TECHNOLOGY PERCEPTION AND ADOPTION AND NEEDED BEHAVIOURAL CHANGE GIRO ZERO PROJECT

Workstream 2.4

GIRO ZERO: Promoting Road Freight Transport in Colombia towards zero emissions

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Executive Summary

In summary, this document explores the technology perception and adoption by exploring barriers, drivers and initiatives for the decarbonisation of road freight transport. To collect primary data, we have conducted four focus groups concentrated in four specific topics, namely regulation, technology, financing, and finally information and communications technology (ITC). It focuses on evaluating alternative options to reduce the amount of CO_{2e} emissions for the Colombian road freight transportation sector based on NetZero stakeholders' views. The findings from the focus groups showed that the main barrier hindering decarbonisation is the lack of knowledge on new or upcoming technologies and the main driver is a framework of incentives to address the adoption of such technologies. The observed initiatives, through data collection: from macro to micro level interventions, included launching and deployment of infrastructure to provide zero emissions fuels, scrapping old vehicles, and assessing the feasibility of each of the technologies based on their technical and economic feasibility. The study generates insights on the most important barriers and drivers around technological adoption for transport decarbonisation, and a guide on the availability and feasibility of these technologies in the context of Colombia to propose specifics topics about the needings of behavioural change to achieve NetZero Goals. This study shows its potential to influence the sector giving a special focus on technologies. Outputs from this research are being used for policy makers as well as practicioners as a guide seeking transport decarbonisation in a pan-country level action.

1 Introduction

The time is running out to reach the goals of reducing global warming lower than 1.5ºC[1], according to Intergovernmental Panel on Climate Change (IPCC) (2021),. Every sector and country in the world have to focus on reaching their own NetZero target by adopting appropriate government policies and industry interventions. In Colombia, 12 % of emissions are generated by transportation sector (INGEI, 2016), which 4.6 % are emissions coming from Road Freight Transportation (RFT) (Giro Zero, 2022). The Colombian government has set up a goal of reducing the country's GHG emissions by 51% and black carbon by 40% by 2030 (Colombian Government NDC, 2020).

Research has shown the relevance to build ways seeking decarbonise transportation, i.e., McKinnon (2007), McKinnon et al. (2014) and Toelke & McKinnon (2021). A qualitative evaluation in German logistics sector was evaluated by Tacken (2014) to identify the key drivers and barriers of green logistics measurements and initiatives. While recent research produced by Delgado (2020) and Giro Zero (2022) attempted to evaluate scenarios for the long-term CO_2e reduction, this paper contributes to the literature by shading light on the context of the Colombian road freight transport.

The aim of this research report is to undertake an assessment of emission reductions actions carried out by the Colombia road freight transport sector, and the main initiatives and policies that can be considered and addressed for reaching 2050 NetZero target. Focus groups were concentrated in regulation, technology, financing and Information, and communications technology (ITC) around road freight transport decarbonisation. The focus groups were organized based on four research questions (RQs):
RQ1. What are the gaps, drivers and barriers to achieve low-emission Road Freight Transportation?
RQ2. What are the vehicle technologies that will steer Road Freight Transportation towards zero emissions?
RQ3. What financial barriers hinder the transition to zero emissions in Road Freight Transportation?
RQ4. How do the measurement and use of ICT contribute to the reduction of emissions?

The research is structured around an examination of distinct aspects the drivers encouraging the emissions reductions and the barriers interfering this result as well as an assessment of the green logistics measures, industry standards and initiatives, with a particular focus on carbon reduction in road freight transport. The remaining sections includes a literature review on the Colombian road freight transport and decarbonisation, followed by the methodology section. Subsequently, the findings section includes the analysis of the data gathered from the focus groups research, and then concluding remarks that highlight the contribution of this research and further research opportunities.

[1] Global surface temperature will continue to increase until at least mid-century under all emissions scenarios considered. Global warming of 1.5°C and 2°C will be exceeded during the 21st century unless deep reductions in CO2 and other greenhouse gas emissions occur in the coming decades.

2 Literature Review

Transportation accounts for 12% of Colombian GHG emissions, the Colombian Road Freight Transport (RFT) sector accounts for 4,6% of GHG emissions (Giro Zero, 2021) and represented more than 43 % of energy consumption in 2012 (Román-Collado, 2018) and 35,5% of CO_{2e} emissions within the energy category (Delgado R et al, 2020). In Bogota and Medellin, freight trucks generated 22% and 77% of particulate matter (PM) in the 2012-2013 fiscal year, respectively (DNP, 2018).

