportunities

→ Expansion of Biofuel Infrastructure

Over the next five years, it is anticipated that the U.S. will see an increase in biofuel stations, with projections indicating the addition of **3,000 new E85 stations by 2028**. This expansion will make ethanol more accessible to flex-fuel vehicle owners, further boosting the market for FFVs.

→ Technological Advances in Flex-Fuel Engines

By 2028, new flex-fuel engine technologies are expected to improve fuel efficiency by an average of **10–15% when running on ethanol**. These advancements will attract a larger segment of eco-conscious consumers looking for sustainable yet cost-effective vehicle options.

Challenges

Fuel	Stoich AFR
Gasoline	14.7
E20	~13.8
E85	~9.8

Fuel	Volume FC Change
E20	+3 to 5%
E50	+10 to 15%
E85	+25 to 35%

Fuel	Typical Price
Gasoline C	~R\$6.59/L
Hydrated Ethanol	~R\$4.47/L

Ethanol-to-Gasoline Price Ratio

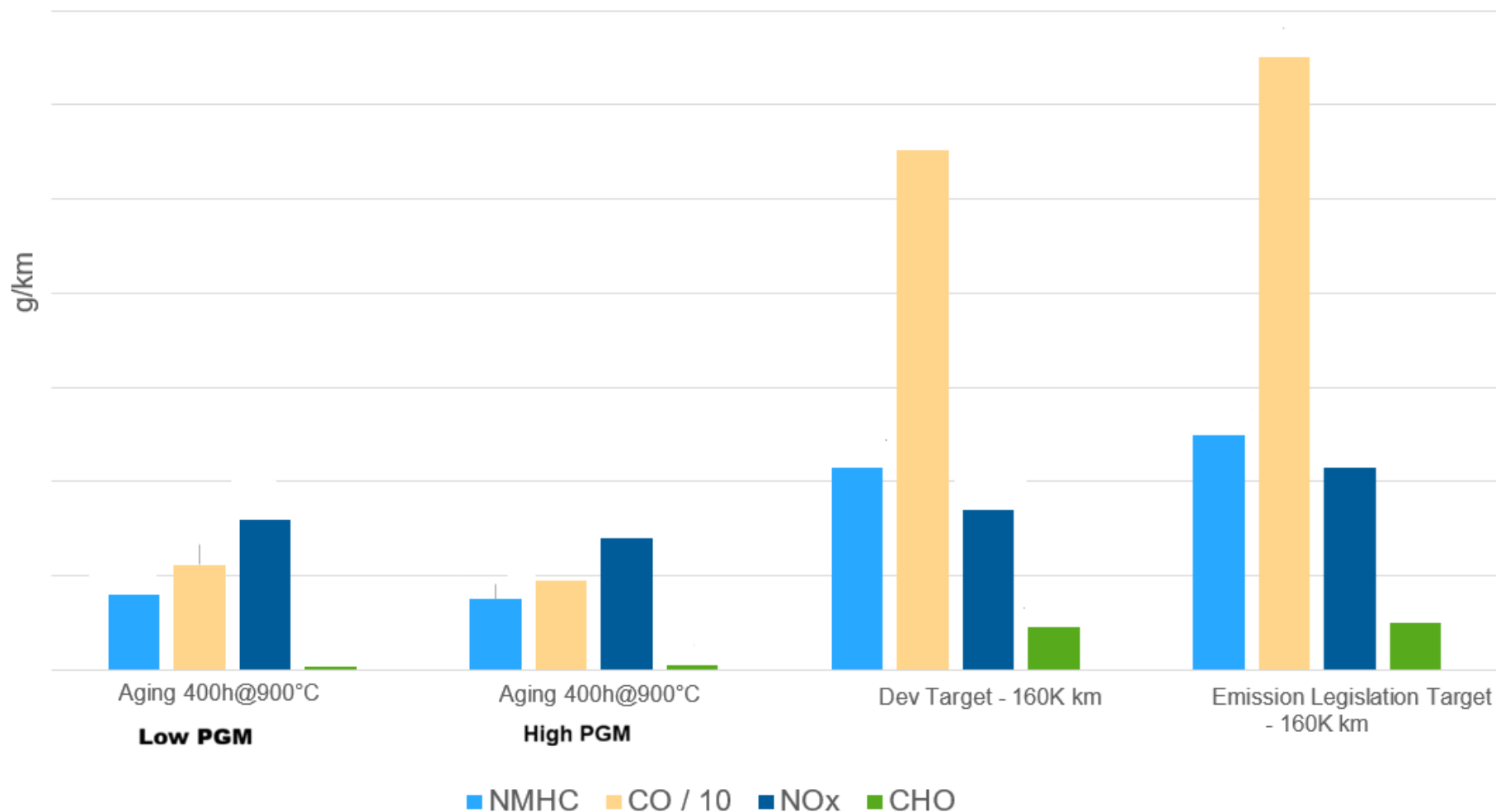
$$\frac{4.47}{6.59} \approx 0.68$$

So ethanol costs about **68% of the gasoline price & be compensated excess FE**

System	Effects to be checked	Mitigations
Fuel System	<ul style="list-style-type: none"> Corrosion Water absorption Ethanol attack Material swelling Stress cracking 	Durability tests Fuel blend identification (Sensor based)
Engine Durability	<ul style="list-style-type: none"> Increased fuel flow Possible oil dilution Moisture accumulation Corrosion 	
Emissions	Cold Start Emissions (Biggest Challenge) <ul style="list-style-type: none"> Difficult fuel vaporization Rich combustion during start Higher HC emissions Delayed catalyst light-off 	Fuel blend identification (Sensor based) Best suited Technology Optimised PGM & PGM Ratio
TCO	<ul style="list-style-type: none"> Maintenance Cost Based on Ethanol blend fuel cost 	

