



Roadmap do Mercado Brasileiro de
VEÍCULOS PESADOS A GNV

Brazil Roadmap for Natural Gas and Biomethane Heavy Duty Trucks & Buses

Part 1

Strengths, Weaknesses, Opportunities & Challenges (SWOC)

July 2021



Roadmap do Mercado Brasileiro de
VEÍCULOS PESADOS A GNV

INTRODUCTION & APPROACH

U.S.-Brazil Energy Forum (USBEF)



- This work has been conducted under the U.S.-Brazil Energy Forum (USBEF), the energy bilateral framework co-chaired by the U.S. Department of Energy (DOE) and Brazil's Ministry of Mines and Energy (MME)
- This project has been funded by the U.S. Department of Energy's Office of Energy Efficiency and Renewable Energy (DOE-EERE)

The Principals

- **Jeffrey Seisler**, *Principal Contractor and Expert (CEO, Clean Fuels Consulting)*
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- **Heloisa Borges**, *Director Oil, Gas & Biofuels, Energy Research Agency (EPE)*

With technical support from Gustavo Galiazzi (ABEGAS) and Ricardo Vallejo (Consulgas)

Roadmap Development Process & Activities

- **First two weeks in February 2021:** Series of stakeholder teleconferences ~ 2 hours x 6 Stakeholder groups. Additional meetings w/Inmetro, BNDES and EPE. Total of ~100 stakeholders.
- **Mid-March 2021:** Requested and received feedback from each Stakeholder group on SWOCs and Draft Roadmap.
- **27th May 2021:** Virtual Workshop. Three-hour session *presented the results of draft Roadmap to all stakeholder groups to get reactions, input, guidance, questions, etc. for the development of the Final Roadmap.*
- **19 July 2021:** Roadmap finalized and delivered to Brazil MME and EPE.



Public-private input from ~ 100 stakeholder institutions and companies was obtained for a *full* range of perspectives*

- *Government:* National governments of Brazil and the U.S. as well as Brazilian municipal governments. 
- *The downstream natural gas industry.* 
- *Vehicle manufacturers and NGV systems and component suppliers.* 
- *Fleet operators:* Both private sector commercial and municipal public sector operators of buses and trucks. 

- *Fuel station and infrastructure suppliers.* 
- *Civil society:* Non-governmental organizations; natural gas, environmental and health advocates; universities; financial institutions and other entities supporting non-petroleum-based fuels for the transport sector. 

*A small number of participating stakeholders in the listed participants may be missing due to on-line registration or record-keeping issues for the various virtual meetings conducted in the development of the Roadmap. Apologies to those who might be missing from the stakeholder lists. 6



PUBLIC SECTOR STAKEHOLDERS

BRAZIL & U.S.



MME - Ministério de Minas e Energia
EPE - Empresa de Pesquisa Energética
BNDES - Banco Nacional de Desenvolvimento Econômico e Social
ANP - Agência Nacional do Petróleo, Gas Natural e Biocombustíveis
Ministério de Economia
Ministério de Infraestrutura
INMETRO
CETESB - Companhia Ambiental do Estado de São Paulo
Secretaria de Infraestrutura do Estado de São Paulo
Secretaria de Estado e Desenvolvimento Econômico - Rio de Janeiro
Secretaria de Infraestrutura do Estado da Bahia
Secretaria de Estado de Desenvolvimento Econômico do Estado de Sergipe
Secretaria de Estado de Desenvolvimento Econômico do Estado de Minas Gerais

Secretaria do Meio Ambiente e Infraestrutura do Rio Grande do Sul
Secretaria de Infraestrutura e Meio Ambiente do Estado de SP
Agência de Transporte do Estado de São Paulo
Empresa Metropolitana de Transporte Urbano - SP
Prefeitura Municipal de São Paulo
URBS - Empresa Municipal de Regulação do Transporte Público da Cidade de Curitiba
IPPUC - Instituto de Pesquisa Urbana da Cidade de Curitiba

U.S. Embassy Brasilia
U.S. Foreign Commercial Service
U.S. Department of Commerce
U.S. Department of Transportation
U.S. Consulate Rio

NATURAL GAS COMPANIES, VEHICLE MANUFACTURERS & NGV SYSTEMS/EQUIPMENT SUPPLIERS



Compagás
BahiaGás
Naturgy
Comgás
Gasmig
Gás Brasileiro
Cegás
Neogás
CTG/Galileo
Golar (*now
NewFortress
Energy*)
Raizen



IGÁS
LOGÁS
Eneva Comercial-
izadora
MSGAS
Cigas
Algas
Esgas
Gaspetro
MTGAS
Copergas



ABRAFEGNV
Mat Cilindros
Convergás (Hexagon)
Landi Renzo
Scania
Cummins
Volkswagen Ônibus e Caminhão
Iveco
Associação Brasileira de Engenharia
Automotiva
Marcopollo
Caio
New Holland (CNH)
ANFAVEA



CIVIL SOCIETY, FLEET OPERATORS, INFRASTRUCTURE & FUEL STATION SUPPLIERS



Universidade de São Paulo - IEE
Universidade de São Paulo - RCGI
Instituto Mauá de Tecnologia
Instituto Saúde e Sustentabilidade
Associação brasileira de produtores de Biogas
Associação Brasileira de Engenharia Automotiva
ABEGAS
FIESP
Comitê do Gas Natural Veicular
SEDE - Secretaria de Estado de Desenvolvimento
Econômico
FGV ENERGIA
FGV CERI
CONSULGÁS
Universidade federal do Rio de Janeiro - COPPE
Universidade Federal do Rio de Janeiro - IE
Fórum do Gás
Confederação Nacional da Indústria
SAE – Brasil



- Transmaroni
- Alliance GNLog
Transportes
- Patrus Transportes



- Aspro
- Junqueira
Compressores
- Multiflow
- Inoxcva
- Metroval
- Ipiranga
- Raizen
- Fecombustíveis
- Anfavea



Roadmap do Mercado Brasileiro de
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SWOC ANALYSIS FORMS THE BASIS OF THE ROADMAP

Views of the Six Stakeholder Groups

- Strengths
- Weaknesses
- Opportunities
- Challenges/Threats

Everyone has a
different
perspective of a
similar vision



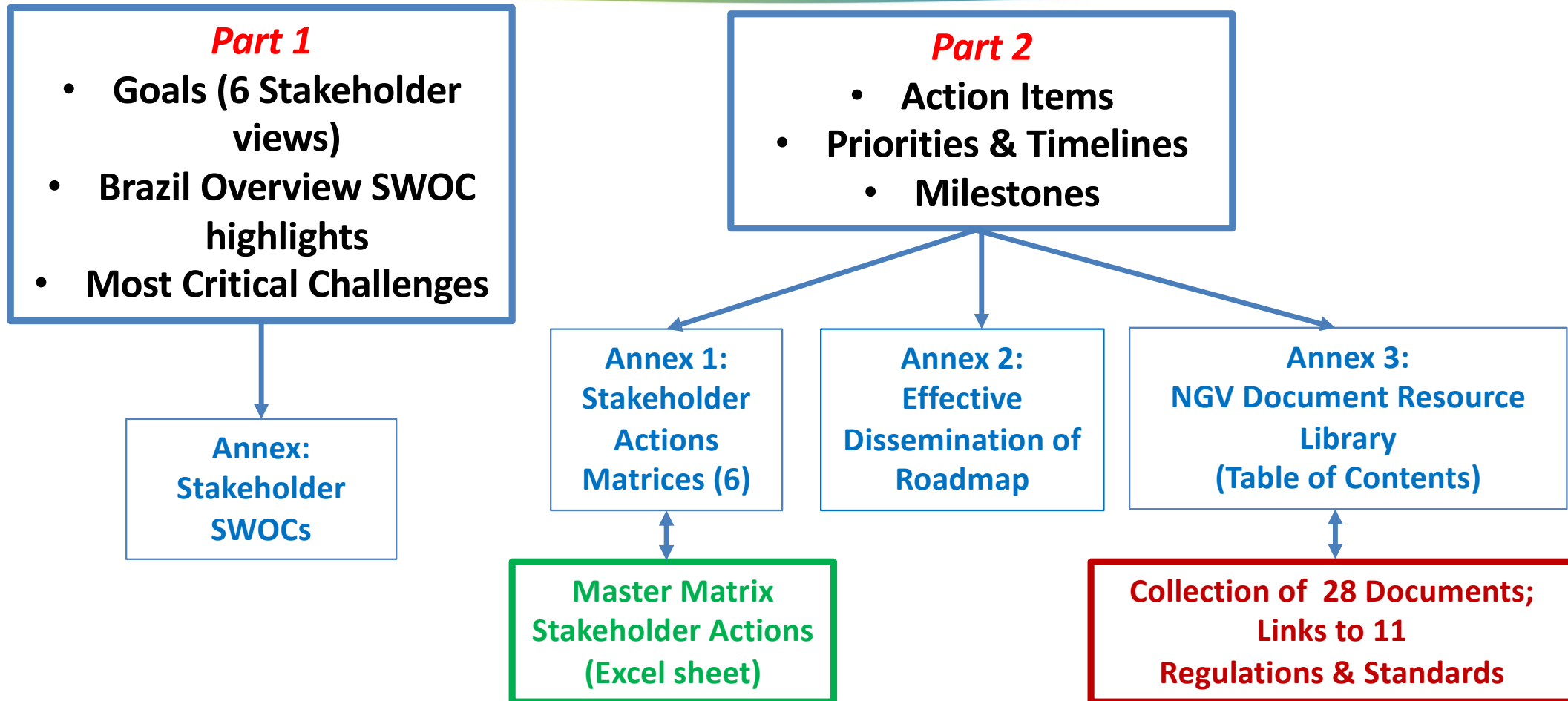
*A chalice to drink from or....
a profile of two faces?*

The Roadmap is a Dynamic Document: A decision '*tool*' to provide guidance & direction

- **Serves as a *guideline*** but must be *flexible* to be modified as determined appropriate or desirable by policy makers *with input from the stakeholders*.
- **Feedback (and *data*) required** from stakeholders & ultimate customers to *measure the success of meeting milestones & goals*.
- **Conduct periodic *reviews* to adapt** roadmap activities and priorities to changing circumstances. (i.e. annual workshop of experts)

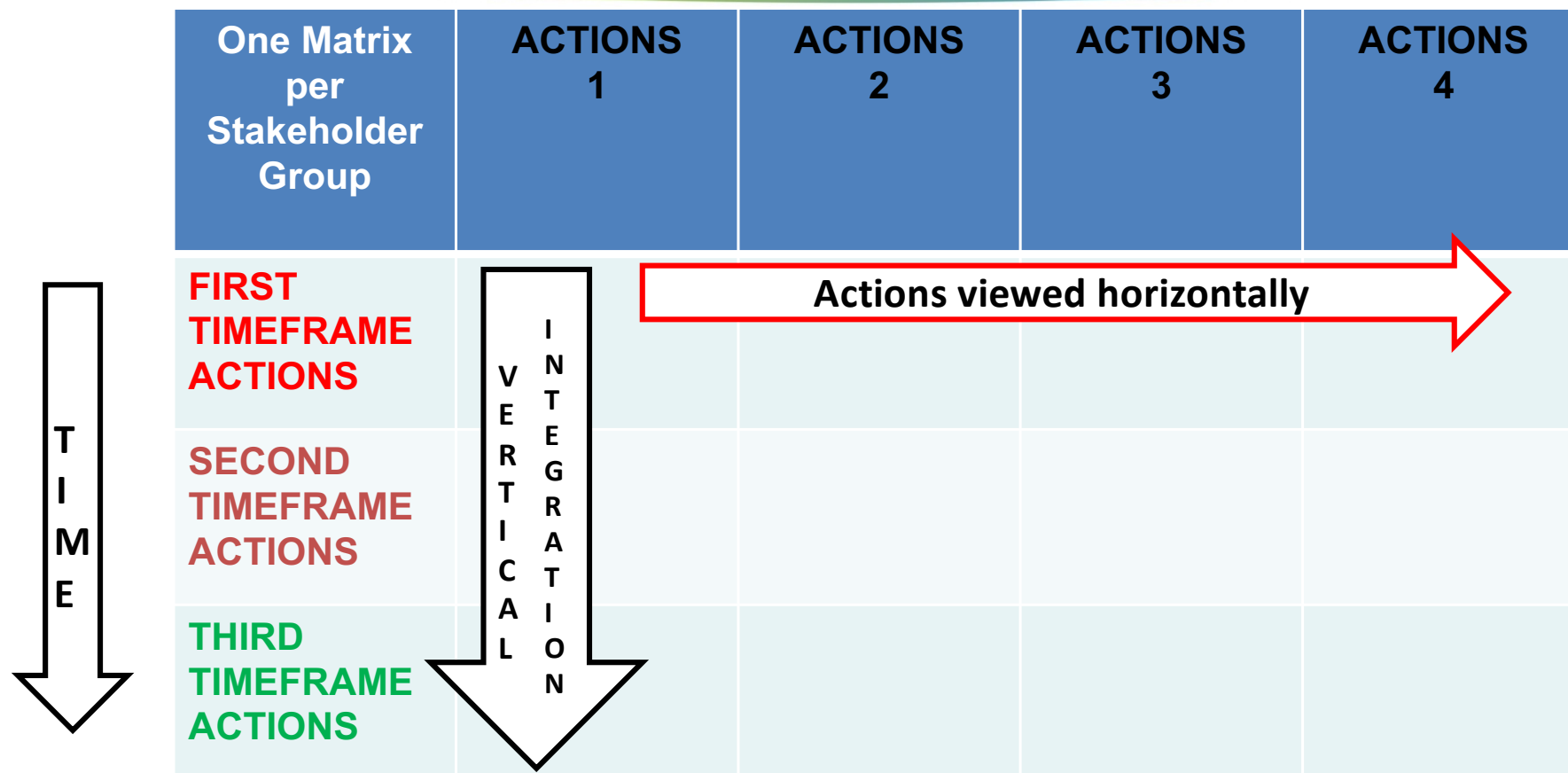


Overview of Complete Roadmap & Documents



What the Roadmap looks like

All stakeholders have important roles to play.



