Ethanol as Decarbonization Opportunity

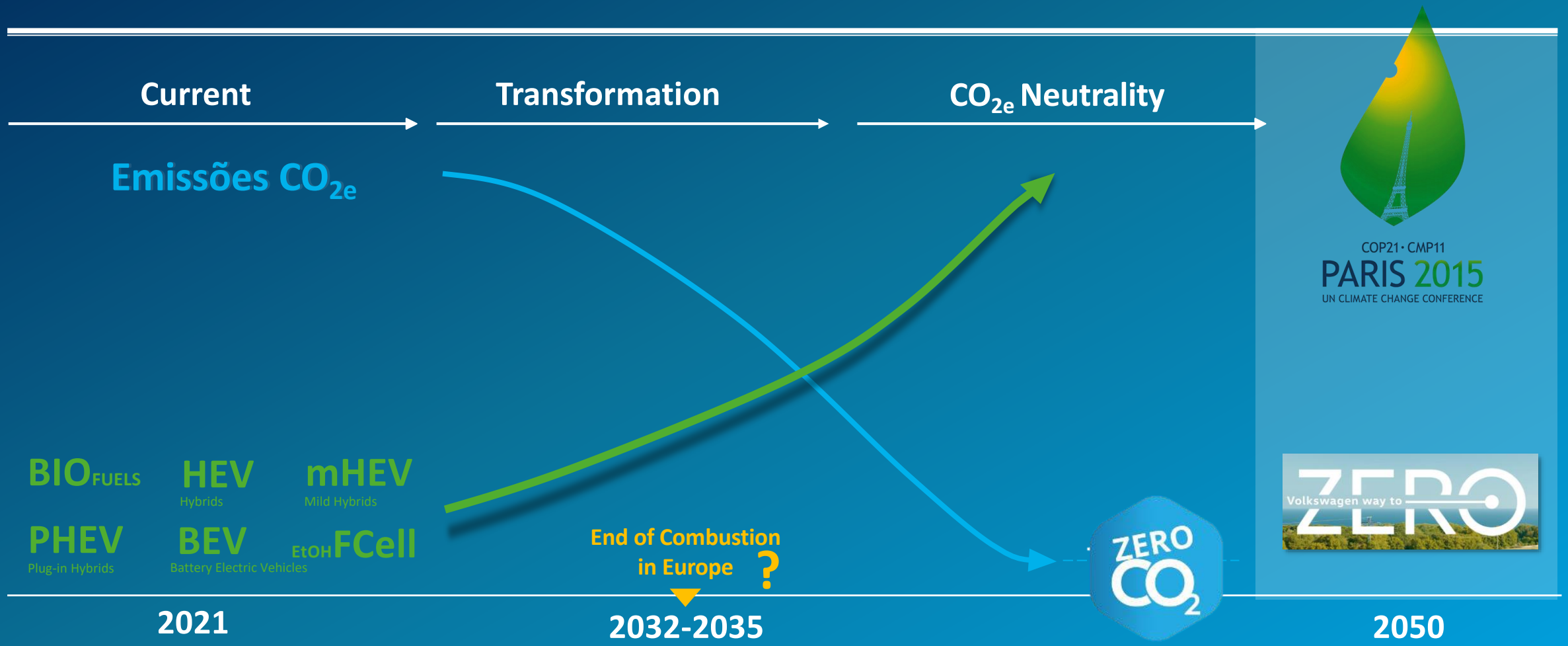
Way to Zero Center

BioFuels and Products R&D

Volkswagen South America

16.05.2023

Volkswagen group was the first OEM to sign Paris agreement, commiting CO_{2e} neutrality until 2050



CO_2e Concepts

2050 Volkswagen way to ZERO

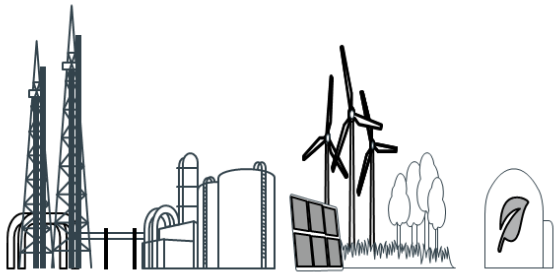
Cradle to Grave CO_2e

Cradle to Gate
Supply Chain included

Production

Well-to-Wheels

Well-to-Tank



Fuel / Energy

Tank-to-Wheeels

Vehicle Use

Grave
Recycling and Indirect activities

Disposal

Decarbonization Index Concept

Manufacture		*Vehicle Use*		*Others*
Supply Chain *	Production (internal)	Energy Sources	Consumption	Recycling & Indirect Activities *

$$DKI = CO_2e_C + \left[\frac{gCO_2e}{MJ} \times \frac{MJ}{km} \right] \times km + CO_2e_G$$

Decabornization Index (tCO_2e/Veh)

Carbon Intensity, IC

Energy Consumption, CE

2050 Volkswagen way to ZERO

$$DKI_{fleet}(Year) \stackrel{def}{=} \sum_{m=1}^{\#models} DKI_m * \frac{Year\ Sales_m}{TotalSales\ in\ Year}$$