Today, the penetration of clean alternative fuels and efficient engines in the Colombian Road Freight Transportation (RFT) sector is nearly non-existent, e.g., only 0.1 % of trucks used low-emission fuels in 2020 (RUNT, 2020). Among all trucks larger than 3.5 tons, and those that participate in the regulated long-haul market, the share of diesel vehicles is 97 % (Giro Zero, 2021). Most trucks use carbon intensive engines, specifically, 32.3% had engines below Euro standards or Pre-EURO, 55.7% Euro I to Euro III, and 12 % Euro IV or higher (Giro Zero, 2022). The high prevalence of trucks with Pre-Euro standards in Colombia is particularly alarming because Pre-Euro vehicles generate 25% of emissions of PM in Colombia, despite being only 1.3% of vehicles in Colombia (Giro Zero, 2021). The adoption of electric trucks in Colombia would be particularly beneficial for the environment because the Colombian electricity matrix is remarkably clean, 68% of installed electric capacity is generated from hydroelectric plans, in contrast to 17% in the rest of the world.

The Colombian long-haul market connects three agents: shippers (producers / consignors), transport companies, and independent carriers. Colombian regulation prevents shippers from hiring independent carriers directly, with some exceptions[2]. Instead, shippers must hire transport companies. Transport companies guarantee that regulations are respected, insurance policies are acquired, paperwork is completed and processed, and contracts are put in place to guarantee their execution.[3] Transport companies move the goods with their trucks or outsource shipping to independent carriers. Independent carriers account for 80% of trucks and 90% shipping capacity in the Colombian market. While 3,550 companies are authorized to provide road freight transport services, only 52% of these companies were active in 2021 (Giro Zero, 2021).

Several recent studies include a road freight transportation focus to achieve goals of decarbonisation. McKinnon (2007) and more recently (2018) proposed an analytical framework incorporating all the factors which influence freight traffic levels and related energy consumption. Bataille C. et al. (2020) simulated future scenarios for Colombia changes in Mt CO_2 per year in 2050 compared to 2015. Their study concluded that, in a business-as-usual scenario, Colombia's emissions would be 8.9 Mt CO_2e higher than 2015 emissions, and this results come from the following estimations: because of overall GDP increases 21Mt CO_2e in freight, due to less tonne kilometres per $GDP reduces 14.6 Mt CO_2e, due to energy efficiency increases 3.4 Mt CO_2e and due to fuel GHG intensity reduces 1.0 Mt CO_2e. Giro Zero (2022) has plotted some future scenarios to guide NetZero transition in the Colombian road freight transport sector with a combination of logistics and fuel technology options.

There is also an emerging literature stream on decarbonisation of road freight transport. McKinnon A. et al (2014) proposed six categories of external factors that influence the carbon

[2] Transport companies are a required actor in transport contracts (Decree 1079 of 2015, chapter 7, article 2.2.1.7.3). For exceptions, see decree 2044 of 1988.

[3] Transport companies are licensed by the Ministry of Transport after demonstrating shareholders' equity of around 250.000 USD (Decree 1079 of 2015)

emissions at company level, i.e., technology, infrastructure, market, behaviour, energy, regulation (acronym TIMBER Framework). These categories were widely mentioned on the focus group meetings conducted on this research. In addition, Seuring & Müller (2008) and Hina (2021) developed a typology that has external and internal triggers or drivers of sustainable supply chain management. One of these categories is “supplier management for risks and performance”, in which the reputation of the organization from environmental and social standards or criteria plays a main role. Tacken (2014) also developed a research framework of barriers and drivers for third-party logistics service providers to guide decarbonisation initiatives.

Aarnink S. et al. (2012) categorize barriers in three main groups as technological, institutional and financial and concludes that much of the actions in 2012 was focused on reducing fuel consumption and other operative initiatives. Toelke (2021) explored the operations of small- & medium-sized road carriers in Europe and concludes that the biggest drivers internal or external for decarbonisation investments are costs saving potential, customer preference and manufacturers of trucks. A conceptual model was constructed with and inductive approach, including factors that impact on emissions reduction, starting from the ambition set by the government of Colombia, the barriers, and drivers in the context of internal and external stakeholders and the monitoring of results. The model is presented in Figure 1.