Action Matrices Included in Part 2 Roadmap Annex + 1 Master Matrix (separate Excel spreadsheet)

Framework for the Roadmap

Part 1

- Goals (6 Stakeholder views)
- Brazil Overview SWOC highlights
- Most Critical Challenges
- Annex with Stakeholder SWOCs







Part 2

- Action Items
- Priorities & Timelines
- Milestones
- Annex: Stakeholder Action Matrices

- Where we want to be
- Where we are today
- What is in the way

- What has to be done
- What is most important to do & in what order
- Landmarks & measures of success

Each Stakeholder group has its own set of goals

- *Government* 
- *The downstream natural gas industry* 
- *Vehicle manufacturers and NGV system and component suppliers* 
- *Fleet operators* 
- *Fuel station and infrastructure suppliers* 
- *Civil society* 



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- # The Current Situation
- *Stakeholder Goals*
 - *Brazil SWOC overview*

GOALS

Public Sector



- ***Reduce air pollution*** and greenhouse gas emissions (specifically CO₂ & particulates) in the transport sector and specifically in the HDV truck and bus sectors, *which endanger public health.*
- ***Expand distribution of fossil natural gas*** via pipeline and tank transport to areas not (yet) served by pipeline.
- ***Introduce renewable biomethane*** into the gas distribution network(s).

GOALS

Gas Industry



- Open new markets for natural gas (including LNG & biomethane)
- Promote economic efficiency of the market players & stakeholders.
- Optimize the existing pipeline network, especially transmission.
- Expand natural gas distribution potential.
- Promote *renewable* biomethane as a competitive, *driving force* in future energy markets.
- Simplify the legal/regulatory framework for natural gas.
- *Legitimize natural gas as a contributor to a 'cleaner fuel future'.*

GOALS

Vehicle Manufacturers and NGV System/Equipment Suppliers



- Sell trucks and buses (including NGVs).
- Sell natural gas conversion systems & equipment.
- Provide environmentally friendly vehicle and engine technologies.
- Provide vehicles that achieve the best TCO* for the customer.
- Build a long-term sustainable market for HD gas buses and trucks and engines.

***Total Cost of Operation**

GOALS

Fleet Operators



- Run a *profitable* business.
- Keep vehicles on the road, serving customers.
- Achieve the best TCO for fleet vehicles.
- Environmental sustainability is important.

GOALS

INFRASTRUCTURE & FUEL STATION SUPPLIERS



- Provide economic, safe and user friendly fueling for NGV fleet operators for CNG, LNG (& biomethane)
- Solve the NGV Chicken & Egg syndrome by installing a *substantial* natural gas fuel infrastructure *for HDVs and buses*.
- Reduce the regulatory barriers to delivering CNG, LNG and biomethane to fleet customers.

GOALS

Civil Society



- Advocate and support -- with information, analyses and *intellectual leadership* – the efforts of all stakeholders to reduce emissions and improve air quality, including in the transport sector.
- Advocate and support the increased use of renewable energy to mitigate the impacts of climate change.

SWOC HIGHLIGHTS

BRAZIL OVERVIEW (Highlights)

Where we stand today



Full SWOCs – Brazil overview & Stakeholders in Annex to Part 1.

STRENGTHS

NGV Technology

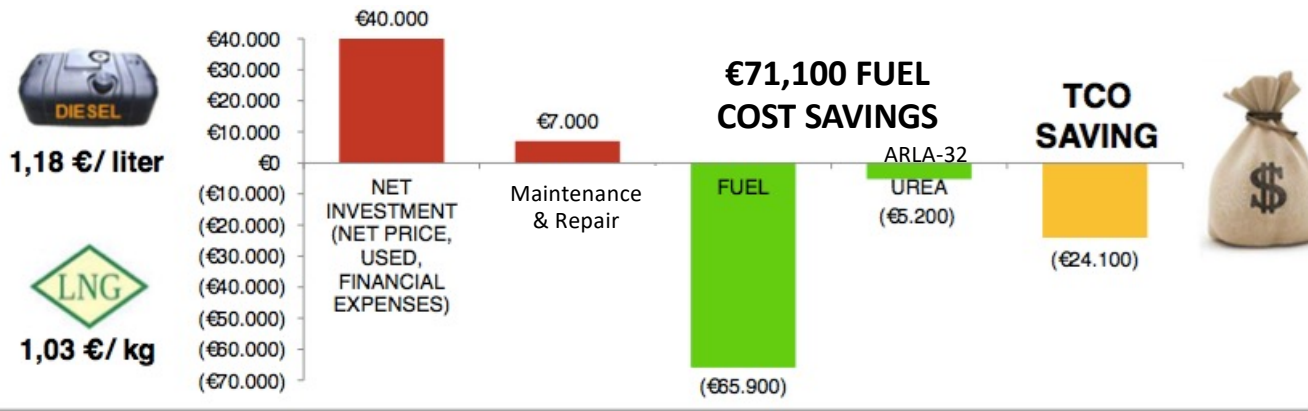


- ***Proven technology*** widely available, with more than 28 million NGVs globally.
- ***OEM vehicles and engines are available*** with state-of-the-art emissions technology (Euro VI) resulting in lower pollution than diesel. ('Availability' = 'they exist' but not necessarily in every market, including Brazil.)
- ***TCO*** (Total Cost of Ownership) ***can be***, for ***most*** natural gas heavy duty vehicle applications, more competitive than diesel.
- ***TCO is better than other fuel alternatives*** (electric & hydrogen fuel cells).

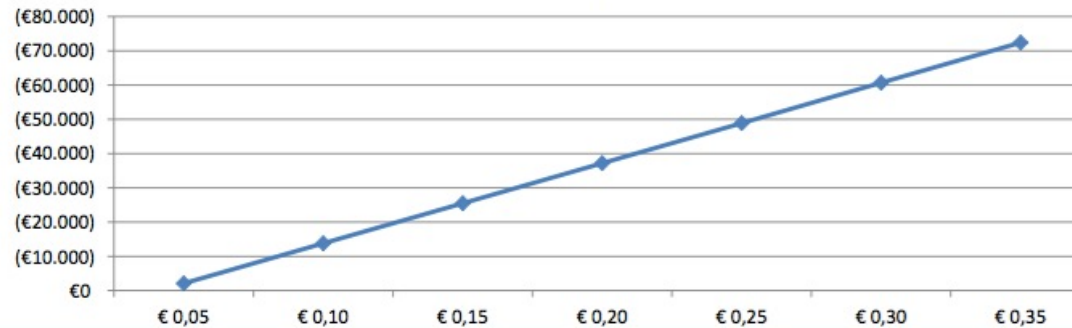
Economic sustainability is affected by the price differential between diesel & natural gas

Total Cost of Ownership (TCO) simulation (European LNG example)
 (IVECO 4x2 Arctic-medium-long haul mission: 120,000km per year/7 years)

Based on LNG @ 22% less than diesel

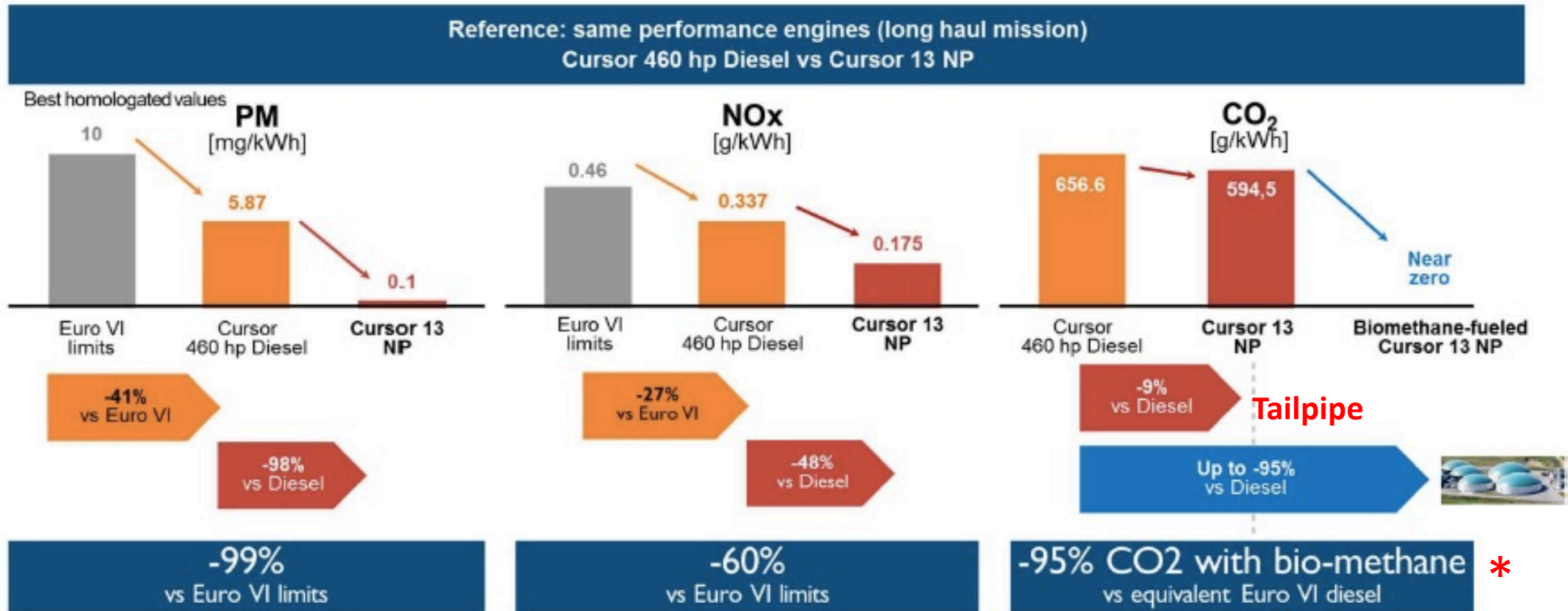


TCO REDUCTION (€)
120.000km - 7 years



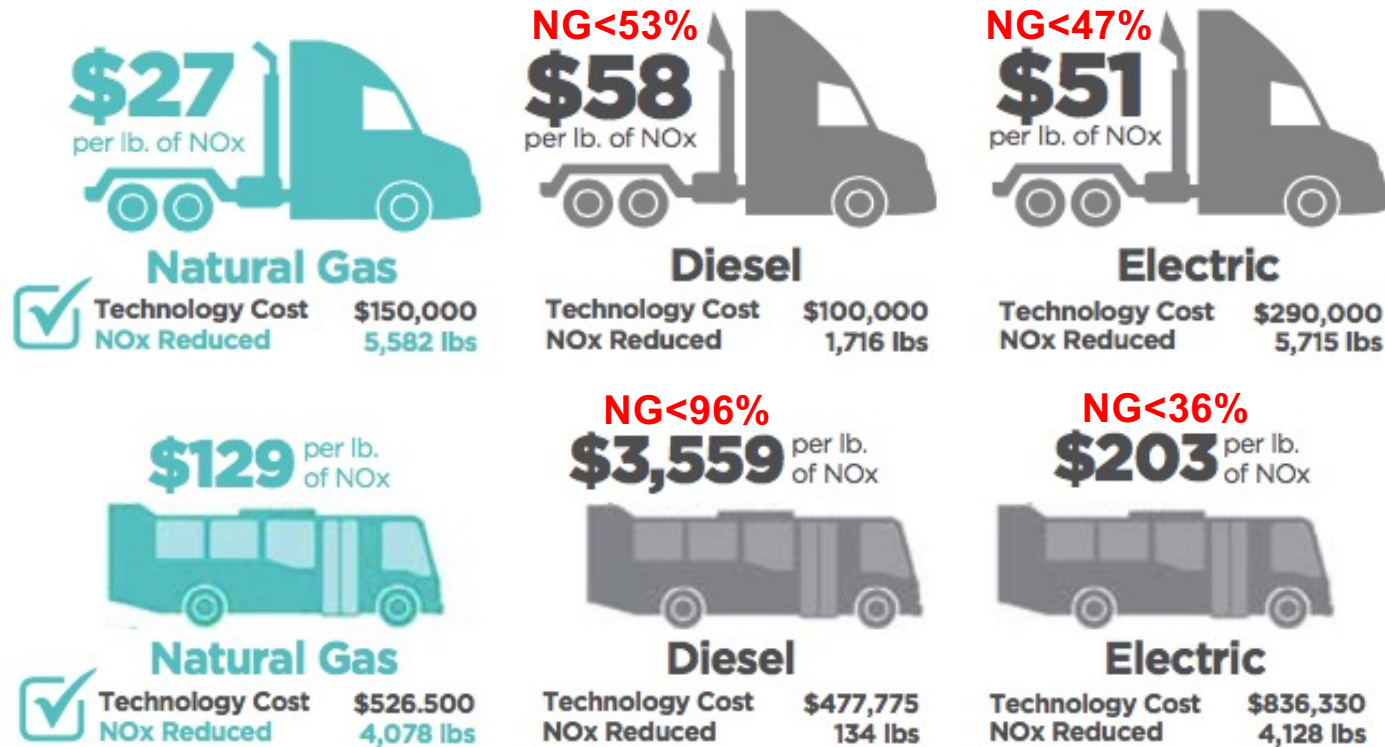
**NO PRICE DIFFERENCE
 =
 NO TCO SAVING
 =
 NO REASON TO USE LNG**

Natural gas trucks can achieve emissions levels in accordance with increasingly stringent regulatory limits



* -95% CO₂ on a well-to-wheel basis; *not* tailpipe emissions.