Objective: Reduce Carbon Intensity of Brazilian fuel Matrix

RenovaBio

Law 13.576/17

Objective: Reduce energy consumption

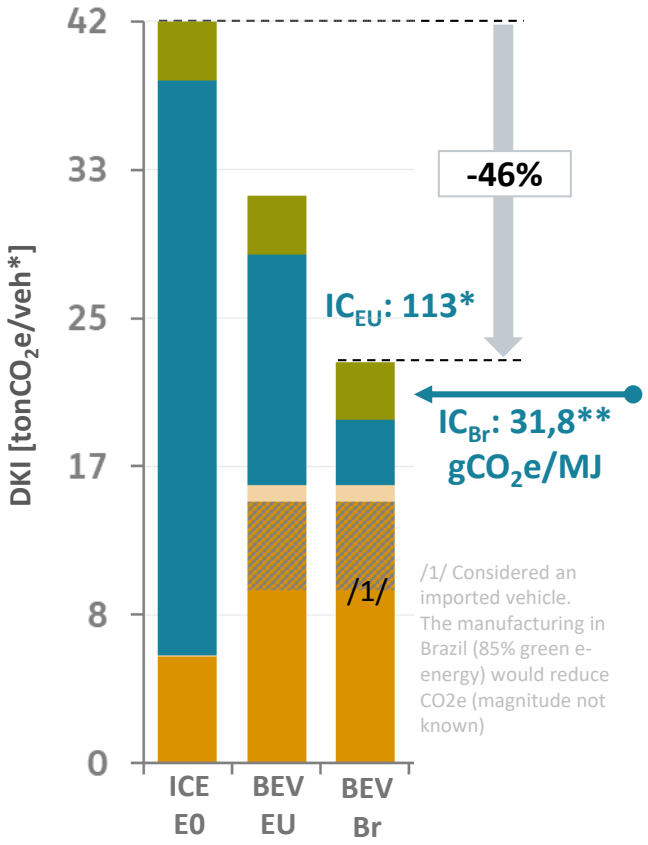
ROTA 2030

Law 13.755/18

* Methodologies in development

DKI: DekarbonisierungsIndex (Decarbonization Index)

Electrification: Opportunities/ Challenges

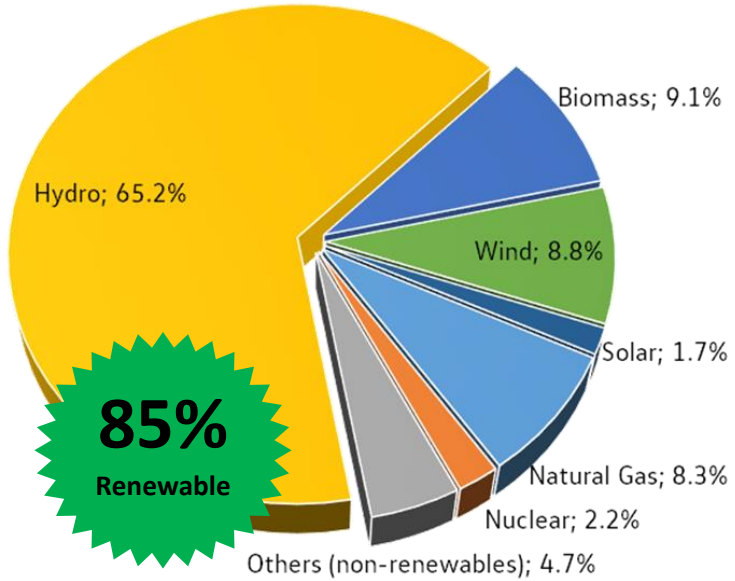


/1/ Considered an imported vehicle. The manufacturing in Brazil (85% green e-energy) would reduce CO2e (magnitude not known)

* Source: B-TR assumptions for Europe 2020
** Source: EPE (Gov. agency of energy research)

Electric Energy Matrix Brazil 2020

Source: EPE



* All figures are B-TR estimative (to be confirmed)

Supply Chain / Production | Energy sources | Consumption | Recycling & Indirect Act.

$$DKI_{\text{Decabornization Index (tCO}_2\text{e/Veh)}} = CO_2e_C + \left[\frac{gCO_2e}{MJ} \times \frac{MJ}{km}\right] \times km + CO_2e_G$$