Complying emissions for FFV Engines with best suited Technology is within Reach

Emission Results – E22 Fuel



Complying emissions for FFV Engines with best suited Technology is within Reach

Tail Pipe emission wrt E22

NMHC- 186%



CO - 113%



NOx- 35%



CHO- 400%

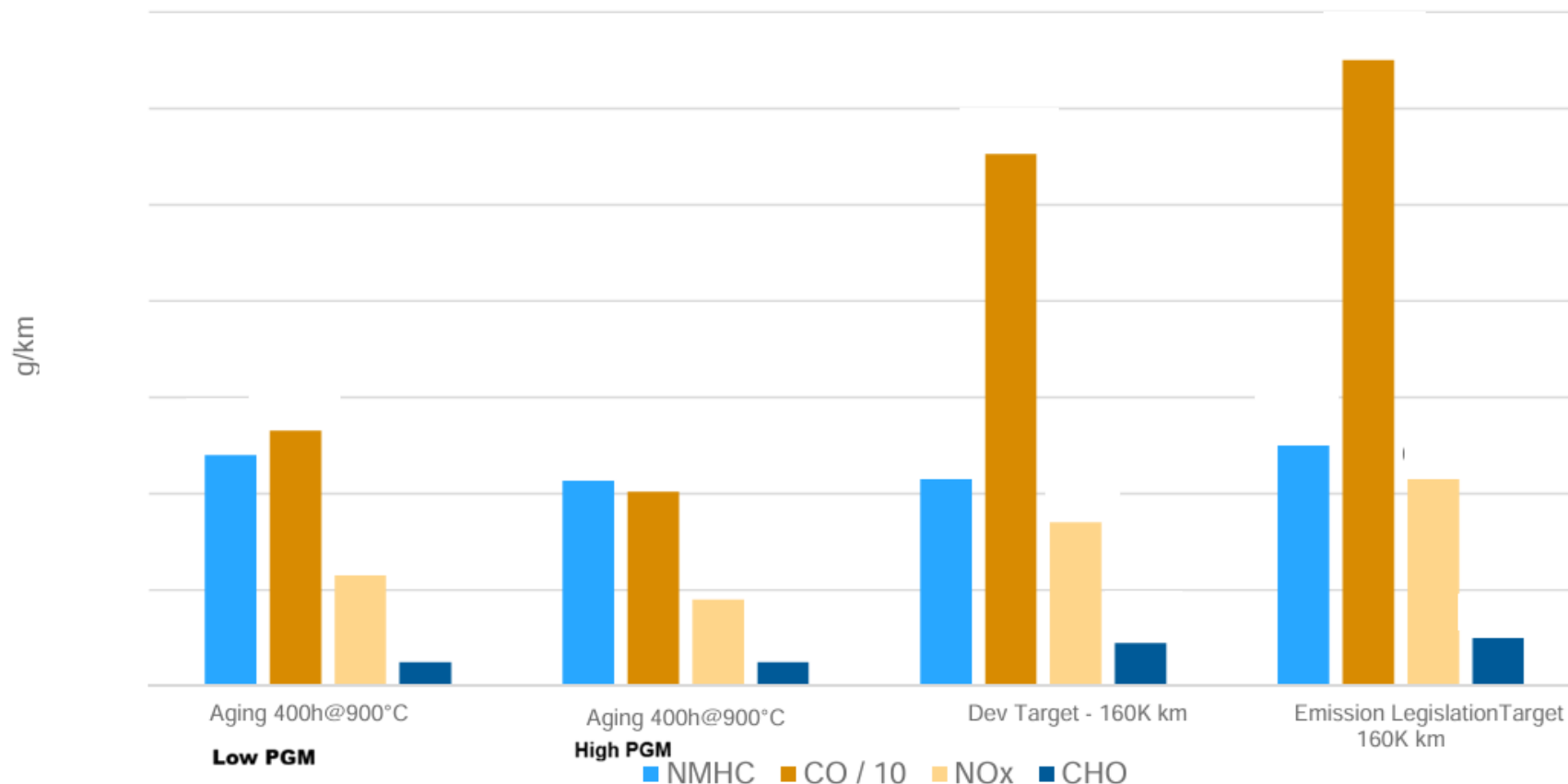


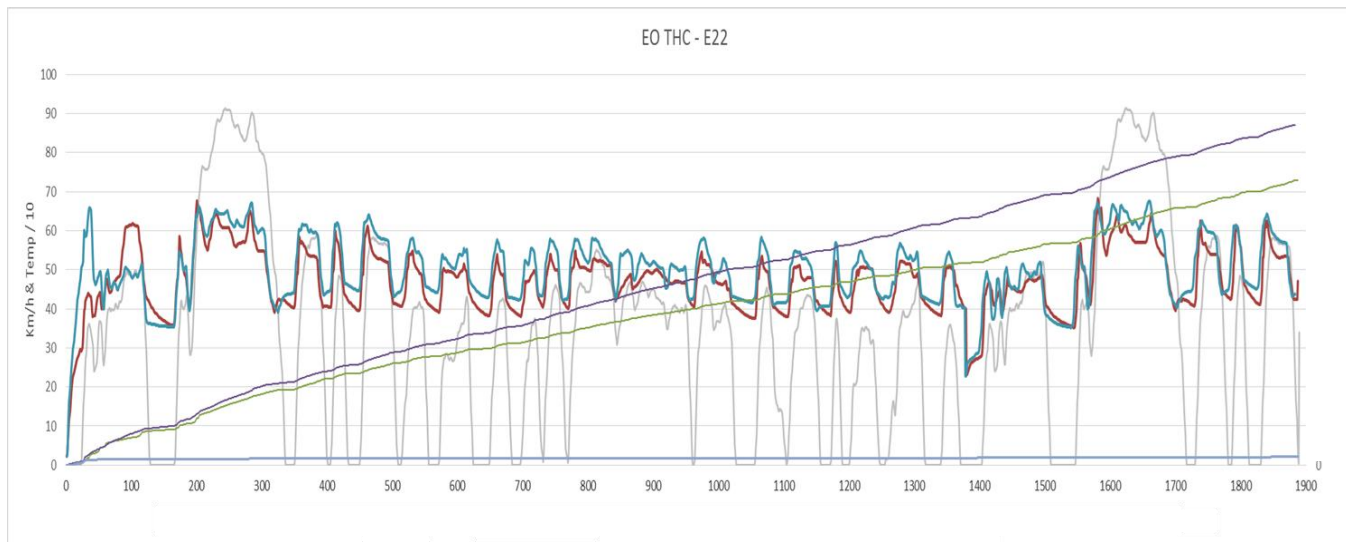
Still within limit

But let's find:

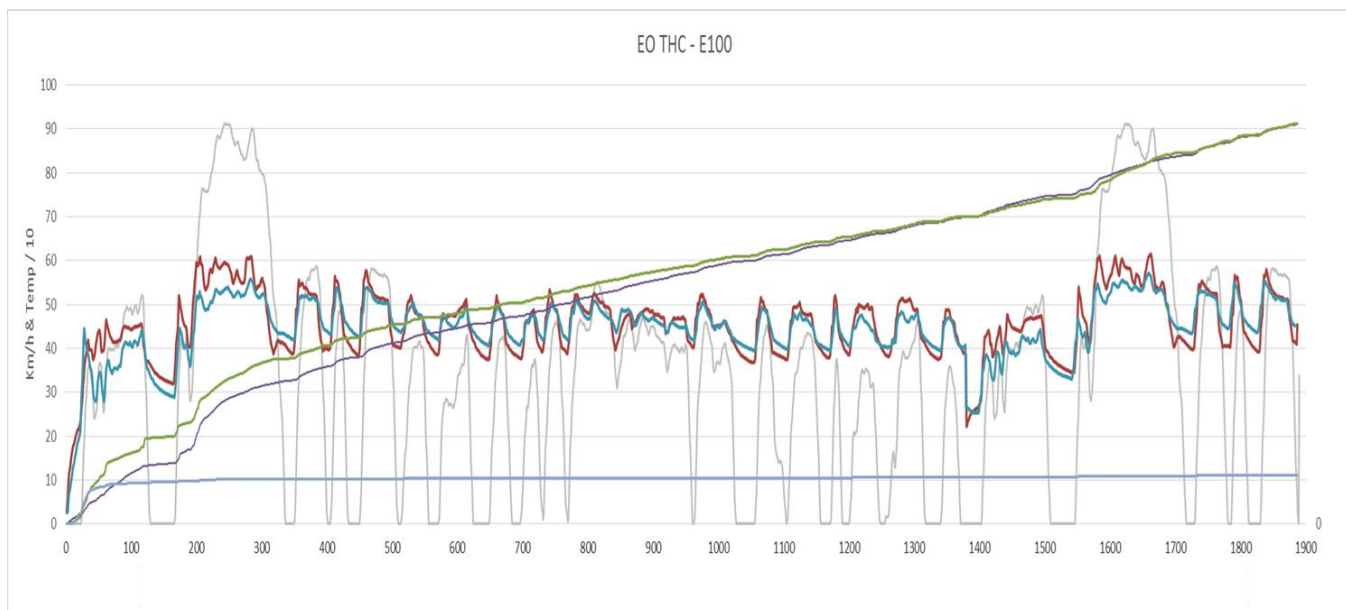
Why and How

Emission Results – E100 Fuel



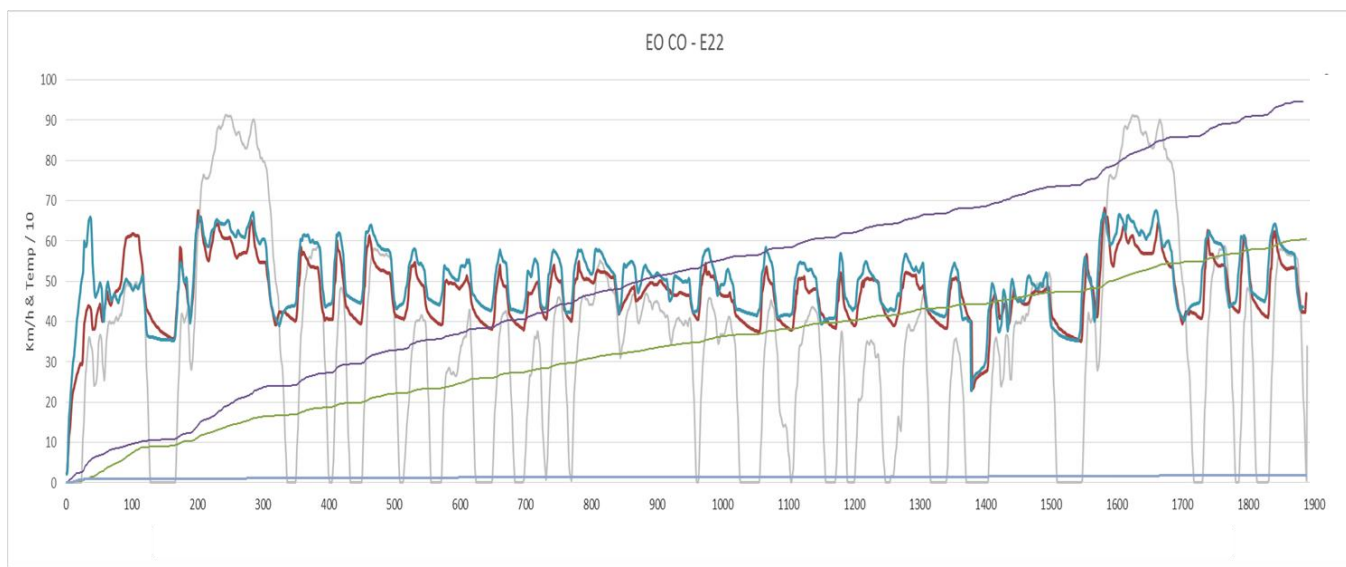


$\eta = 98\%$

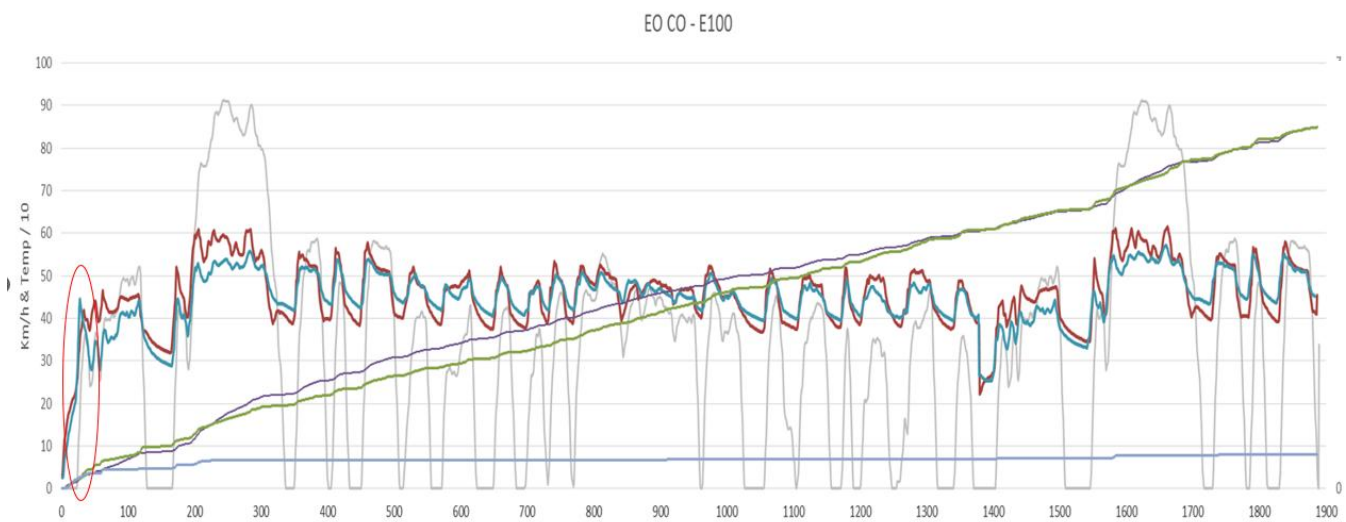


EO THC- 21%↓

$\eta = 91\%$