Low NOx NGVs – trucks and buses -- are a more cost-effective NOx reduction strategy than diesel or electric counterparts (US Case... also exemplary of vehicle cost differentials)



Source: Information from NGVA HDV and Transit Bus Fact Sheets. Emissions comparisons based on Argonne National Laboratory HDVEC tool; <http://afleet-web.ex.anl.gov/hdv-emissions-calculator/>. modelling new low-NOx truck vs diesel in use emissions.

STRENGTHS con't

Natural Gas Benefits & Supply Outlook



- Natural gas:
 - Is a **widely available** resource with **low, local air pollutant emissions**.
 - Has a **lower carbon footprint** than other fossil fuels.
 - In HD trucks can reduce particulate emissions up to 95% and NOx by 85%, contributing to the **reduction of hospitalizations and deaths** due to cardio-respiratory diseases in large urban centers.
 - Has **flexibility** to be stored and transported as a **compressed gas or cryogenic liquid**.
 - **Cannot be adulterated** or stolen from a vehicle (as is possible with liquid fuels).
- The Brazil gas industry is **embarking on a new plan** supported by the government (The New Gas Law, 2021) to **diversify** the natural gas **supply** and **expand** the natural gas **distribution** to areas where gas previously has not been available.
- **Supply of domestic natural gas** is anticipated to increase 80+% by 2030 and continue **strong growth to 2040 and beyond**.¹
- **Biomethane** is a **renewable resource option** that achieves **extremely low CO₂ levels on a well-to-wheel basis**; as much as -95%.²
- Natural gas can **help improve the trade balance** by replacing imported diesel fuel, which represents about 20% of diesel consumed in Brazil.

¹Gas for the Development, BNDES 2021/2020.

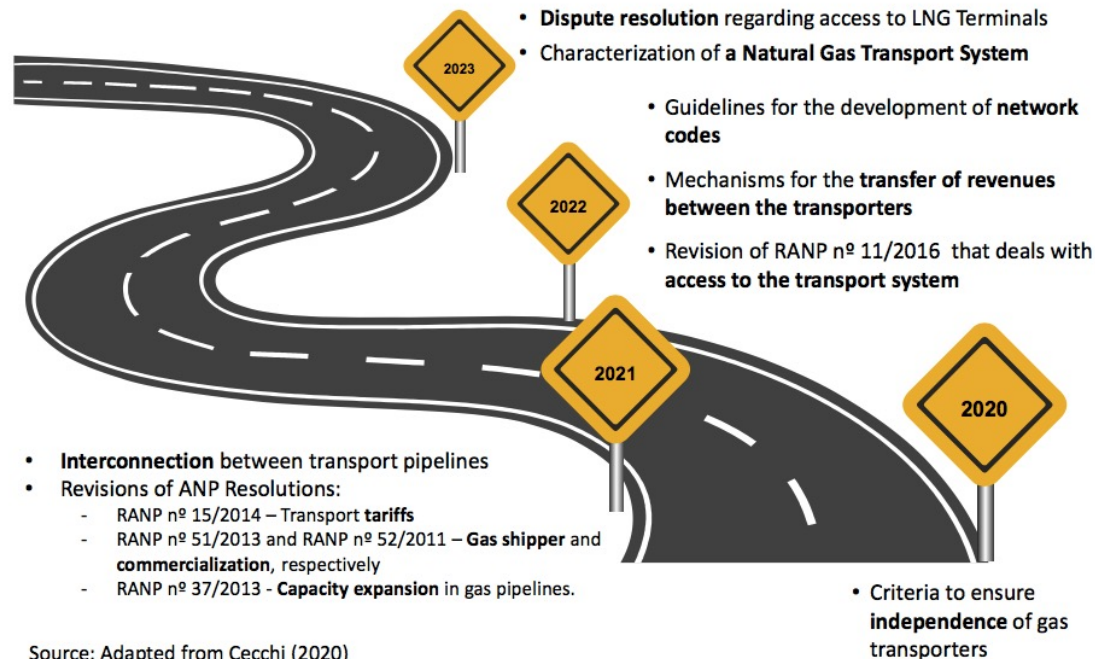
² California Energy Commission; European Commission; etc.

Diversification & expansion of the gas industry (*New Gas Market*) is complex and will take time but creates new opportunities for gas & Brazil



“Novo Mercado de Gás” ANP Regulatory Agenda

Resolutions to be developed/revised by ANP:



Source: Adapted from Cecchi (2020)

Source: Infrastructure & Transportation (H.da Cunha Bisaggio) US-Brazil Energy Forum (USBEF)- Workshop on Natural Gas, 26 October 2020.



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Natural gas infrastructure network for imports, exports and internal distribution will expand considerably in upcoming decades. *(422 Municipalities currently with gas service)*

Main figures about natural gas infrastructure in Brazil

9.409 km transmission pipelines

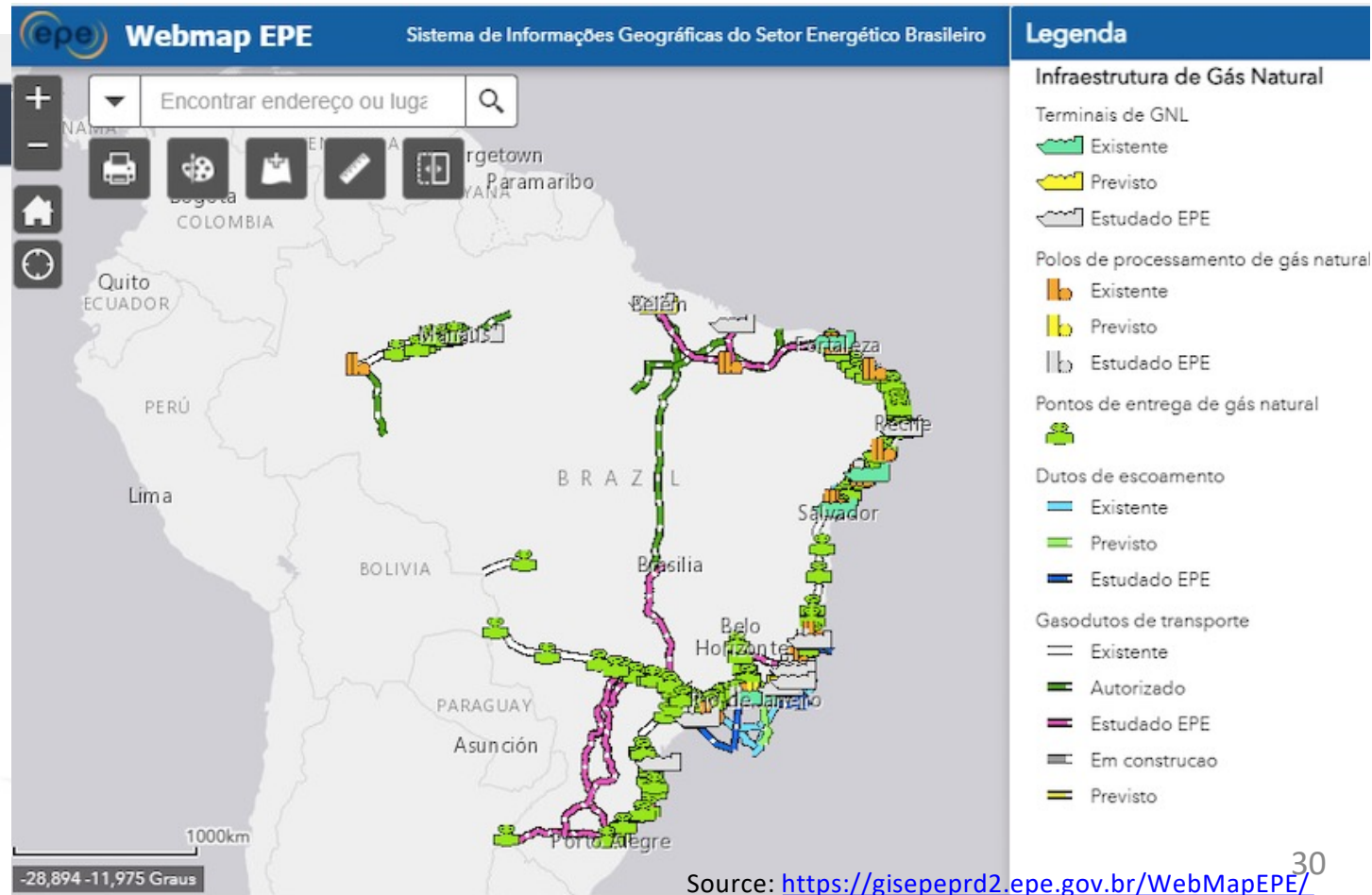
187 delivery stations (*citygates*)

33 compression stations

14 processing plants
(96 million m³/d)

5 LNG regasification terminals (with a total capacity of 99 million m³/d)

Available at
www.epe.gov.br



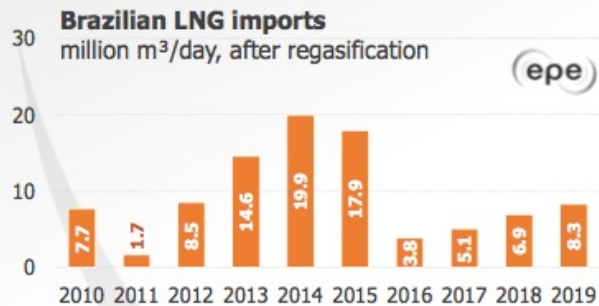


Availability of LNG will increase, also providing new opportunities for the HDV transport sector.

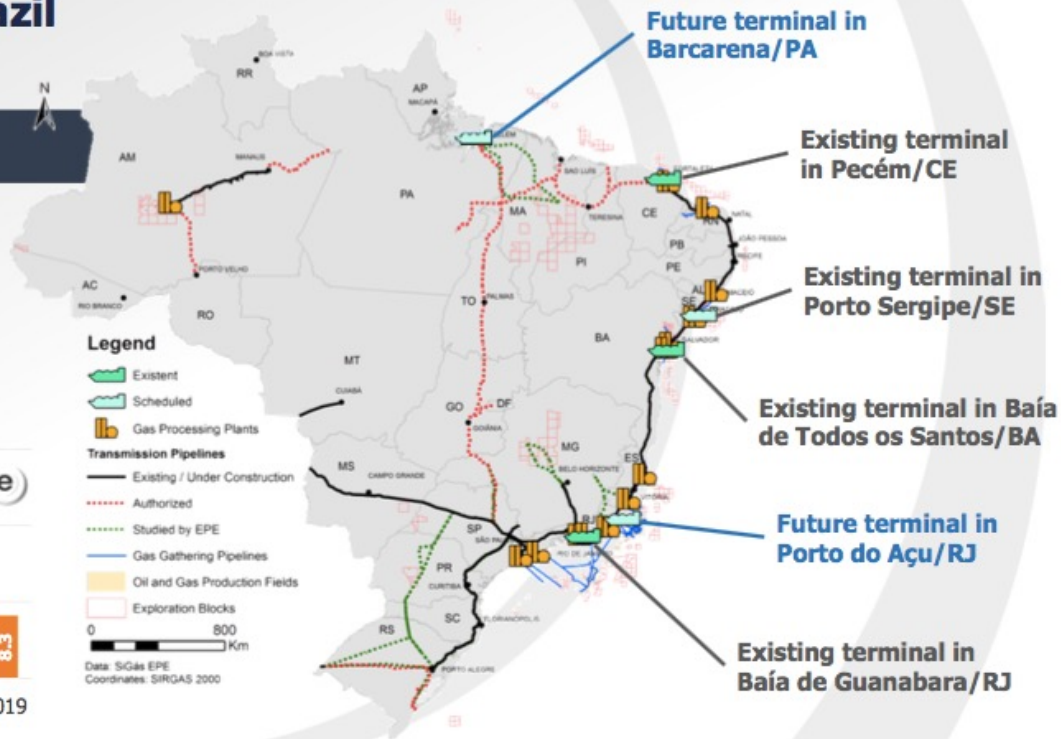
LNG infrastructure in Brazil

Main figures about LNG infrastructure in Brazil

- 4 Existing LNG regasification terminals
- 2 Future LNG regasification terminals