IC= Carbon Intensity

BEVs Opportunities/ Challenges

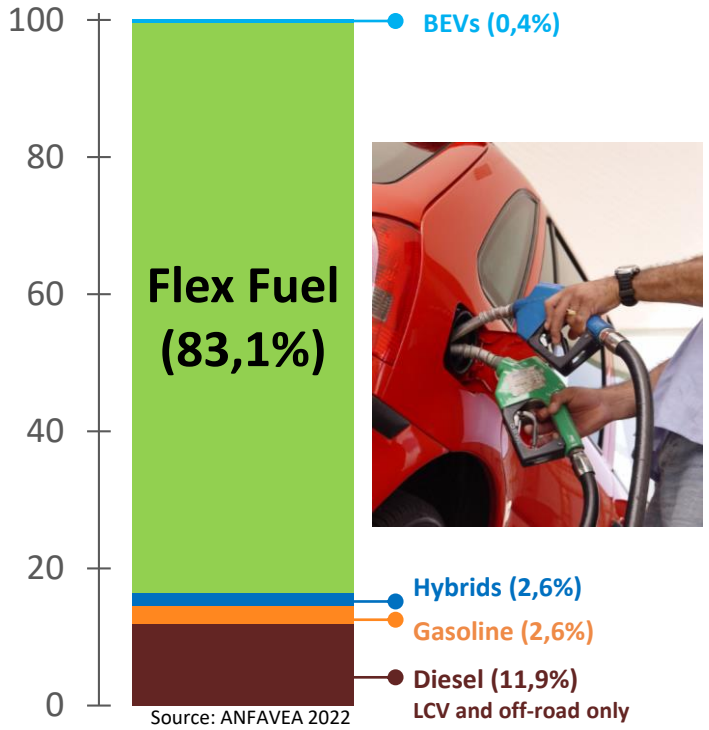
- ✓ Trend in important markets
- ✓ e-Matrix 85% renewable
- ✓ Low operational Cost
- ✓ Zero local pollutant emission
- • GPD/ capita (<30% da EU)
- • Interest rate (13,7%)
- • Charging Infrastructure
- • Government support absence
- • Local competence/ regulations develop.

% Sales	SAM
2022	0,4%
2030	~8,5%

Flex Fuel: Standard Tech in Brazil

New vehicle sales (% mix)

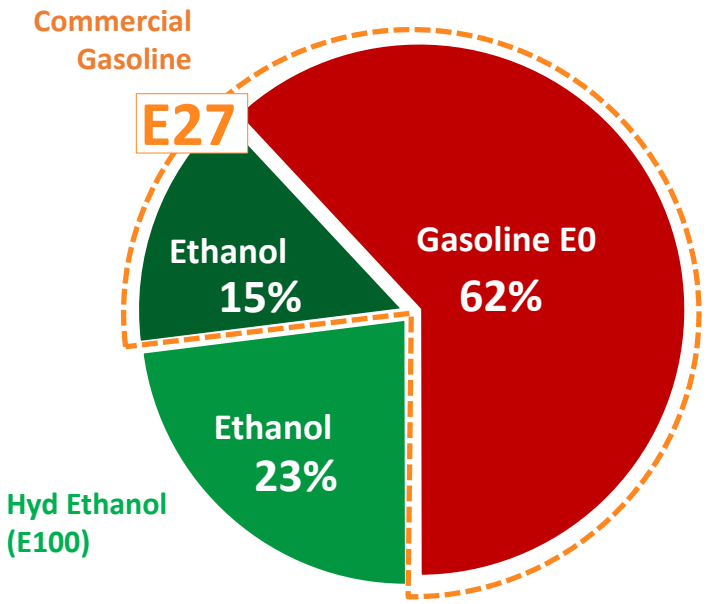
Light vehicles (passenger and light commercial)



Source: ANFAVEA 2022

Otto fuels in Brazil

(% of Energy 2021)



Source: ANP / INMETRO

Carbon Intensity [gCO_{2e}/MJ]

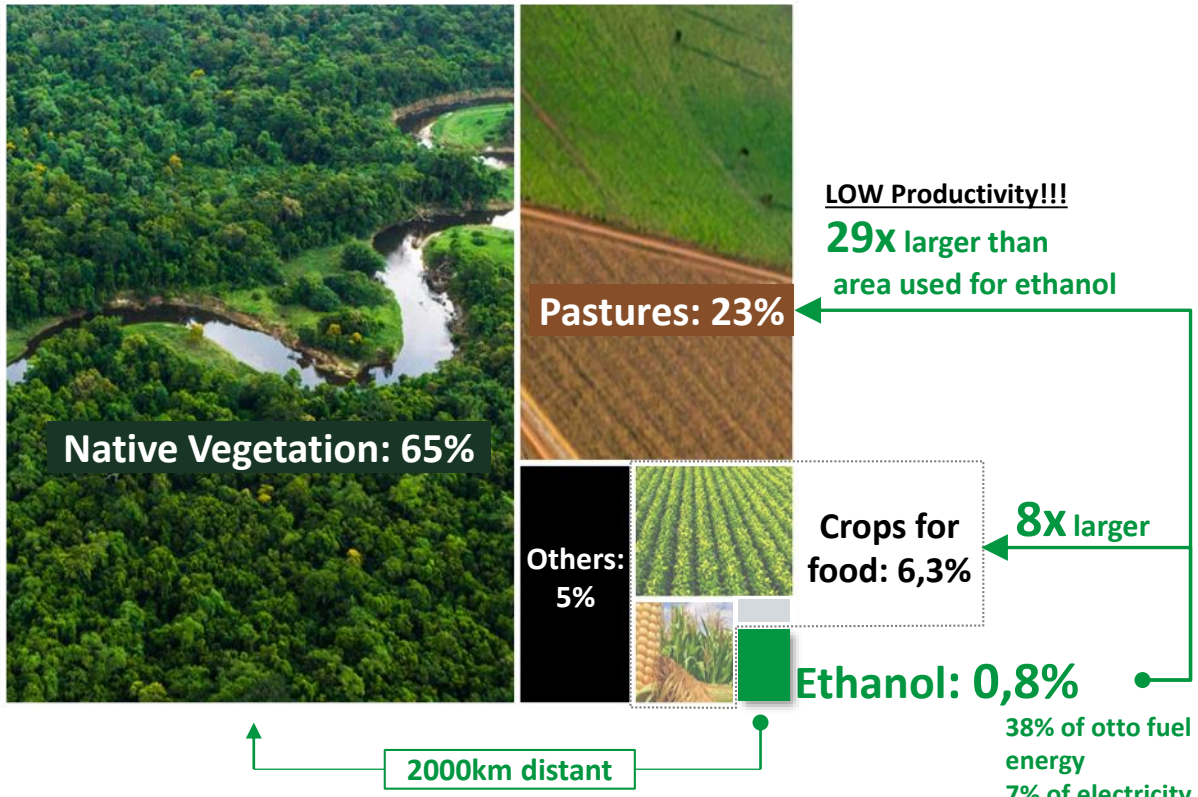
(Status and Energy Ministry Prognosis)