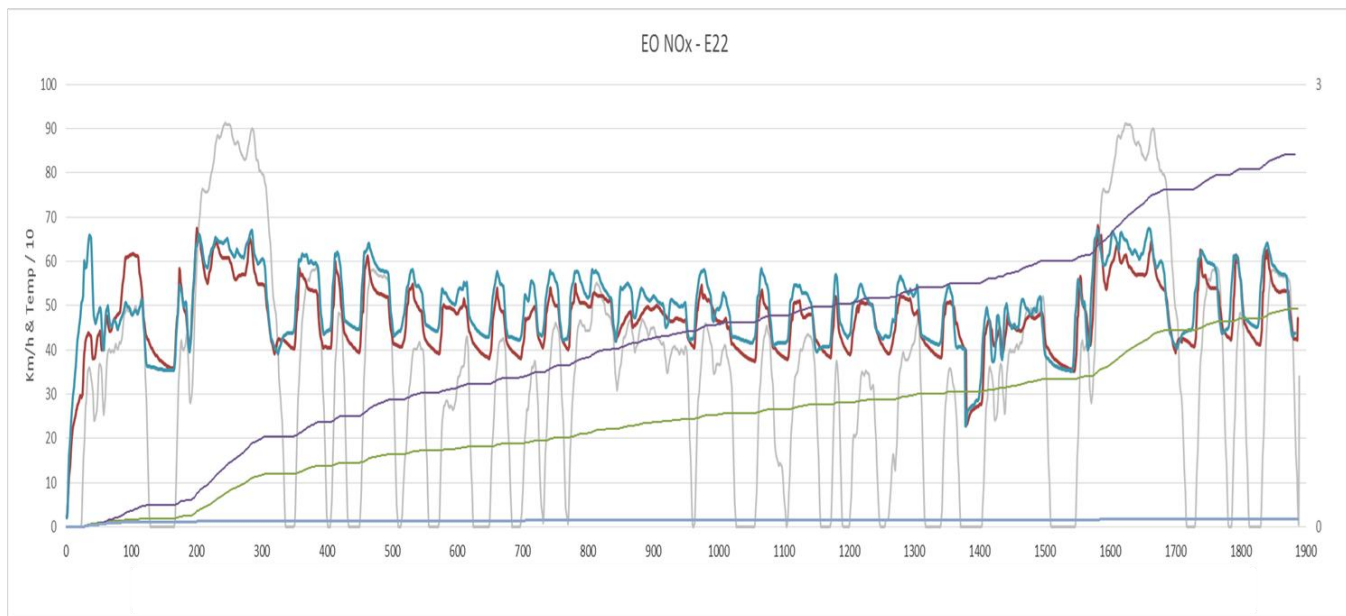


$\eta = 96\%$

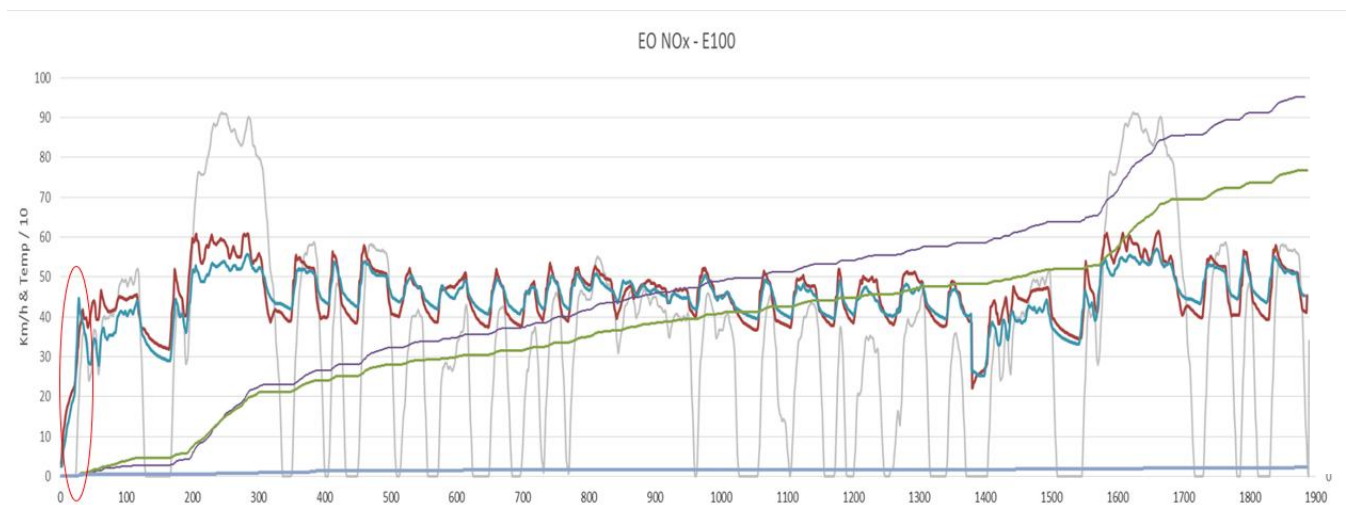


EO CO- 20% ↓

$\eta = 87\%$



$\eta = 98.5\%$



EO NOx- 40% ↓

$\eta = 98.6\%$

Why Conversion Low with E100 than E22 and How to Improve

- **Temperature-** Reduction seen in Cold temp. due to shift to E100

Mitigate with Thermal Management

- **Engine Calibration-** Weak Lambda Cal

Mitigate with Narrow window and swift response , find ideal Lambda inside Catalyst