Source: MME, EPE



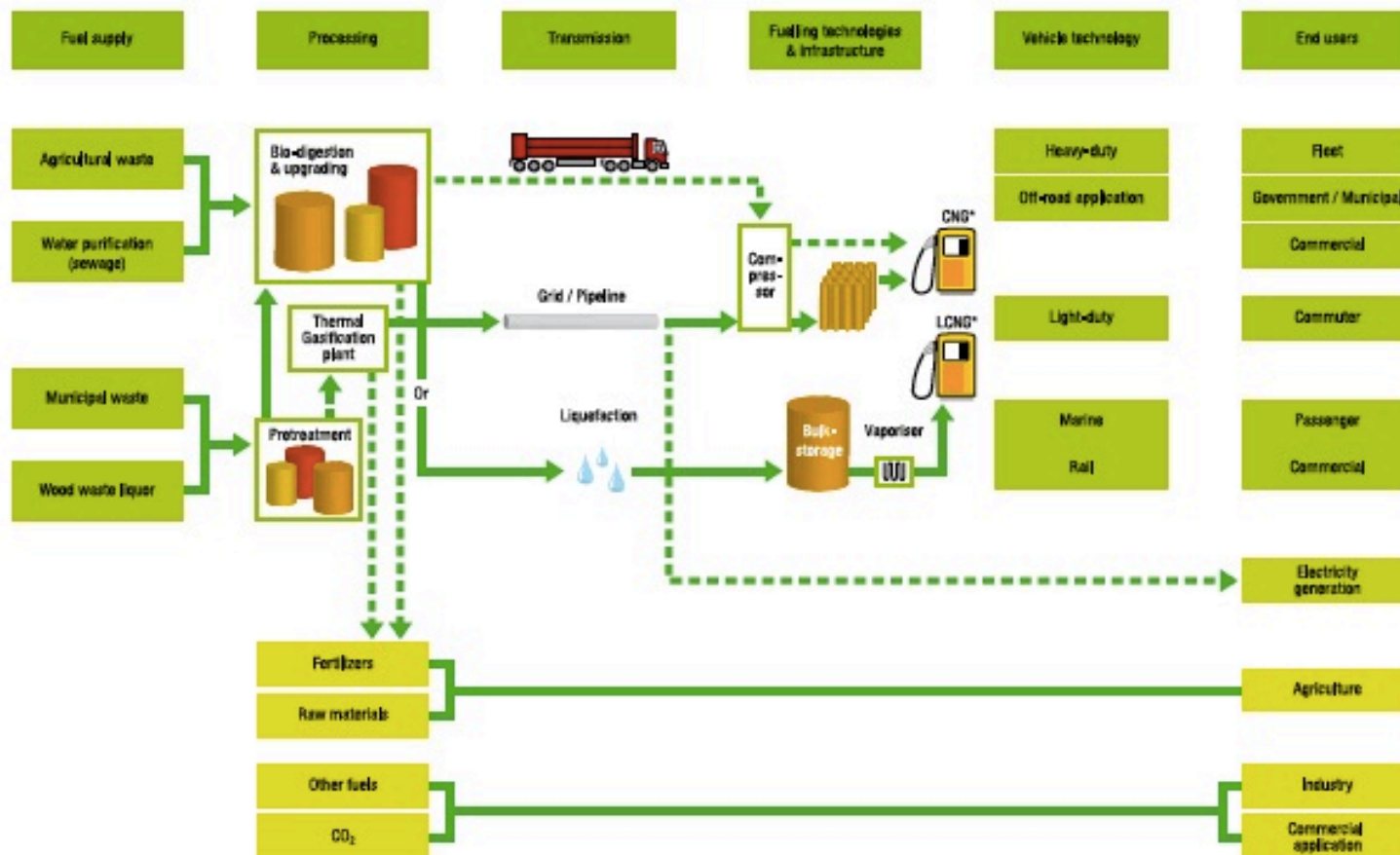
LNG Ports

A nexus for fuel, trucks, trains & ships!!

Renewable biogas-to-biomethane is both a low CO₂ energy strategy AND a waste management strategy

Figure 2 BIOGAS VEHICLE FUEL PATHWAY

Biogas vehicle fuel pathways



Source: Decisionmaker's Guide: How to Implement a Biomethane Project, Bigasmax, European Commission, 2008 (modified 2021)

KEY WEAKNESSES

NGV Technology



- Local production capability for heavy duty NGV technologies and components is lacking. Further development is needed.
- Natural gas HDVs are more expensive than diesel HDVs.
(Early purchase incentives required.)
- Lightweight CNG cylinders Types III & IV suitable for HDVs are not available in Brazil and homologation/certification of these tanks in Brazil is expensive*

** (~R\$ 300,000 / US\$ 53,395, re-certifiable **every** three years, for foreign manufactured cylinders. Source: Inmetro.)*

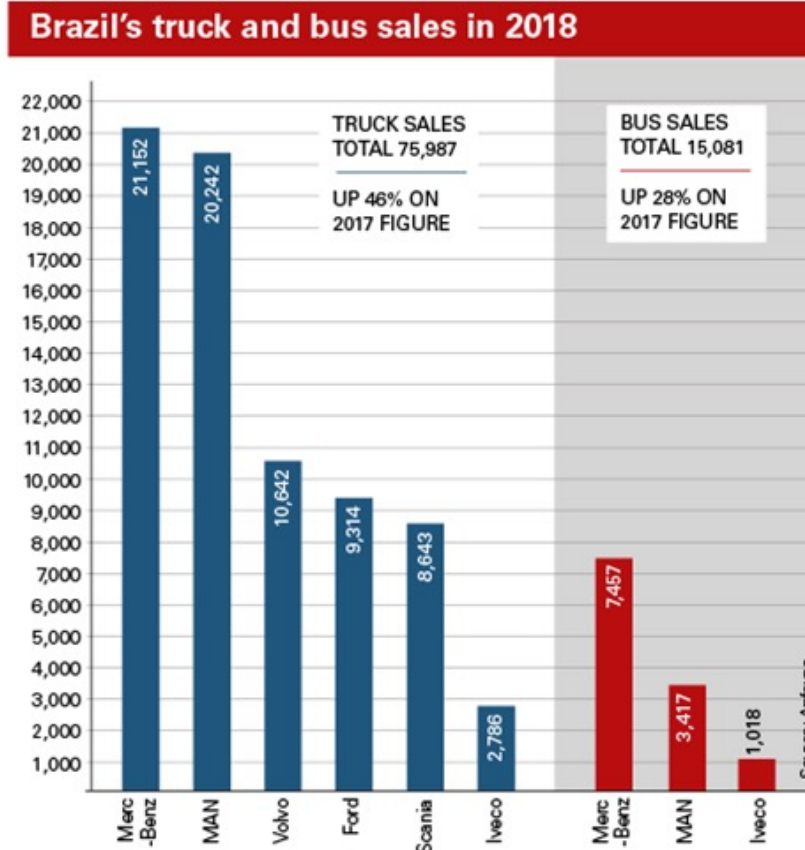


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As of May 2021 only Scania provided HD NGVs in Brazil
1 bus and 1 truck model with a variety of engine sizes

Most of the other OEMs have gas variants but they are not (yet) offered in Brazil

Empresas Companies	Caminhões Trucks	Ônibus Buses
Agrale		
Audi		
BMW		
CAOA		
CNH (Iveco)		
DAF		
FCA (Fiat, Jeep)		
Ford		
General Motors		
Honda		
HPE (Mitsubishi, Suzuki)		
Hyundai		
Jaguar Land Rover		
MAN		
Mercedes-Benz		
Nissan		
PSA (Peugeot, Citroën)		
Renault		
Scania		
Toyota		
Volkswagen		
Volvo		



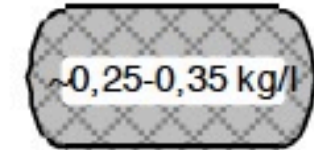
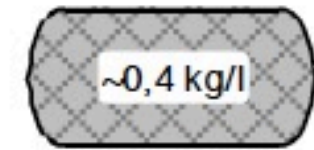
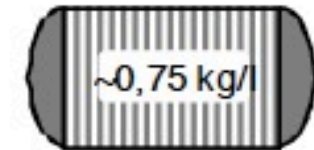
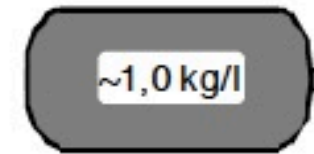
Also:
Cummins offers
5, Euro V models
of natural gas
engines

Source: Brazilian Automotive Yearbook, 2020.

Source: Motoring on: Brazil's heavyweight OEMs prepare for growth, Tony Danby, Automotive Logistics, May 2019

Weight-to-Volume of CNG cylinders for trucks and buses favor the Types III & IV lightweight cylinders

- CNG type 1 (200bar)
 - Full metal, steel or aluminium
 - ~ 1.0 kg/l
- CNG Type 2 (200bar)
 - Metal liner with hoop wrapped FRP (glass or carbon)
 - ~ 0.75 kg/l
- CNG type 3
 - Metal liner (steel, stainl. Steel, aluminium) fully wrapped FRP
 - ~ 0.4 kg/l
- CNG type 4
 - Plastic liner fully wrapped with FRP
 - 0.25-0.35 kg/l



Luxfer



FRP = Fiber reinforced plastic



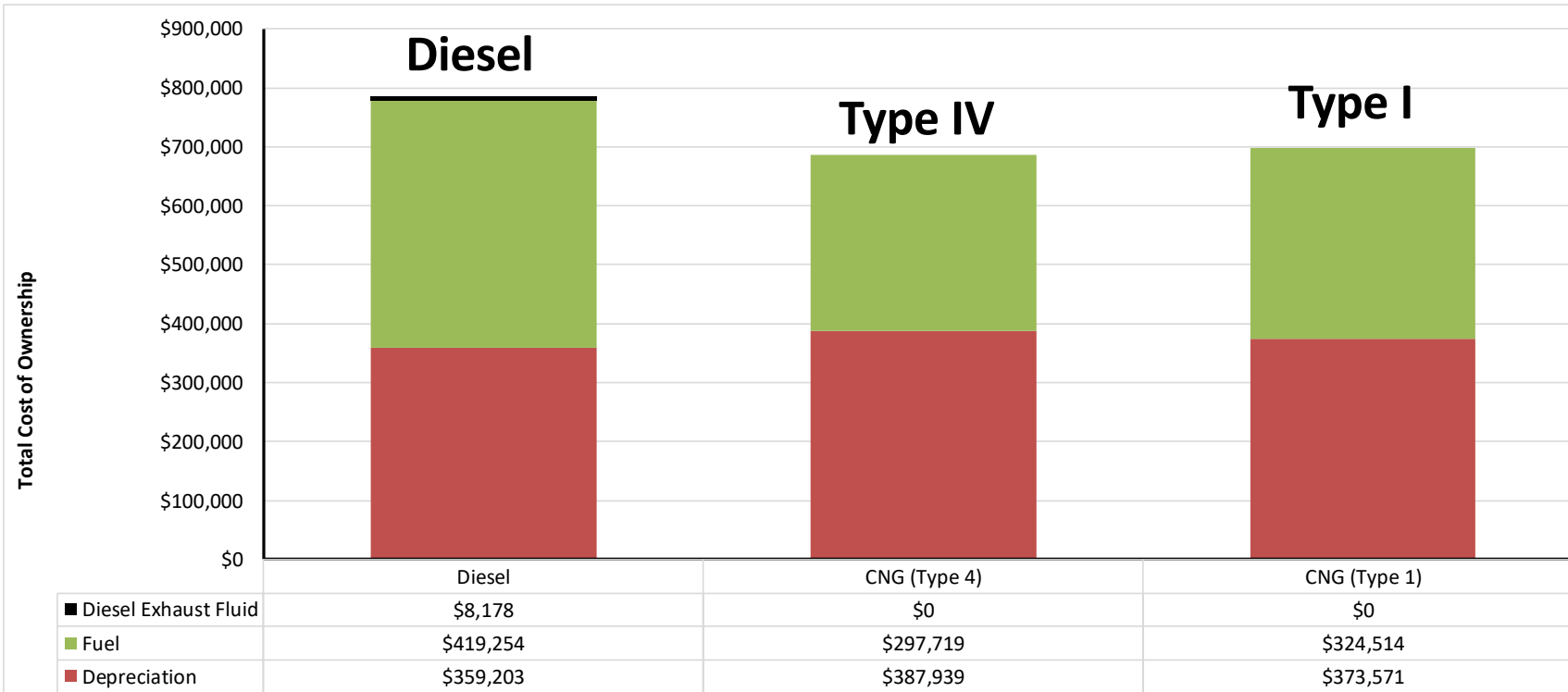
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12-yr Bus Cost of Ownership of Type I vs IV CNG Cylinders

Lower cost of Type I offset by higher fuel costs (U.S. case)

Source: Argonne National Laboratory. A.Burnham. 2021.