Year:	2020	2032
Gasoline E0	87,4	87,4
Anhyd Ethanol	26,9	20,3
Gasoline E27	75,1	73,7
Hyd Ethanol	28,5	21,6
Biodiesel	24,0	21,1
Electricity	31,8	26,6

Source: EPE/ Ministry of Energy

Ethanol Sustainability
Ethanol Production Increase Potential

Land Use (% of area):



- **Ethanol production only uses 0,8% of Brazil area, very low risk of deforestation and food competition.**

Ethanol 1G residues
BioMethane

Volks usará biometano em Taubaté e São Bernardo

Apoiada nos compromissos com a prática ESG, montadora utilizará metade do gás produzido pela Raízen em Piracicaba a partir de resíduos de cana

Source: Valor Econômico

BioGas from Sugar/Ethanol residues (Source: Raizen)

Supply Chain / Production | Energy sources | Consumption | Recycling & Indirect Act.

$$DKI = \underset{\text{Decabornization Index } (tCO_2e/Veh)}{} CO_2e_C + \left[\frac{gCO_2e}{MJ} \times \frac{MJ}{km} \right] \times km + CO_2e_G$$

Source: Portal R3

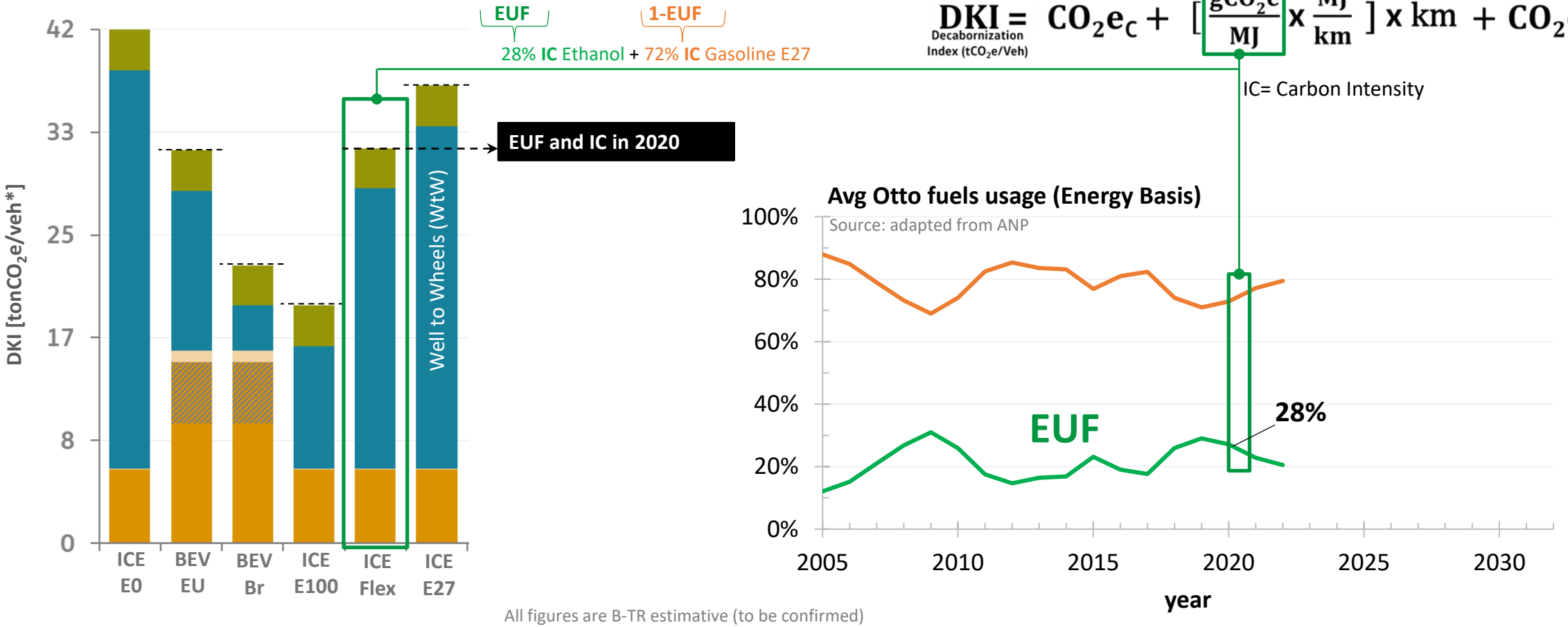
- **VWB Bio Methane adoption will contribute for life cycle CO_{2e} reduction.**