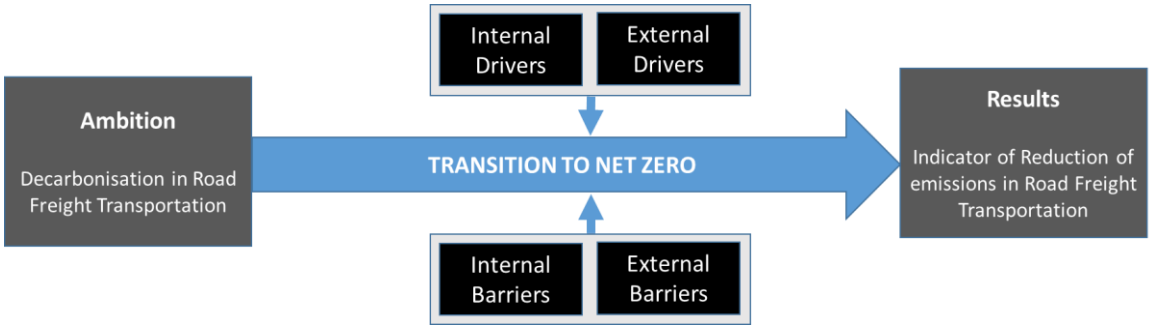

Figure 1. Research framework

This study contributes in several ways. First, this study is the first known effort to systematically review and analyse the qualitative perception to decarbonize road freight transportation in Colombia. Second, it proposes a qualitative methodology to analyse the main drivers and barriers and from this point it proposes a possible agenda to address the roadmap to NetZero in RFT.

3 Methodology

The data collection process was performed by designing four independent focus groups with a set of questions to each topic and type of stakeholder. The reason for choosing focus groups as methodology is that it allows for dynamic discussion among multiple stakeholders. Sanchez R. et al. (2010) shows that from above of four or more trend sessions in a focus groups topic the theory saturation implies that the percentage of new ideas or opinions tend to be lower in additional sessions. Subsequently, from the conceptual model presented in **Error! Reference source not found.**, the following specific questions were design previously to conduct the four focus groups. The questions asked in the focus groups were:

1. Which are the gaps, drivers and barriers to achieve low-emission Road Freight Transportation?
2. What are the vehicle technologies that will steer Road Freight Transportation towards zero emissions?
3. What are the financing models that could incentivise the adoption of zero carbon vehicle technologies?
4. How do the measurement and use of ICT contribute to the reduction of emissions?

5. Table 1. Research questions for Focus Groups

Focus Group	Stakeholder	Questions
Focus Group 1 Gaps & Barriers	**Central question**	**What are the gaps, drivers and barriers to achieve low-emission Road Freight Transportation?**
	General Panel	What are the main barriers to reduce emissions in Road Freight Transportation sector?
		What initiatives or practices have your organisation implemented to reduce emissions in Road Freight Transportation sector?
		How affects current regulation for the reduction of emissions in Road Freight Transportation sector?
		What are the solutions / incentives / regulation) offered by your organization for low-emission in Road Freight Transportation?
Focus Group 2 Truck Technology	**Central question**	**What are the vehicle technologies that will steer Road Freight Transportation towards zero emissions?**
	Original Equipment Manufacturer (OEM)	What are the benefits and features of the technologies that your organisation offers?
		What are the current costs of buying and operating low/zero emissions vehicles?
		How will you weight the costs between CAPEX-OPEX for low/zero emissions vehicles?
		What is the demand for Charging Infrastructure for low/zero emissions vehicles?
	Truck Buyers/owners	What are the reasons that make you hesitate to renew your fleet towards zero emissions?
Focus Group 3 Finance	**Central question**	**What are the vehicle technologies that will steer the Road Freight Transportation towards zero emissions?**
	Truck Buyers/owners	Have your organisation purchased low or zero emission vehicles and why?
		What financial sources have you used and why?
	Financing institutions	What financial tools does your organization offer for low or zero emission vehicles and how can its impact in the sector be increased?

	Business Associations	Some of the financial barriers for the renovation of trucks towards zero emissions have been mentioned. How to overcome them?
Focus Group 4 ICT, KPIs & Logistics optimisation	**Central question**	**How do the measurement and use of ICT contribute to the reduction of emissions?**
	logistics service providers, carriers, shippers	Have your organisation set a goal to reduce your emissions?
		How was this goal decided?
		How do you measure emissions in freight transport?
		From your experience, what ICT tools does your organization use to monitor and reduce emissions?
	Software producers	From your experience, what ICT tools does your organization offer to monitor and reduce emissions?
		What is the value and benefits that these tools can bring to freight transport users?
		What is the value and benefits that these tools can bring to freight transport users?
	Associations, unions and public sector	What guidelines and standards will your entity provide to freight transport users to guide them in estimating the emissions they generate?

The focus groups have participation of 32 organisations including: 7 Original Equipment Manufacturers (OEMs), 6 industry producer/shippers, 5 public sector organisations, 4 business associations, 5 trucking companies and logistics service providers, 3 software providers, 2 consultant company, and 1 truck owner.