Cost of Ownership - Transit Bus Fleet



Total fuel cost:	\$427,432	\$297,719	\$324,514
TCO w/Depreciation	\$786,635	\$685,658	\$698,085

Diesel

- \$500,000
- 15,000 kg
- 4.4 mpdgc
- \$3/dgc

CNG (IV) bus

- \$540,000
- 16,000 kg
- 3.7 mpdgc
- \$2/dgc

CNG (I) bus

- \$520,000
- 19,000 kg
- 3.4 mpdgc
- \$2/dgc

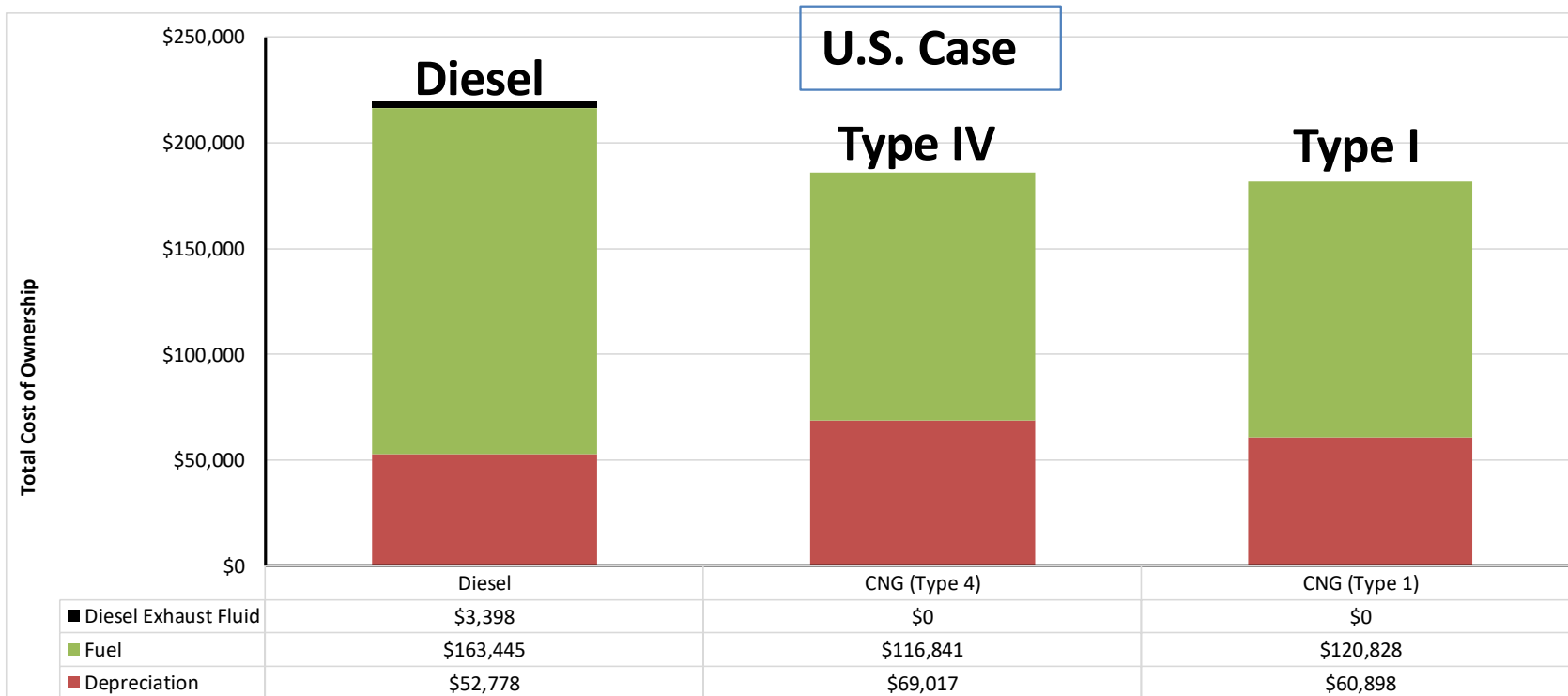
~5% fuel penalty for 10% increase in weight for transit (urban) duty-cycle

5-year Tractor Truck Cost of Ownership of Type I vs IV CNG Cylinders

Smaller MPG penalty for *highway* driving = *Slightly* lower Type I TCO costs

Source: Argonne National Laboratory. A.Burnham. 2021.

Based on short-haul ~105,000 km/year. TCO becomes positive @ more KMs w/fuel savings.



Total fuel cost: \$166,843 \$116,841 \$120,828

TCO w/Depreciation \$219,621 \$185,858 \$181,726

Diesel

- \$130,000
- 10,000 kg
- 4.4 mpdgc
- \$3/dgc

CNG (IV) semi

- \$170,000
- 11,000 kg
- 5.6 mpdgc
- \$2/dgc

CNG (I) semi

- \$150,000
- 14,000 kg
- 5.4 mpdgc
- \$2/dgc

~1.5% fuel penalty for
10% increase in weight for
highway driving duty-cycle

KEY WEAKNESS



Fluctuations in fuel price differential: gas vs. diesel

- Fluctuations of both diesel and gas prices, as well as the *Real* exchange rate, affect the generally favorable price differential between the two competing fuels.
- Diesel pricing system is subject to the pricing strategy of the major refiners and oil importers in Brazil.
- The gas price is adjusted every three months and can lag, up or down, related to diesel.



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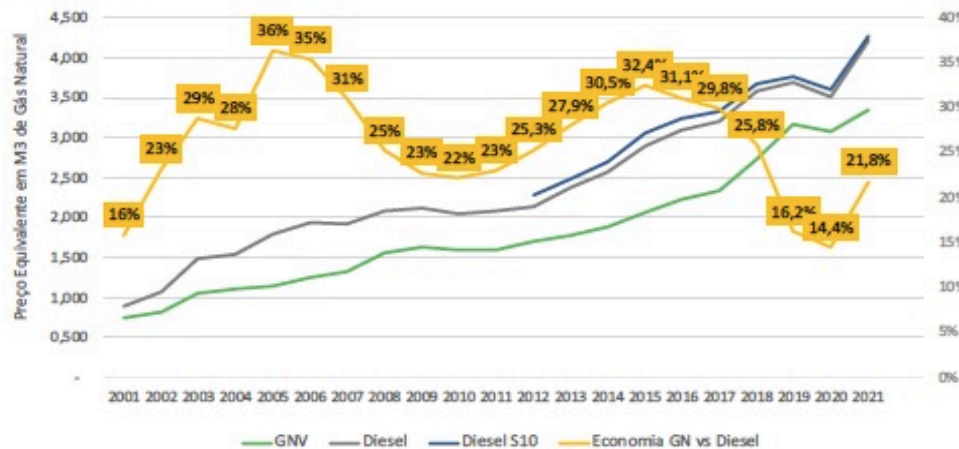
Fluctuating price differential (gas vs. diesel) lengthens the TCO and makes fleet decisions more difficult

Competitividade do Gás Natural

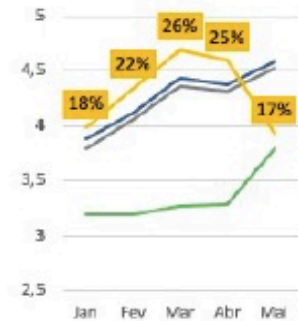
20-year average gas vs diesel price differential = 24.9%

2021 5-month average gas vs diesel price differential = 21.6%

Competitividade



2021



Typically, natural gas must be 30-50% less than diesel to create a favorable TCO.

Custo Considerando Equivalência Energética

Combustível	R\$/m³ EqGN	USD MMBTU
Diesel	4,5753	\$23,36
Gás Natural	3,7900	\$19,35
Economia do GN		17,2%

Dados:

Diesel 9.159 Kcal/litro
 GN 9.400 kcal/m³
 MMBTU = 26,8 m³
 Dollar Com: R\$ 5,25

EqGN = equivalente a gás natural

OPPORTUNITIES *Technology*



- LNG in HDVs provide longer range and reduced weight compared to CNG, which is more appropriate for shorter-and-medium distances.*
- Dual-fuel technologies (diesel-gas) might add more TRUCK options for more fleet owners/operators.
- Euro VI will raise the price of diesel trucks, potentially making NGVs more cost-competitive.

*Storage density is the primary reason for using LNG as a vehicle fuel. LNG can store 2.5 times more natural gas than CNG. 1 ft³ of LNG = 600 ft³ of natural gas. 1 ft³ of CNG (3600 psig) = 240 cu ft of natural gas.

Dual-Fuel (diesel-gas) may provide an option to convert new or used HDVs to run variably on 0-90% gas-to-diesel (best for over-the-road trucks). Systems can be removed for second-hand market.

Currently there are no Brazilian regulations specifically covering D-F systems.

VEHICLES CONVERTED IN
Italy - Costa Rica - Emirates - Venezuela - Bolivia - Pakistan - Egypt

HEAVY DUTY



IVEVO STALIS 10.3L 309/316KW



VOLVO FH12 12.1L 338KW
VOLVO FH440 13 L 294 KW



DAFXF430 12.5L 355KW



RENAULT PREMIUM 11.1L 272KW



MAN AG430 10.5L 316KW



VOLVO CV420 11.7L 308KW



IVECO STRALIS 7.9L 259 KW



IVECO EUROSTAR 10.5L 309KW



CHALLENGES/threats

Regulatory-related



- **The absence of regulations for LNG** trucks, tanks, fuel connectors/receptacles and fuel stations (including Liquid-to-CNG stations [L-CNG]) **prevent the use of the LNG option.**
- **Import tariffs impede new, environmentally friendly (and beneficial) technologies** from coming to Brazil, such as NGVs and associated equipment like lightweight CNG cylinders Types III and IV required by the HD NGV suppliers.
- While **NGVs are subject to import tariffs, electric vehicles are not**, establishing a potential competitive disadvantage for NGVs if/when HD EVs also are imported.
- The amount and level of **various taxes** on vehicles and their use **affect the TCO** of HD NGVs.

CHALLENGES/threats

Policy-Related



- Creating **Federal government funding**, incentives and fiscal support mechanisms for NGVs **is necessary** to motivate a sustainable, customer-driven market for natural gas HDVs.
- **Incentives (and mandates) for electric** and hybrid vehicles, particularly if they exceed those for NGVs (CNG & LNG), **will influence (and reshape) customer decisions** about their use of diesel and alternative fuels.
- Over time, **concerns about fossil methane as a greenhouse gas** and its contribution to global warming will impact NGV markets, at least globally, if not nationally; *(potentially motivating a shift toward greater production and supply of biomethane).*