Ethanol Usage and C-IntensitySensibility

Supply Chain | Production | Energy sources | Consumption | Recycling & Indirect Act.

$$DKI = \underset{\text{Decabornization Index (tCO}_2\text{e/Veh)}}{DKI} = CO_2e_C + \left[\frac{gCO_2e}{MJ} \times \frac{MJ}{km}\right] \times km + CO_2e_G$$

IC= Carbon Intensity



All figures are B-TR estimative (to be confirmed)

- **Currently relatively low Ethanol Usage in Brazil reduces E100 potential for CO_2e reduction.**

Ethanol Usage and C-IntensitySensibility

Supply Chain | Production | Energy sources | Consumption | Recycling & Indirect Act.

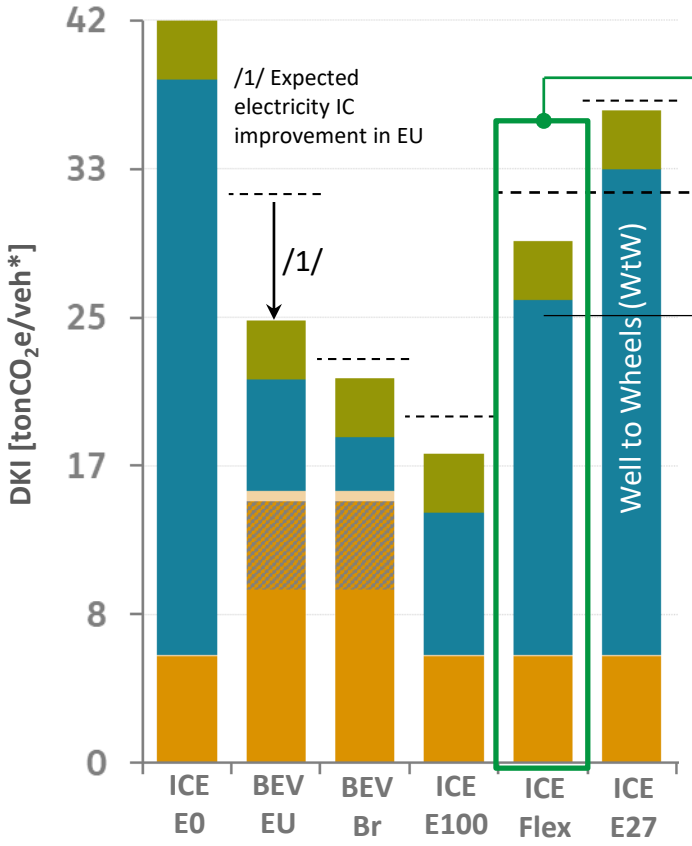
$$DKI = CO_2e_C + \left[\frac{gCO_2e}{MJ} \times \frac{MJ}{km}\right] \times km + CO_2e_G$$

DKI: Decabornization Index (tCO_2e/Veh)