Going into more detail about the participation of women, the events described above were attended by 42 participants, of which 24% were women. Giro Zero has sought to give a leading role to women, conveying a message of inclusion in the freight transportation sector, since there is a low participation of women in freight transportation, however, the women involved are key leaders in the sector and interact with empowerment in the events.

Some of the women who participated in the focus groups were:

- María Juliana Rico, economist and executive director of ANDI's Automotive Industry Chamber, speaker and leading voice of entrepreneurs, affiliates and manufacturers.
- Karol Andrea García, lawyer and union director of the automotive and machinery sector of FENALCO, spokesperson, director and union president of FENALCO, important representative of manufacturers and leading voice in inter-institutional governmental roundtables.
- María Adelaida Molina, logistics efficiency manager of Cementos Argos, key participant of the private industry, connects the ideas of the events with the cement industry, a leading and important voice in the private industry.
- Evelyn Duque, environmental management and sustainability initiatives professional at Cementos Argos, a key participant from the private cement industry, connects the ideas from the events with the work opportunities provided by the project in order to ground everything discussed in the focus groups in the cement industry, a leading voice of the logistics programs and drivers of the private industry.
- Susana Pupo, Caribbean regional manager and commercial vice president of Financiera de Desarrollo Territorial (FINDETER), leading voice in the strategic axis of the financing and transportation segments, managing key initiatives for this segment.
- Carolina Restrepo Expocafé, coordinator of sustainability projects, design and execution of programs and initiatives that seek and provide a sustainable vision in the Colombian coffee industry, innovating in the Colombian coffee sector, leading voice and key

representative of women in the coffee sector, as well as with strong convictions of sustainability for the entire coffee supply chain.

- Heidee Hernández Solística, national head of environmental management, representing private industry, leading voice on green initiatives, efficient driving and road safety.
- Laura Franco Renting Colombia, leader of sustainable projects, representative of the financing and business segments or alternative models for the acquisition of zero and low-emission technology vehicles such as leasing, leasing, etc.
- Luisa Martínez Solística, HSE manager in Latin America, leader in everything related to industrial safety, road safety, environment and occupational health in the different business units such as warehousing, maquila, cold chain, transportation, urban and national distribution, maintenance workshops and others, being a key woman in Colombia, Panama, Costa Rica, Guatemala and Nicaragua, she is also an active leader in the private industry and the transportation sector articulating green initiatives not only at national level but at Latin American level in a managerial, administrative and operational way. She is a key member of the GiroZero network, as she supports all opportunities for collaboration and joint work, adding significant value to all the focus groups she attended.
- Luz Ángela Girón ANSV, an important agent in road safety, supports initiatives for structuring projects and public policies for safe driving, road safety and speed management with a focus on safe systems that ensure the lives of all actors on the roads. Therefore, her ideas are connected in a keyway with efficient driving, which is a fundamental strategic axis of the project.
- Ana María Sandoval Surtigas, coordinator of large users of Surtigas, so she is a woman leader in the gas sector, the alternative energy that is having a great reception in Colombia, which connects with the sustainability initiatives that the sector needs.
- Tatiana Ruiz Cemex, sustainability manager of Cemex, where she is responsible for integrating sustainability and sustainability in the business strategy, endorsing cost-efficient sustainability models, so it is driven by the cement industry green initiatives to reduce the carbon footprint, aligning interests between the private sector and academia.
- Nidia Hernández, executive president of the Colombian federation of freight transporters (COLFECAR) and union leader of the board of directors of one of the largest associations in the country, is the first woman to lead the cargo transport union and a key agent in the cargo sector, which is why she actively encourages affiliates to implement green initiatives and coordinate with academia so that research can help the different transport companies.
- María Camila Páez DNP, female leader and key player in the public sector, advisor to the transport sub-directorate of the infrastructure and sustainable energy directorate of the national planning department, supporting the zero and low emissions mobility team. Leading and active voice in the DNP as she articulates and provides support from the different freight sectors, complementing her actions with those of private industry and academia, prioritizing green projects as national government initiatives. Very good comments and discussions that add value to the sessions as it brings that perspective from the public side and is interested in logistics initiatives, management, and administration of zero and low emissions.

Giro Zero is interested in knowing the perspectives of women leaders in the sector, as they are women who hold senior management positions, being in charge of many actors in the chain of the freight transport sector and knowing the sector in different ways, so it helps the project to identify gaps, know initiatives and understand the behaviour of the sector to have a better understanding of the perceptions and inclinations of the low-emission technology

transition. On the other hand, priority is given to the participation of women, always seeking that in the events many women attend, prioritizing their participation.