- **Catalyst Technology-** Typical Gasoline (E5/10) may have lower LO

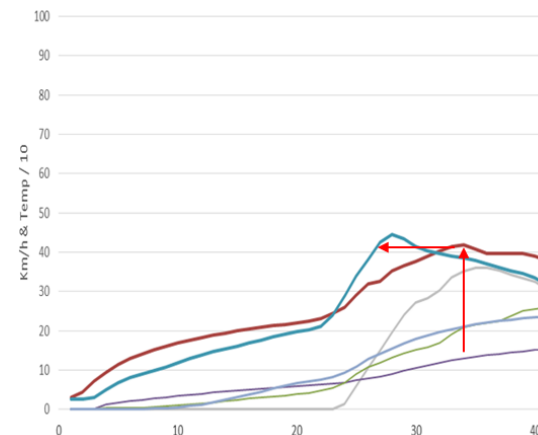
Mitigate Technology having Better LO

Optimise OSC dynamic Performance

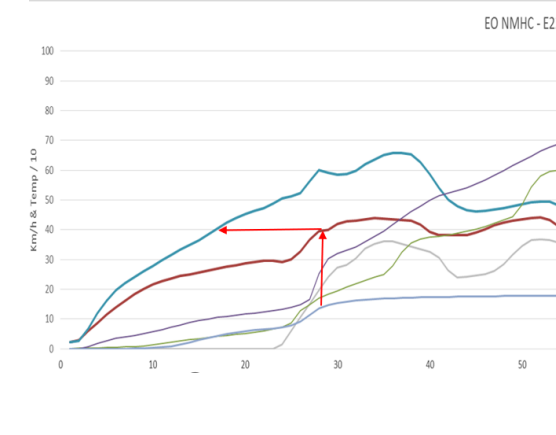
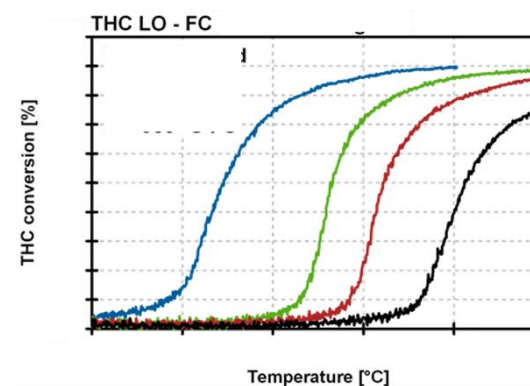
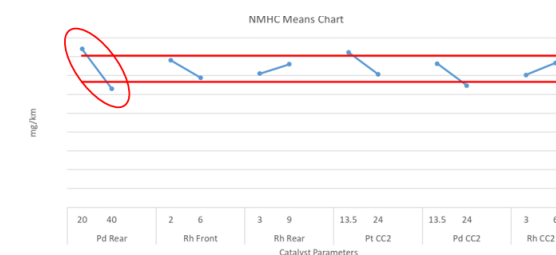
- **PGM Content :** Typical Gasoline (E5/10) may have lower PGM (Pd)

Mitigate Technology by improving PGM especially Pd by ~ 10-15%

E100



E22



NA OEM Mitigation Plans

How U.S. OEMs technically enable and improve Flex-Fuel vehicles

Technology / action	What OEMs do	Why it helps
Ethanol/f	Determine ethanol concentration and adapt engine controls to the actual gasoline/E85 mixture	Allows one vehicle to operate across different ethanol concentrations. Modern FFVs adjust fueling, ignition and emissions control accordingly. [afdc.energy.gov] , [mpgomatic.com]
ECU adaptive calibration	Change injection quantity, spark timing and air-fuel control as ethanol concentration changes	Ethanol has different stoichiometry and combustion characteristics from gasoline, so calibration must continuously compensate. [afdc.energy.gov] , [mpgomatic.com]
Higher fuel-flow	Modify fuel pump and injection system to provide the greater volume of ethanol-blended fuel required	Ethanol's lower energy content means more fuel volume is required for equivalent energy input. The U.S. DOE specifically identifies fuel-pump and injection-system modifications as FFV requirements. [afdc.energy.gov]
Ethanol-compatible fuel system	Use compatible pumps, lines, seals and other wetted components	Prevents material-compatibility problems associated with high ethanol concentrations. [afdc.energy.gov]
Optimized spark timing	Use ethanol's knock resistance to permit more favorable combustion phasing where engine design/calibration allows	Can improve thermal efficiency and/or performance relative to operating the same engine without exploiting ethanol's knock resistance. [mpgomatic.com]
Emission-control recal	ECM changes air-fuel control and manages the three-way catalyst under different blends	Important because FFVs still rely on a TWC and closed-loop control for regulated emissions. [afdc.energy.gov]

Results & summary

- **FFV Powertrain/Vehicle is a strategic pathway to reduce fossil fuel dependency & reduce imports significantly**
- There are certain technical challenges with FFV mainly from Fuel economy wrt Km/L however easy to compensate once demand increase and price of ethanol goes significantly down
- There are success stories from Brazil and North America for FFV hence opportunity for India to develop
- Emission point of view the FFV catalyst technologies are available and the biggest challenge of cold emissions be addressed easily