IC= Carbon Intensity

EUF: 38% **IC** Ethanol + 62% **IC** Gasoline E27

1-EUF

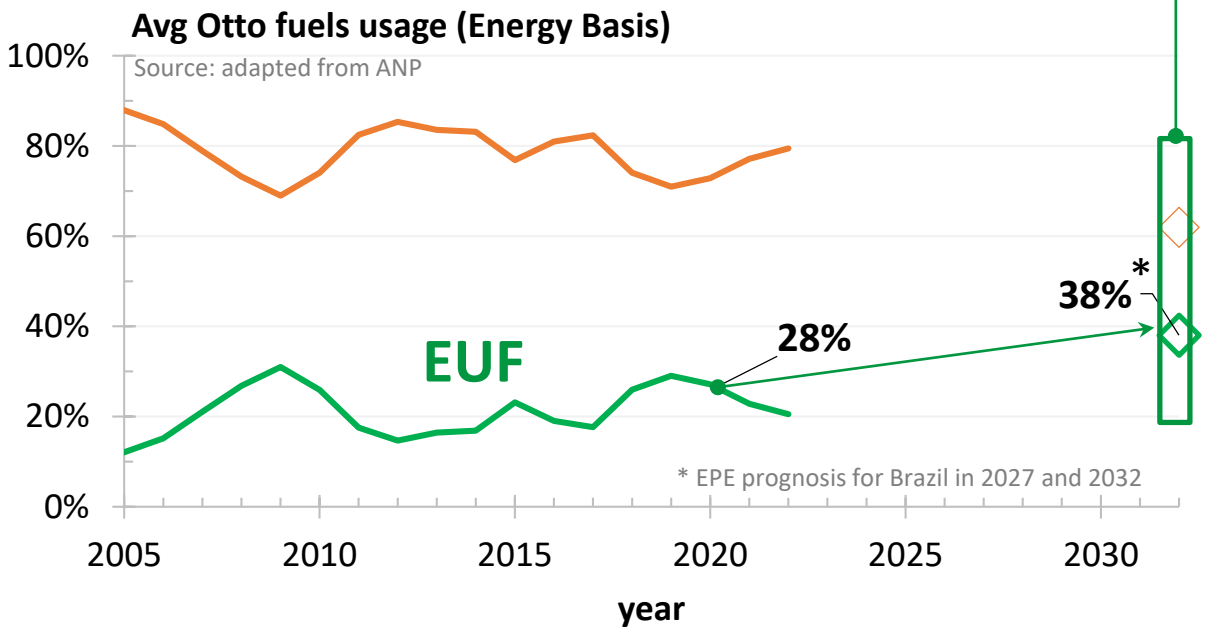


28,5gCO$_2$e/MJ

Process Improvement — RenovaBio

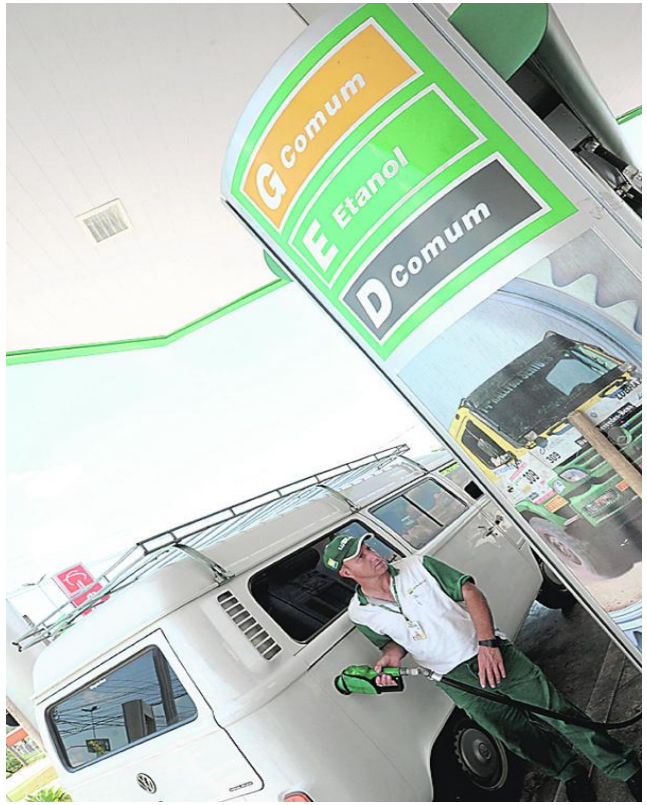
21,6gCO$_2$e/MJ

Source: EPE/ Ministry of Energy



Influencing
Fuel choice at Gas Station

Which fuel should I use?



Customer reasoning

$$\left(\frac{R\$}{km}\right)_{E100} \leq \left(\frac{R\$}{km}\right)_{E22}$$

$$\left(\frac{R\$}{l}\right)_{E100} \leq \mathbf{EDR} * \mathbf{EP} * \left(\frac{R\$}{l}\right)_{E22}$$

E100 = commercial hydrous ethanol

$$\frac{\left(\frac{MJ}{l}\right)_{E100}}{\left(\frac{MJ}{l}\right)_{E22}} \stackrel{\text{def}}{=} \textbf{Energy Density Ratio (EDR)}$$

Defined by…
→ Fuel characteristics/ specification

69,3 %

$$\frac{\left(\frac{MJ}{km}\right)_{E22}}{\left(\frac{MJ}{km}\right)_{E100}} \stackrel{\text{def}}{=} \textbf{Energy Parity (EP)}$$

Depends on…
→ Engine: Comp. Ratio, Displacement, Temperature, etc
→ Vehicle: Aed, Roling Resistance, Transmission
→ Route, Driving behavior