CHALLENGES/threats

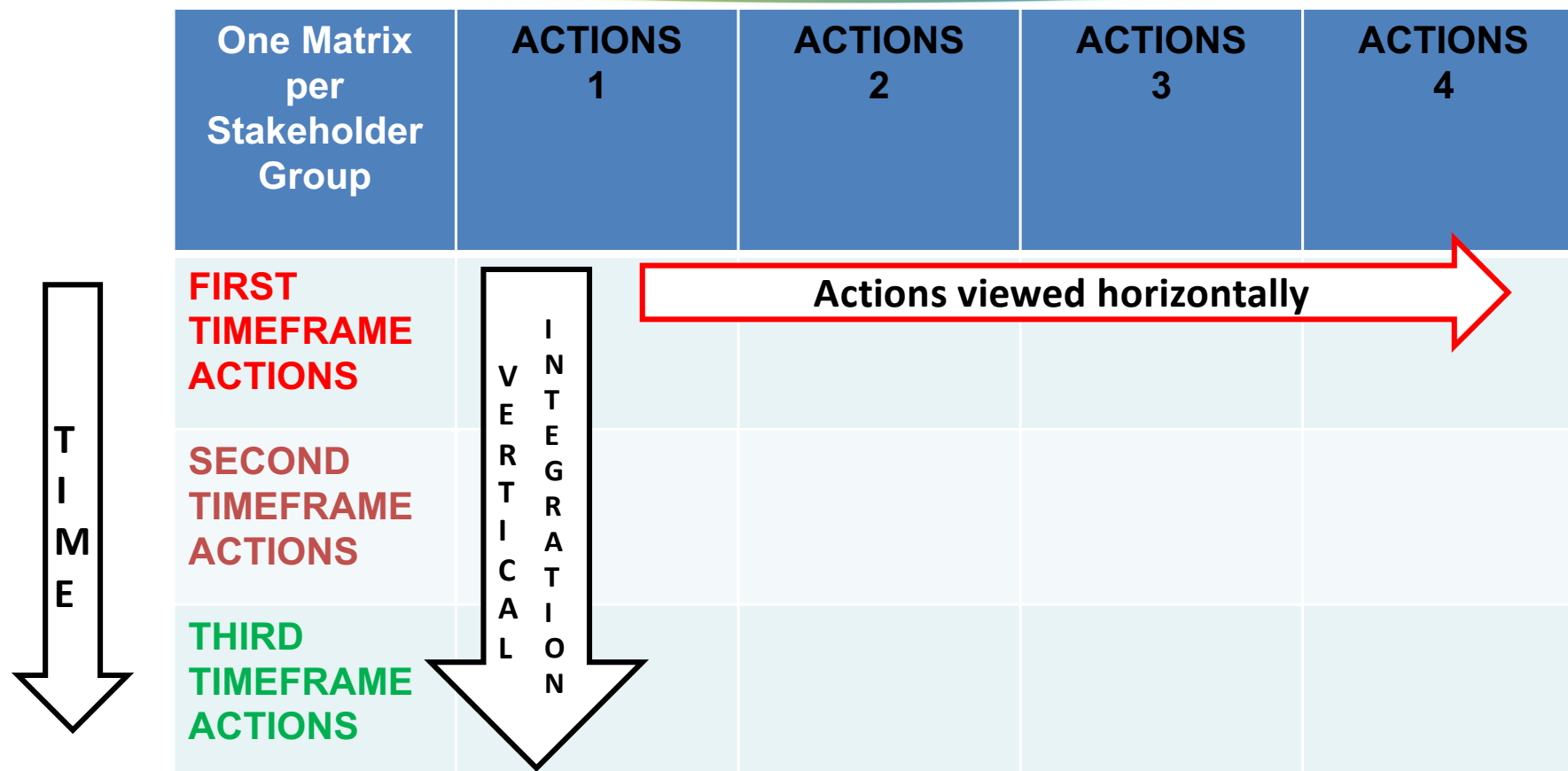
Technology-related



- OEMs claim their investments to upgrade truck production to Euro V (compatible with Proconve 7) have not yet been amortized. Further investments to upgrade to Euro VI compliance (by 2023) might affect additional investments to produce NGVs.

WHAT CAN STAKEHOLDERS DO.... AND WHEN SHOULD THEY DO IT?

See Part 2 of the Roadmap



ANNEX: STAKEHOLDER SWOCs

Strengths, Weaknesses, Opportunities & Challenges/Threats

- *Brazil Overview* 
- *Government/Public Sector* 
- *The downstream natural gas industry* 
- *Vehicle manufacturers and NGV systems and component suppliers* 
- *Fleet operators* 
- *Fuel station and infrastructure suppliers* 
- *Civil society* 

Development of the SWOCs

- Each of the six stakeholder meetings were presented with a sample/example SWOC for discussion.
- This was based on in-depth research and documentation regarding Brazil's overall political-socio-economic-energy-transport 'situation'.
- The sample SWOCs also were based upon empirical evidence of the global NGV commercialization experiences – political, technical and marketing -- gleaned over the past four decades.
- Based on the discussions and feedback with each stakeholder group, the SWOCs were revised and returned to the participants, who then provided further reactions and input to the contractor team developing the Roadmap.
- These final SWOCs for each stakeholder group presented below must be viewed individually and together. As such, they hold the key to understanding the views and needs of each stakeholder and what actions are required *by* each stakeholder group (see Part 2 of the Roadmap) to develop and sustain the Brazil market for heavy duty natural gas trucks and buses.



BRAZIL OVERVIEW

SWOC



STRENGTHS

NGV Technology



- ***Proven technology*** widely available, with more than 28 million NGVs globally.
- ***OEM vehicles and engines are available*** with state-of-the-art emissions technology (Euro VI) resulting in lower pollution than diesel. ('Availability' = 'they exist' but not necessarily in every market, including Brazil.)
- ***TCO*** (Total Cost of Ownership) ***can be***, for ***most*** natural gas heavy duty vehicle applications, more competitive than diesel.
- ***TCO is better than other fuel alternatives*** (electric & hydrogen fuel cells).

STRENGTHS con't

Natural Gas Benefits & Supply Outlook



- Natural gas:
 - Is a **widely available** resource with **low, local air pollutant emissions**.
 - Has a **lower carbon footprint** than other fossil fuels.
 - In HD trucks can reduce particulate emissions up to 95% and NOx by 85%, contributing to the **reduction of hospitalizations and deaths** due to cardio-respiratory diseases in large urban centers.
 - Has **flexibility** to be stored and transported as a **compressed gas or cryogenic liquid**.
 - **Cannot be adulterated** or stolen from a vehicle (as is possible with liquid fuels).
- The Brazil gas industry is **embarking on a new plan** supported by the government (The New Gas Law, 2021) to **diversify** the natural gas **supply** and **expand** the natural gas **distribution** to areas where gas previously has not been available.
- **Supply of domestic natural gas** is anticipated to increase 80+% by 2030 and continue **strong growth to 2040 and beyond**.¹
- **Biomethane** is a **renewable resource option** that achieves **extremely low CO₂ levels on a well-to-wheel basis**; as much as -95%.²
- Natural gas can **help improve the trade balance** by replacing imported diesel fuel, which represents about 20% of diesel consumed in Brazil.

¹Gas for the Development, BNDES 2021/2020.

² California Energy Commission; European Commission; etc.

WEAKNESSES

NGV Technology



- While many natural gas HDVs (heavy duty vehicles) and engines are available for a wide range of applications, very few are available in Brazil. Local production capability for heavy duty NGV technologies and components needs further development.
- Natural gas HDVs are more expensive than diesel HDVs.
- The cost per kilometer (m^3/km) can be, depending on application, less competitive than diesel.
- Euro VI technologies will reduce the relative environmental benefits of introducing NGVs.
- Heavy, Type I all-steel CNG cylinders reduce the carriage weight and autonomy (range) of HDVs.
- Lightweight CNG cylinders Types III & IV suitable for HDVs are not available in Brazil and homologation/certification of these tanks in Brazil is expensive

WEAKNESSES con't



Infrastructure and Markets

- Existing natural gas pipeline does not yet reach potential customers.
- Lack of fueling infrastructure specifically for HD NGVs. (Classic chicken & egg).

Fuel prices

- Fluctuations of both diesel and gas prices, as well as the Real exchange rate, affect the generally favorable price differential between the two competing fuels.
 - Diesel pricing system is subject to the pricing strategy of the major refiners and oil importers in Brazil. The gas price is adjusted every three months and can lag, up or down, related to diesel.
-



Knowledge about NGVs

- Policy makers (Federal, state and municipal), fleet operators and industry knowledge about the economic, environmental, energy security, operational and other related opportunities and challenges of increased use of methane (renewable or fossil) in the heavy duty truck and bus sectors varies widely.

Government policy

- Federal policy for alternative fuels (including bio/renewable fuels) does not yet include the use of natural gas in heavy duty vehicles.
-

OPPORTUNITIES



Technology

- LNG in HDVs provide longer range and reduced weight compared to CNG, which is more appropriate for shorter-and-medium distances.
- Dual-fuel technologies (diesel-gas) might add more vehicle options for more fleet owners/operators.
- Euro VI will raise the price of diesel trucks, potentially making NGVs more cost-competitive.

Infrastructure and Markets

- A variety of private and semi-public fueling station options and strategies will be available to serve a growing HDV market: on-site at fleets (mobile and stationary); shared fueling stations exclusively for multiple heavy-duty fleets in urban centers; truck stations along 'Blue Corridors.'
- Creating a Carbon Credit (CBIO) exclusively for biomethane production could stimulate and help the gradual replacement of diesel.

Information/education

- Opportunity to create new institutional mechanisms to inform policy makers, fleet operators and industry about the economic, environmental, energy security, and other related opportunities and challenges of increased use of methane (renewable or fossil) in the heavy-duty truck and bus sectors.

OPPORTUNITIES con't

New Horizons for Natural Gas



- Diversifying natural gas suppliers has the potential to increase the domestic supply and will contribute to the competitiveness of natural gas.
- Potential to expand the gas supply to customers beyond the pipeline using small scale LNG (SSLNG) and LNG tank trucks (to supplement existing CNG tank truck supply).
- Natural gas can replace imported diesel in the HD trucking and public transport sector in selected parts of the country where gas is (and will be) available at competitive prices.
- Projected growth in biomethane production (mainly in the interior agricultural regions) adds a renewable fuel option for HDVs.
- Government is open to a position of 'fuel neutrality' related to carbon emissions reduction strategies and policies.

CHALLENGES (THREATS)



Technology

- OEMs claim their investments to upgrade truck production to Euro V (compatible with Proconve7*) have not yet been amortized. Further investments to upgrade to Euro VI compliance (by 2023) might affect additional investments to produce NGVs.

Regulatory Challenges

- Import tariffs severely impede new, environmentally beneficial technologies from coming to Brazil, such as NGVs and associated equipment like lightweight CNG cylinders Types III and IV required by the HD NGV suppliers.
- The amount and level of various taxes on vehicles and their use affect the TCO of HD NGVs.
- While NGVs are subject to tariffs, electric vehicles are not, establishing a competitive disadvantage for NGVs.**
- The absence of regulations for LNG trucks, tanks, fuel connectors/receptacles and fuel stations (including Liquid-to-CNG stations [L-CNG]) prevent the use of the LNG option.

*Program for The Control of Air Pollution by Motor Vehicles created by the National Council of the Environment as an air quality control in urban centers. The Proconve P7 is the Brazilian version of Euro V, which is already in force in Europe and represents the fifth stage of progressive reduction of emissions.

** June 2019, EVs were declared exempt from IPI and IOF taxes.



Roadmap do Mercado Brasileiro de
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CHALLENGES (THREATS)

Policy-Related



- Creating Federal government funding, incentives and fiscal support mechanisms for NGVs is necessary to motivate a sustainable, customer-driven market for natural gas HDVs.
 - Incentives (and mandates) for electric and hybrid vehicles, particularly if they exceed those for NGVs (CNG & LNG), will influence (and reshape) customer decisions about their use of diesel and alternative fuels.
 - Over time, concerns about fossil methane as a greenhouse gas and its contribution to global warming will impact NGV markets, at least globally, if not nationally; potentially motivating a shift toward greater production and supply of biomethane.
 - Strengthening of regulatory and inspection entities to monitor the entry and development of NGV technologies.
-



Roadmap do Mercado Brasileiro de
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BRAZIL GOVERNMENT/PUBLIC SECTOR SWOC



STRENGTHS



Policies & Analyses are Moving Forward

- Environmental challenges and health impacts of emissions from the transport sector are recognized and have been evaluated.*
- Existing NGV policies, standards and regulations provide foundation for expansion to the HDV sector.
- Some financing and incentives at national, regional and local jurisdictions exist for EVs and NGVs (good potential for expansion of financial incentives).
- Strong national support for expansion of natural gas supply and infrastructure.
- The governmental program New Gas Market (NGM) wants to stimulate demand, in order to stimulate more investments in supply.
- Some 'horizontal' mechanisms already exist for Interagency coordination of energy /transport policy. (Energy Policy Committee; Interagency Working Group on Natural Gas)
- RenovoBio policy: Biomethane defined as renewable energy & Carbon Credits provided biomethane can be used to reduce biofuels production footprint.

*For example: *Evaluation of the impacts on public health and its value due to the implementation of natural gas vehicle in the energy transport matrix - public transport (bus) in the metropolitan regions of Sao Paulo and Rio de Janeiro*, Evangelina Vormittag, Technical Director, Institute of Health and Sustainability

WEAKNESSES

Information & Policy Gaps



- There is room for improvement at the existing Federal policy for alternative fuel vehicles that incorporates EVs, ethanol and natural gas (fossil and biomethane) for the land-based transportation sector (LDVs, HDVs, municipal vehicles (buses & garbage trucks) off-road, and potentially, rail.)
- Federal-level communications vertically to state and municipal governments about clean alternative fuels and implementation strategies is lacking.
- The ‘knowledge-base’ about NGVs – cost/benefits – should be shared more effectively by policy makers at different levels of government.
- While national data for light duty vehicles exists, there is little data available on alternative fuel usage and vehicles in Brazil. A special mechanism may have to be created to achieve this as the data will help measure the success of implementation strategies.*
- There are significant gaps in standards/regulations & certifications for HD NGVs (see ‘Challenges/Threats’).
- The price differential between natural gas and petroleum fluctuates due to the commodity prices of the fuel (in the ‘oil basket’) as well as fluctuations in the exchange rate, which also affects the price of imported diesel.
- There are not yet substantial incentives for biomethane vehicle applications.
- The local production of NGVs and related equipment needs development.

*Examples of institutionalized AFV data collection include: The U.S. Alternative Fuel Data Center (AFDC) created by legislation in 1992 and the European Alternative Fuels Observatory (EAFO) created by the European Commission.