1,01

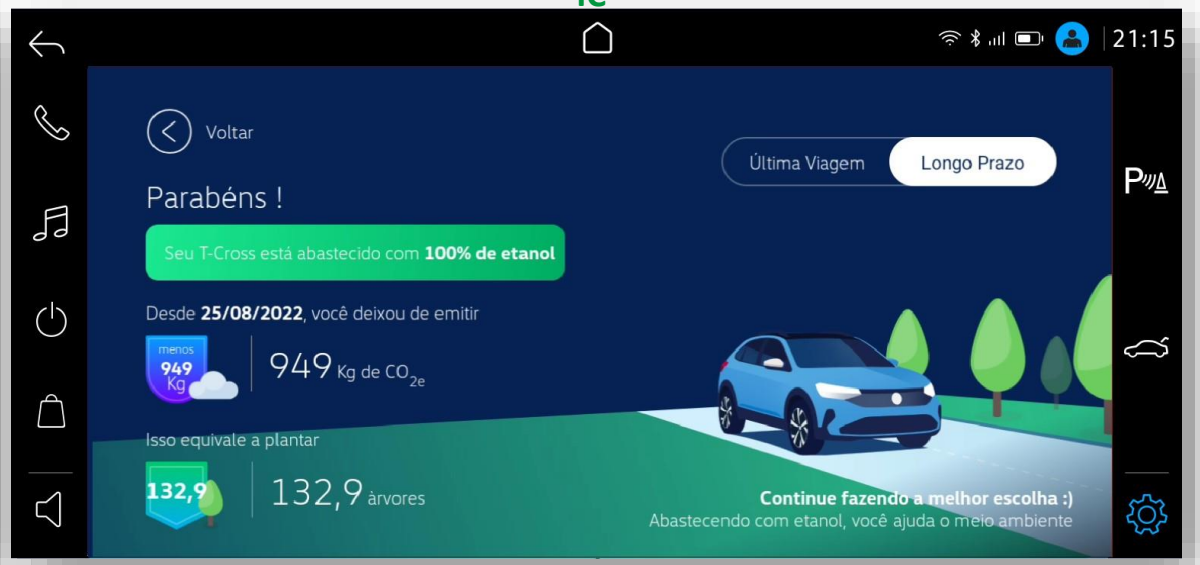
➢ **The higher the Energy Parity of a vehicle and the Energy density of ethanol fuel, the higher the chance to be worthy (financially) to select Ethanol.**

App: Abasteça Consciente (Awareness)

Increase usage of low carbon fuels

Supply Chain / Production | Energy sources | Consumption | Recycling & Indirect Act.

$$DKI_{\text{Decabornization Index (tCO}_2\text{e/Veh)}} = CO_2e_C + \left[\underbrace{\frac{gCO_2e}{MJ}}_{IC} \times \frac{MJ}{km}\right] \times km + CO_2e_G$$



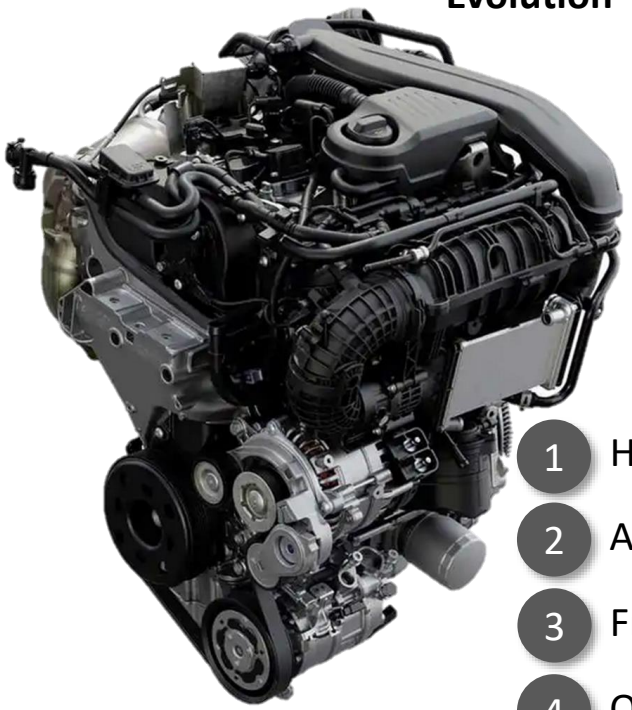
Fonte: B-TE

Next steps:

- Know the VWB customer choice (using Cloud and Data Analytics)
- Additional actions to influence choice and results measurements (C-Credits, Mileage/tress accumulation, game)
- Differentiate ethanol with low C-Footprint (?)

Energy Parity and Energy Consumption Improvement

ICE Powertrain Evolution



+

1. High Compression Ratio
2. Alternative Cycle
3. Friction Reduction
4. Optimized Transmission

Supply Chain / Production | Energy sources | Consumption | Recycling & Indirect Act.

$$DKI = \underset{\text{Decabornization Index } (tCO_2e/Veh)}{} CO_2e_C + \left[\frac{gCO_2e}{MJ} \text{ x } \frac{MJ}{km} \right] \text{x km} + CO_2e_G$$

IC CE

Low Voltage ⟷ High Voltage

Mild hybrid (mHEV P0)	Full hybrid (HEV)	Plug-in hybrid (PHEV)
48 V (Li-ion)	>200 V (Ni-MH / Li-ion)	>200 V (Li-ion)