OPPORTUNITIES



- Develop/adapt a methodology/model to evaluate competitiveness of NGVs vs Diesel, Total Cost of Operation (TCO).*
- Opportunity to reduce the particulates emitted by HDV, which are significant causes of respiratory diseases.+
- Leadership by example: Government fleet vehicles (fed/local) to run vehicles on alternative fuels (including natural gas)
- NGV policies can assist other industrial sectors to leverage gas distribution.
- Build relationship between local and multinational companies to supply technologies (and possibly develop or improve International value chain [i.e. Scania, IVECO, etc.])
- Use local industry to accelerate the new biofuels and biomethane (Virtual cycle of investment.)

*e.g. Argonne National Laboratory AFLEET model, possibly can be adapted to fit the Brazil market(?).

*[technical note concerning this subject at: https://www.epe.gov.br/sites-pt/publicacoes-dados-abertos/publicacoes/PublicacoesArquivos/publicacao-570/NT-EPE-DPG-SDB-2020-01_NT_Impacto_saude_uso_bios.pdf](https://www.epe.gov.br/sites-pt/publicacoes-dados-abertos/publicacoes/PublicacoesArquivos/publicacao-570/NT-EPE-DPG-SDB-2020-01_NT_Impacto_saude_uso_bios.pdf)

CHALLENGES (THREATS)



Policies affecting imported environmental technologies

- National tariffs on incoming equipment (Value Added Tax-VAT ~18%) provides an economic deterrent for imported products.*
- Strict rules for and enforcement of requirements for products with a minimum level of local content could impede market entry of imported NGV technologies.

Standards & regulations

- Gaps in standards/regulations/certifications hamper the introduction of new technologies required for HD NGVs. (Specifically related to LNG trucks, tanks, fuel connectors, etc.)
- Certification procedures for imported NGV technologies are very expensive; i.e for lightweight CNG cylinders Types III and IV.
- Policy for pipeline injection of biomethane currently being developed (for biomethane from urban and agricultural waste - animal and vegetation).

*It is questionable if these will be reduced, given the existing spare capacity of local OEMs. But, Margarete Gandini, general coordinator of Implementation and Inspection of Automotive Regimes at the Secretariat for the Development of Industry, Commerce, Services and Innovation, linked to the Ministry of the Economy indicated (2021 03 3) that discussions have been underway to create a program to develop emerging technologies not available in Brazil.



Market entry status quo

- OEMs have invested in diesel vehicles in Brazil and the launch of a new NGV HDV policy could pose a threat to their principal markets.

Tax structure

- Natural gas sales are taxed differently by each state.⁺

+ Most of the sales tax (ICMS) receipts go to the producing state. Therefore, producing states lower taxes on natural gas to incentivize the consumption. However, non-producing states introduce prohibitive sales on natural gas, since the fuel will only reduce their tax receipts. Liquid fuels work differently. The state where the fuel was consumed receives all of the tax receipts. Therefore, many non-producing states prefer to continue incentivizing diesel.



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THE DOWNSTREAM NATURAL GAS INDUSTRY

SWOC



STRENGTHS



Natural gas as an energy choice

- Natural gas is a well-known commodity in the energy mix for Brazil.
- New sources of natural gas and biomethane in the interior of the country provide strong supply into the future, for both fossil and renewable gas.
- Opening the market for natural gas has the potential for increasing investments in infrastructure expansion and diversification of new suppliers in the sector.
- Natural gas is a pathway to the transition to de-carbonization.

Biomethane as a renewable option

- Biomethane is amongst the lowest CO₂ fuel on a well-to-wheel basis . As such it represents a possible 'destination' for the gas industry as well as part of a waste management strategy.
- The price of biomethane as a domestic fuel will tend to be more stable than imported fuels.
- There is a Brazil standard/regulation for biomethane pipeline injection.*
- Producers of biomethane for the transport sector receive carbon credits. (Fuel distribution companies buy the credits related to the amount of fossil fuels sold each year; also applies to ethanol producers). Began in 2020. (RenonvaBio.)

*ANP Resolution no. 685, DE 29.6.2017 - DOU 30.6.2017 establishes the rules for quality control approval and the specification of the biomethane from landfills and sewage treatment plants.

STRENGTHS con't *NGV Technology-Related*



- CO₂ tailpipe emissions from trucks is reduced by ~ 10-15%.
- Natural gas is the cleanest fossil fuel with proven low emissions competitive with state-of-the-art gasoline and diesel engines.
- HDV engines produce lower noise (~10db++) than diesels due to the high-octane rating of ~120 (Methane number equivalent ~ 70-75).*

*Multiple manufacturers' test results: Scania, Iveco, Cummins, etc.

WEAKNESSES

Energy Price-Related Issues



- The price differential of natural gas relative to petroleum fluctuates due to changes in the price of natural gas, diesel, taxes and the fluctuations of the Real (also since approximately 18% of diesel is imported).
- International prices of natural gas, regulated in three months blocks, and the exchange rates pegged to the US dollar, have an impact on the stability of (fossil) natural gas prices in Brazil.
- The price of domestic natural gas is based on the price of international LNG, partially imported, taking into account transport, storage, regasification, injection into the pipeline and taxes. International prices (and seasonality) affect domestic gas prices positively or negatively.
- Transportation of biomethane is more expensive because the production facilities are not close to the places where it typically is injected into the pipeline network (or used as a vehicle fuel).
- In the future biomethane will become a commodity but the biomethane price may be linked to the price of petroleum fuels.

WEAKNESSES con't



Issues Related to Standards & Regulations

- Brazil is going through a modernization of its regulatory framework for natural gas. The evolution of the regulations must create opportunities and measures to attract investment in the gas sector to increase the supply and stimulate demand. Policy makers should create an environment that maximizes predictability, transparency and minimizes risk for the industry.
- There are no domestic manufacturers of CNG II, III ,or IV cylinders. Lighter weight CNG cylinder Types III and particularly IV are used in buses and trucks to limit a reduction of the vehicle carriage weight.*
- CNG tanks (Types III and IV) must pass an expensive domestic certification procedure despite being certified internationally (ISO or UNECE R.110.)
- There are no standards for LNG trucks, onboard LNG fuel tanks, fuel connectors/receptacles, or fuel stations.+
- There are no LNG fuel station standards and they must be developed. Also, for L-CNG standard are needed and are in the works.

*ISO 11439 is used to certify CNG cylinders, adopted as Mercosur Technical Regulations (RTM).

+NBR 11353, renewed in 2020, will try to introduce LNG equipment. Liquefied-to-compressed (L-CNG) standards are being developed.



OPPORTUNITIES



- Government – municipal, state and federal -- has a variety of policy options to incentivize the development of and investment in the gas sector as well as the development of new technologies that recognize the potential environmental contributions of natural gas and biomethane.

Gas Availability

- Promotion of new markets; also to levelize gas price.
 - Pipeline expansion into interior parts of the country strengthen long term gas industry viability and open new markets.
 - Government has a variety of policy tools available to encourage investment in the gas sector and the development of new technologies that recognize the potential environmental contributions of natural gas, LNG and biomethane.
-

OPPORTUNITIES con't



Biomethane as a renewable resource

- Biomethane is not subject to the relationship to oil prices and exchange rates. Biomethane contracts could be possible to resolve price differential issues.
- Biomethane can reduce 95% of CO2 emissions on a well-to-wheel basis. (Based on sugar cane/vinasse, filter cake, the solid residue from sugar cane.)*
- Potential for biomethane credits at the fuel station. (Green Gas).

Socio-economic improvements

- Pollution reduction in the transport sector improves health outlook of population.
- Potential to increase competitive position of domestic equipment suppliers who currently import technology.
- Potential to monetize the social/economic benefits of natural gas (generate jobs) as it replaces imported diesel in the HDV market.

* RenovaBio.

+Financial and non-financial incentives, mandates, development of standards/regulations, investment in RD&D, and leadership by example (using alternative fuel vehicles in government fleets).

CHALLENGES (THREATS)



Cost/Economic factors

- Tax on NGV technologies imported to Brazil increases price of NGVs, making some prohibitive.
- The price differential of natural gas to petroleum fluctuates due to the commodity prices of the fuel as well as the fluctuations in the exchange rate, which also affects the price of imported diesel.
- Challenge to monetize the social/economic benefits of natural gas (generate jobs) as it replaces imported diesel in the HDV market.

HDV industry competitive issues

- Advocacy (and preference) of truckers for status-quo diesel fuel and trucks is strong.
 - Only one Euro VI natural gas truck is available in Brazil.
 - There is no second-hand market for HD NGVs.
 - The advent of Euro VI, cleaner diesel truck technology may be a competitor to natural gas HDVs.
 - Carbon credits may not be applicable to fossil natural gas as a vehicle fuel.
 - Competitive forces from the EV industry.
-

CHALLENGES (THREATS) con't *Policies with unforeseen consequences*



- **Gas composition:** Ethane content currently is about 6%, with the legal limit at 12%. The Brazilian National Petroleum Agency (ANP) *is considering* raising this to 18%, which negatively affects natural gas engine performance.*
- Potential to prioritize biogas for electric generation as a CO₂ reduction strategy would divert biomethane for the vehicle sector.

*Five major HD engine manufacturers recommend that ethane limits should not exceed 4-11% ethane content in natural gas as vehicle fuel. *Effects of Natural Gas Composition Variations on the Operation, Performance and Exhaust Emissions of Natural Gas - Powered Vehicles*, Hien Ly, IANGV Conference paper, 2002. The same conclusion was also reached by ANP in the report “Revisão da RANP nº 16/2008”.

<http://antigo.mme.gov.br/documents/36112/491926/Relatório+sobre+especificação+do+gás+natural+06+08+2020+vf.pdf/7840def7-7473-66f9-0639-f4fab7be3462>

VEHICLE MANUFACTURERS AND NGV SYSTEMS & COMPONENT SUPPLIERS SWOC



STRENGTHS



- Technology (HD trucks) availability: Gas engine and vehicle technology is available in Brazil to meet the needs of the bus and HD truck industries.* (Classes/size/weight of vehicles need to be identified.)
- Environmental advantages of NGVs are well proven and documented (CO, NOx, particulates, etc.) compared to diesel vehicles.
- Dual-fuel option (diesel-natural gas, compression ignition) for HDVs presents viable alternative to 'dedicated' methane-only variants/options. (Conversion system can be removed so the truck can be re-sold as a 'diesel'.) Can achieve Proconve7 with methane catalyst.
- Government policy makers are supportive of expanding the NGV – LNG and biomethane - market to HDVs.
- The market is very large and there is space for everyone.
- Options for renewable biomethane also are attractive and possible.

**Scania: product based on modular system. Gas engine is adaptable to the system. 340hp, 280hp, 9/1 & 13L and 320hp for buses).*

WEAKNESSES

Technology Availability & Cost



- Natural gas buses and trucks currently are more expensive than diesel variants.
 - More natural gas bus options are needed to satisfy potential customers.
 - Use of CNG cylinders Types III & IV are popular for weight reduction but neither type are certified for use in Brazil.
 - CNG cylinders Type III & IV are expensive; more-so with additional import tariff.
 - Truck manufacturing is segmented (chassis, bodies, engines) and there is too much bureaucracy to produce the vehicles (and certify cylinder technologies), which reduces the vehicle options. This has a negative effect on customers buying the vehicles.
 - Engines and vehicles are made in Brazil but parts are coming from abroad and are subject to import tariff.
 - Issues about LNG environmental aspects (i.e. boil-off) and price compared to CNG.
-

WEAKNESSES con't



OEM-customer service issues

- Dealer network will need training re: cost/benefits of NGV product line.
- If service/maintenance of customer vehicles is provided, OEM facilities must be upgraded in consideration of natural gas (CNG, biomethane, or LNG)

Standards & Regulatory Issues

- Regulatory agencies and certification authorities are not always ready to certify new technologies as fast as the technologies are available.
- Lack of harmonization of fuel connectors and receptacles. Buses and trucks will need to use NGV-2 (not currently provided at public stations)[†]
- There are no LNG fuel station or tank standards, which must be developed.

Fuel Infrastructure

- Public fueling stations may be used in transition phase, however, HDV's high fuel consumption risks reducing the gas available for LDVs at public stations.
- There are no 'truck stops' on strategic, long-haul routes in Brazil suited for refueling high-fuel consuming, heavy duty natural gas vehicles (LNG, CNG or biomethane).

[†] Some trucks are fitted with NGV-2 AND the bayonet, but it is not optimal. Adaptors to NGV-2 are not optimal.

OPPORTUNITIES



- The market(s) for methane buses and trucks is an open field.

Technical options

- NGV options are price-competitive with Euro VI 'clean diesel' HDVs (particularly when diesels are fitted with Selective Catalytic Reduction [SCR] systems)
- LNG provides an opportunity for improved range and reduced weight (of fuel storage).
- Large fleet of existing diesel trucks that can be repowered. Also can be extended to garbage trucks and others. (probably after ~5 years).
- Biomethane opportunity is a great benefit (especially considering emissions on a well-to-wheel basis).

Government fiscal policy options

- Generic tax reduction opportunities may be available: import duties, road tax and ownership tax.
 - Obtain government exemptions from import duty on CNG cylinders and parts being made abroad but systems are being constructed in Brazil.
-

CHALLENGES (THREATS)



Cost & Economics

- Import tax increases the price of vehicles and equipment to suppliers and customers.⁺
- TCO is priority but the political environment, particularly for gas price, will continue to be a challenge.
- The devaluation of the Real that affects the fuel price differential makes gas vehicles less competitive when compared to similar diesel vehicles.
- Re-homologating cylinders (and other technologies) upon arrival is expensive and hinders sales.
- Product 'dumping' (very cheap equipment) occurred with CNG Type 1 cylinders from China.
- Carbon credits may not be applicable to NGVs. Applicable to biomethane but not for fossil gas.

Gas Composition

- Gas composition. Ethane content is about 6%, with the legal limit at 12%. The Brazilian National Petroleum Agency (ANP) is considering raising this to 18%.*
- ANP is considering to reduce methane content to 80%. Legislation for 'the north' allows lower methane content.*

⁺Equipment manufacturers are importing parts (for manufacturing in Brazil).

*Methane content below 83% can be destructive to HD NG engines. Engine manufacturers range of 'ethane tolerance' content is 4-11%.



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FLEET OPERATORS SWOC



STRENGTHS

Quality of NGV Technology



- Natural gas engines are mechanically simpler than diesel engines. (Otto cycle vs compression ignition).
- For truck transport, LNG provides the longer range required.
- CNG trucks (and intercity buses) with a range of 500km is adequate.*
- Performance of the NG trucks/engines is diesel-like.
- NGVs are as safe or safer than diesel trucks.+
- Natural gas trucks are quieter than diesel trucks.

*(TransMaroni: 500km (with 192m³ fuel capacity) is adequate)

+Generally this *is* true, however, this remark is a small sample of Brazilian owners.

WEAKNESSES



Cost issues

- Costs of vehicles and infrastructure are high.
- Costs of tax and licensing can be higher than for diesel.*
- Some subsidization of the higher first cost of vehicles is preferred (necessary?).

Vehicle availability

- LNG trucks are not widely available from manufacturers in Brazil. (One OEM offers one LNG variant.)
- No after sales markets currently exists for re-sale of natural gas trucks.

Fuel station availability and operation

- Not enough fuel stations for both CNG and LNG.
- For CNG:
 - Time of fueling vehicles (CNG) is longer than that of diesel (especially with the bayonet-style fuel connector).
 - The driving range For long-haul trucks on CNG is not always inadequate.

Government information about NGV options

- Lack of information about NGVs from government.

* Full accounting of Federal, state and local government needs confirmation.

OPPORTUNITIES

Cost reduction



- Lease vs Purchase: May provide an option to use the vehicles without the investment in the higher first cost (LNG truck is ~30% more than a diesel variant). (Also, responsibility for maintenance is with the lessor.)
- Long term contracts for gas supply could reduce cost.
- Road tolls for AFVs could be lowered (tax per axle).
- Licensing price for the vehicles could be reduced.
- “*Shared Savings Loan Program*” might be very attractive.*

*Developed by the Nasser Bank (Egypt) for taxi drivers. Bank financed the cost differential to convert vehicles to bi-fuel NG (paying conversion company directly). Loan repayment based on drivers paying the cost of petrol/diesel for their natural gas until the loan is repaid. Truck owner pays nothing up front; bank is assured of on-going repayment based on owner’s fuel consumption.

OPPORTUNITIES con't



Natural gas strategies/availability

- Blue Corridor assessments have been made attempting to determine the best routes for natural gas trucks.
- Biomethane as a renewable, low carbon fuel would be attractive, particularly when its availability is more widespread. (Carbon pricing might be attractive for fleets using biomethane.)
- New gas distributors are becoming involved in promoting natural gas vehicles (buses, etc.) but more players are needed, particularly for LNG.

Information from Government

- 'Government' could supply more consistent information on CNG & LNG.
-



CHALLENGES (THREATS)



- Fuel price differential between natural gas and diesel fluctuates, causing economic uncertainty. (Need at least 35%-45% lower fuel cost to be able to compete with diesel on a life-cycle basis.)
 - Large trucking fleets purchase large quantities of diesel at very competitive prices.
 - On-site fueling station requires a high capital expenditure and is taxed, which affects a fleet-owner's decision to install their own fuel station.
 - Upgrading maintenance facility to suit the gaseous fuels is an additional cost.
-

FUEL STATION & INFRASTRUCTURE SUPPLIERS

SWOC





STRENGTHS



- There are a wide variety of fueling options for both CNG and LNG at different costs for HDVs, for buses and trucks, that can suit different customers' needs: permanent, fixed stations; 'mother-daughter' stations; and mobile fuel stations suited for start-up fleets.
 - In some cases the environmental advantages of NGVs outweighs the disadvantage of longer fueling times for the HDV operators.
-

WEAKNESSES



'Chicken & Egg'

- Not enough options of OEM natural gas trucks and buses.
- Lack of gas availability (pipeline) in many areas.
- Size of station (large footprint) and lack of available land to install station (in urban centers).
- Timing for fueling is too long. (15 minutes for an HDV is not acceptable, for example)

Standards & Regulations

- Regulations and national standards for LNG stations and LNG fuel connectors/receptacles do not yet exist. (But ISO standards and UNECE regulations do provide models.)
- Local regulations and bureaucracy are inconsistent (e.g. minimum distances to building structures can be a barrier).
- Harmonization of Brazil standards with international standards is needed.

Taxes

- Vehicles taxes differ state by state. (Federalization – or harmonization - of taxes and incentives is needed.)
-



Roadmap do Mercado Brasileiro de
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OPPORTUNITIES



Strategies to Locate & Expand Fuel Infrastructure

- The HDV market is a potential anchor for infrastructure development and expansion of the natural gas supply with the support of state governments to regions not served by a gas pipeline.
- Establishment of 'blue corridors' for CNG, LNG or biomethane can deliver gas for vehicles (and other potential markets to regions not serviced by gas pipelines.).
- Biomethane offers a new, renewable (very low CO₂) fuel opportunity. (Biomethane Blue Corridor plan exists.)*
- Opportunities for centralized or small-scale liquefaction for distribution of LNG to the heavy-duty sector.*
- Potential for 'truck stop' CNG/LNG stations. (Can be installed in existing diesel stations.) Starting with single hose for test truck/fleet, not to impair LDV fueling (but more storage capacity would be needed).
- Evaluate the road system and where the highest concentration of trucks travel to take advantage of existing fuel stations. (*Some assessments currently exist.*)
- Potential for mobile fuel station (fuel tank truck that also includes dispenser), especially for fleet 'trials' of NGVs. (Question if the regulatory authorities would allow this option.)
- Portable LNG station (use truck-supplied LNG) to provide gas to fleet operators.
- Co-locate where other gas markets exist that could complement the vehicle sector. Also, for the potential use longer term, of Liquefied-to-CNG stations (L-CNG).

*Four scenarios for a Blue Corridor in the State of São Paulo and analyzes its environmental and economic impacts. The results show that LNG costs up to 40% less than diesel, while reducing: CO₂ equivalent emissions by up to 5.2%; particulate matter (PM) emissions by 88%; and nitrogen oxides (NOx) by 75%. NOTE: The information needs to be updated.

OPPORTUNITIES con't



Cost-Sharing & Phase-in Strategies

- Transition possible from portable (temporary) stations to permanent stations.
- Potential to optimize multiple fleets in the area to 'share' fueling operations (semi-public) or, if regulations would allow it, 'selling through the fence.'⁺
- Larger anchor fleet customers help justify fuel station (also for shared use).
- Lease versus purchase of the stations (for customers to avoid high first cost) 4-5 year lease equipment could be a possibility.
- Transitional approaches include moving from portable stations to permanent, 'public' fueling to optimize potential for sustainability.
- Relationship with gas providers to co-finance stations. Better for bus operators. (BRT bus station).
- Fleets can have their own on-site fuel stations ... (especially LNG).

Taxes

- Potential to incentivize HDVs by reducing tax on vehicles and equipment for fueling stations.

⁺'Selling through the fence' is when a compressor station on property of a fleet operator installs a fuel dispenser on the exterior side of property making it available to sell gas to the public (or other fleets) without entering the property of the fleet operator.

CHALLENGES (THREATS)



Cost issues

- Property tax on conversions and fuel stations is an impediment.
- Electricity rates are very expensive as a commodity.
- Fuel station equipment must be continually maintained at a high level (and is more complicated and expensive than a petrol or diesel station).
- Gas pressure on the inlet side of the compressor varies from 2-to-35 bar. (Inlet pressure has an impact on the need for more compression and, thus, affects the cost/economics of the station).

Miscellaneous issues

- Very challenging to change the status quo mindset of fleet operators (fueling, etc.) to adapt to the more environmentally friendly fuel.
- HDVs use of public fuel stations, without preliminary study, creates a potential conflict for LDV sector access to gas (or should HDVs be integrated into the LDV stations?)⁺
- The small-scale LNG (SSLNG) is under federal regulation; but pipeline distribution occurs under the state domain.* Issue needs resolution.

⁺Time taken when compressor is recycling to refill storage capacity may leave LDV customers without fuel.

*Costs and emissions assessment of a Blue Corridor in a Brazilian reality: The use of liquefied natural gas in the transport sector, Dominique Mouette, et.al. Science of the Total Environment 668 (2019), Elsevier.



Roadmap do Mercado Brasileiro de
VEICULOS PESADOS A GNV

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STRENGTHS



- Currently there are 422 cities served by natural gas pipeline.*
- Expanded use of natural gas can help with the trade balance for imported diesel.⁺
- Natural gas trucks and buses can reduce tailpipe emissions; especially NOx and particulates.
- Biomethane is a renewable resource option that achieves extremely low CO₂ levels *on a well-to-wheel basis*.^{**}
- Specific models and tools (CO₂ calculator; model for comparing cost/benefits of alternative fuels) are under development and can be useful for policy makers and fleet operators.
- Natural gas cannot be adulterated or stolen from a vehicle (as is possible with liquid fuels, including ARLA-32-urea additive to diesel for lower NOx).

*Abegas.

⁺ US\$ 6.6 billion of diesel was imported in 2019. (EPE-BEN 2019).

^{**}When discussing CO₂ reductions of biomethane it must be clear that this relates to Well-to-Wheel (WTW) production, transmission as well as tailpipe reductions .

WEAKNESSES



Markets

- There is a lack of information at the municipal level – also fleet operators -- about the cost and benefits of alternatives fuels in general and NGVs, in particular.
- Any second-hand vehicle market will be dependent upon the availability of fueling stations (also true for the primary markets, commercial truck & municipal fleets).

Incentives

- Municipal fleets (diesel) receive a reduction of fuel taxes.
 - Lightweight cylinders (Types III and IV) preferable for HDVs are expensive and none are homologated/certified within Brazil.
-

OPPORTUNITIES



Policy

- Emissions regulations and energy policies could consider W2W fuel emissions, which would take into consideration net emissions of GHG from the low carbon footprint of sugar-cane-based biomethane or other low-carbon renewable fuels.
- Carbon credits can be put into use (also from public stock exchange) for biomethane only for fuel consumption (to the consumer, although such a mechanism would have to be created).
- Create a specific CBIO program for Biomethane production, with targets for oil exploration companies. CBIO could remunerate producers and large fleet owners who use biomethane to replace diesel.

Infrastructure

- Adaptation of public fuel stations to HDVs might be possible as an option.⁺
- Expansion of the infrastructure and second-hand markets, to take advantage of gas sources in cities that have access to gas (but need stations).

⁺Would need a list of fuel station options for HDVs – private fleets and municipal buses at existing public stations based on dispensers [number and space] storage capacity as well as normal time-of-day and volumetric use patterns that potentially could accommodate HDVs as well as private LDV customers.

OPPORTUNITIES con't

Information & Communications



- Possibility to organize local decision maker associations (mayors, governors, regulators) to assist (and lead locally) with policy development and implementation. (Vertical integration of policies to regional and local levels.)
- Some NGOs/associations of state and localities are needed to help foster the information/policy sharing).
- Possible to develop and use existing decision tools that can be 'user friendly' and suited to the customer-level applications.
- Fuel price labeling at the fuel station. 'Energy equivalency' of natural gas at the fueling stations allows the customer to evaluate the comparative fuel price of different fuels. (Volumetric equivalent to diesel and gasoline -DLE and GLE – vs. cubic meter (m³) or kilogram (kg). *

* Also useful/important for public CNG stations but challenging to implement. (This would require a public information/education program.)

CHALLENGES (THREATS)



- Environmental movement against fossil gas as a CO₂/global warming contributor.
- Policies mandating electric vehicle policies vs. (all) other AFVs*.
- Policies limiting or prohibiting (future) use of ICE engines and/or as well as on diesel fuel.
- NGV business must be attractive to the entire supply chain: production, transmission, distribution, compression, and end users.

* The São Paulo Municipal Law No. 16,802, 2018, established a ten-year deadline for reducing 50% carbon dioxide (CO₂) emissions from buses used in municipal transportation and 20 years for total disposal. An amendment by Municipal Decree makes the mandate more flexible if necessary for technological or financial considerations and allows NGVs to be introduced. To be effective, this has to be attractive to the full supply chain.