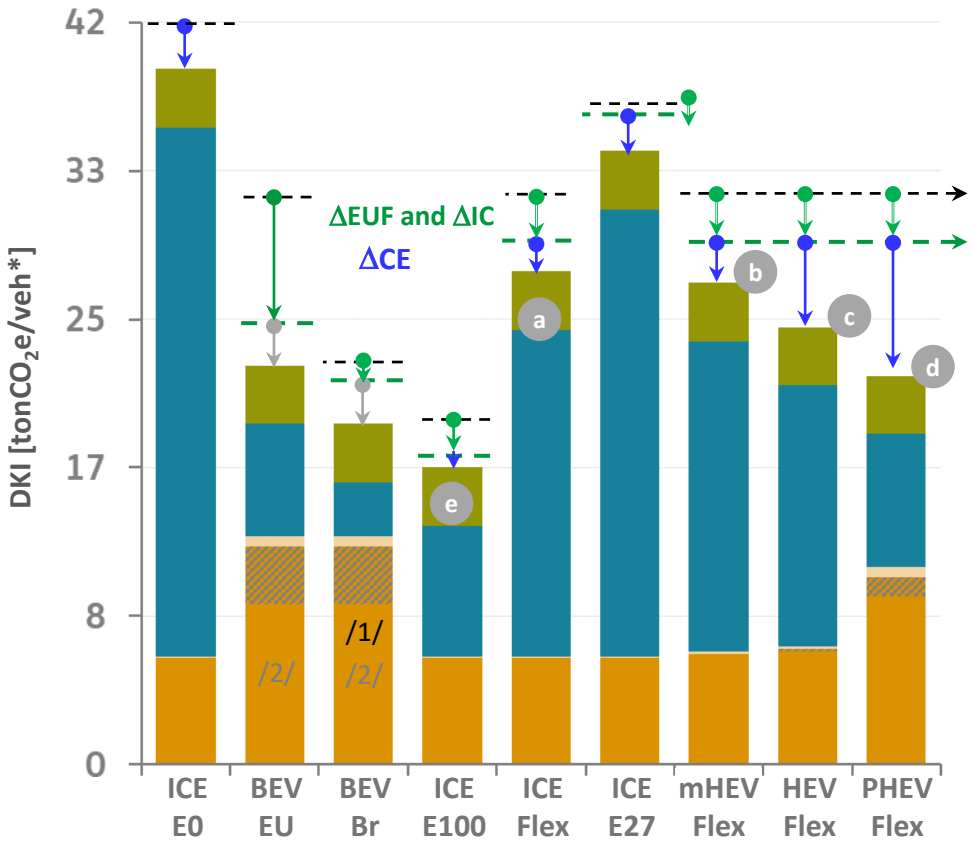
e-Range	~2 km	~20 – 80 km
Decel with engine "off"		
"Boost" e Recuperation		

➢ **Miller cycle combined w/ electrification technologies offers potential for increase vehicle range with ethanol, increasing its acceptance.**

Energy Parity Increase

Supply Chain / Production | Energy sources | Consumption | Recycling & Indirect Act.

$$\text{DKI}_{\text{Decabornization Index (tCO}_2\text{e/Veh)}} = CO_2e_C + \left[\underbrace{\frac{gCO_2e}{MJ}}_{\text{IC}} \times \underbrace{\frac{MJ}{km}}_{\text{CE}}\right] \times km + CO_2e_G$$



EUF and IC in 2020

EUF and IC in 2032

ΔCE: reduction in energy consumption. Due to:
- **Miller cycle,**
- **Optimized transmission**
- **Electrification technology**

Ref. ICE Technology:
- **Otto Turbo DI,**
- **Start Stop/Recuperation**
- **Torque converter automatic transmission.**

/1/ Considered an imported vehicle. The manufacturing in Brazil (85% green e-energy) would reduce CO_2e (magnitude not known)

/2/ Reductions in Battery, Supply Chain and Assembly are internal assumptions.

- **Efficient technologies contribute for ethanol range increase, operational cost reduction and fuel availability.**
- **Ethanol acceptance/ usage increase is an important lever for CO_2e reduction.**

Summary

For Brazil…

- **BEV trend will take longer**
  Drivers: customer preference; low operational cost; renewable electric matrix.
  Challenges: Purchase cost, charging infra, local supply chain,.

- **BioEthanol is a fast way of decarbonization**.
  Driver: Flex techn. for passenger cars is strongly present in current fleet (~80%) and in new licensed (~85%).
  Challenge: Ethanol choice by the customer is relatively low.

- **BioEthanol usage increase is a strong lever for Cradle to Grave CO_2e reduction;**
  It can supposedly occur w/o sustainability issues and can achieve very low carbon intensities.

- **Ethanol oriented ICEs and electrified variants are measures for efficient BioEthanol usage**, increasing its selection by customer, leading to CO_2e reduction.

- **R&D LowC energy/ technologies and precise methodologies on life cycle emissions are necessary to support correct regulation development.**

Obrigado!

Roger.Guilherme@Volkswagen.com.br

Way to Zero Center
BioFuels and Products R&D
Volkswagen South America