Therefore, there are different key female actors in different sectors, public, private, industrial, and financial, which allows to connect the freight transport sector from different perspectives allowing a more efficient articulation of all sectors, in order to close gaps in freight transport.

Data was collected from these focus groups. A pool of 138 quotes from the participating organisations were collected and analysed to identify the main thematic areas.

Table 2. Pool of answers in each focus group

Pool of answers	1st FG: Gaps, barriers & drivers to decarbonise RFT	2nd FG: Truck Technologies	3rd FG: Financial opportunities to decarbonise RFT	4th FG: ITC & Measurement to decarbonize RFT	Total
Equipment provider	11	15	11	0	**37**
Shipper	5	8	6	10	**29**
Public Sector	7	0	7	7	**21**
Business Union	8	5	3	0	**16**
Transport Company	7	2	5	1	**15**
Software Provider	0	0	6	7	**13**
Consultant Company	0	0	1	4	**5**
Trucks owner	2	0	0	0	**2**
Total	**40**	**30**	**39**	**29**	**138**

For the analysis, primary and secondary codes generated to obtain insights about the main drivers and barriers, then each of participants' answers were classified as driver or barrier and whether the participant was representing an internal or external to each organization. Furthermore, the poll of codes was used for a cause-and-effect analysis present in a Sankey diagram in which it is visualized the strongest relations.

4 Analysis

Table 3 presents the primary and secondary codes derived from the focus group data.

Table 3. Primary and secondary code for answers of stakeholders

Secondary Code \ Primary Code	Vehicle Technology	Commitment to reduce GHG	Financing	Regulation	Information and Technology	Infrastructure	Training	Fleet Management	Total
Electric Trucks	11	1		2					**14**
Measurement	1	2			9	1			**13**
Fleet Management	2	2			7		2		**13**
Collaboration		7		3	1			2	**13**
Credits			13						**13**
Charging infrastructure				1		11			**12**
Incentives	1		1	7				1	**10**
Renewal or Scrapping	4			4					**8**
Natural Gas	6	1							**7**
Myths and barriers about reducing emissions		2			1		3		**6**
Bicycles	4								**4**
Driver training							4		**4**
Investments		1	2						**3**
Intermodal		3							**3**
Fuel	2	1							**3**
Taxing			1	1					**2**
Costs			2						**2**
Hybrid Trucks	2								**2**
Hydrogen	1			1					**2**
Drone	1								**1**
Bigger trucks	1								**1**
Off-setting		1							**1**
Total	**37**	**21**	**19**	**19**	**18**	**12**	**9**	**3**	**138**

The results shown that 55% of participants' views can be classified under technology, commitment to reduce CO_2e emissions, financing and regulation, 30% of their views can be categorized under information and technology, infrastructure, training and fleet management, and the remaining 15% of participants' opinions can classified under technology, commitment to reduce CO_2e emissions, financing and regulation.

According to the participants' answers, there were 88 drivers of each were 59 internal and 29 external, and 50 barriers, of which 14 were internal and 36 were external. Most of participants' opinions are classified as internal issues, which shows that they can act over them.

Table 4. Classification of answers

Classification of answers	Internal	External	Total
Driver	59	29	88
Barrier	14	36	50
Total	**73**	**65**	**138**

The most cited codes classified as drivers were the implementation of digital solutions to increase efficiencies, the commitment on NetZero inside each organization, to increase incentives that are more external and access to credit for decarbonization; while the most cited barriers were lack of knowledge, high cost of new technology, access to credit and Investment of charging stations. These barriers are external to each organization, so collaborative agenda is required to overcome them.

Going into more detail, among the drivers to reduce emissions most cited were a) the implementation of digital solutions to increase efficiencies, b) the commitment on NetZero inside each organization, c) to increase incentives that are more external and d) access to credit that can be changed in an internal way from the actors who provide credit.

Table 5. Type of driver or barrier

Type of driver or barrier	Internal	External	Total
Driver	**59**	**29**	**88**
Digital solutions to increase efficiencies	10	3	13
Commitment on NetZero	10	3	13
Increase Incentives	4	7	11
Access to credit	5	1	6
New Technologies	4	1	5
More restrictions to actual fleet	2	2	4
Regulation to incentive transition	3		3
Development of decarbonize ecosystem		3	3
Renewal of trucks	3		3
Measurement of emissions	2	1	3
Implementing Eco driving	3		3
Paying market carbon offsets		2	2
Change to multimodal	1	1	2
Hybrid technology good performance in urban routes	2		2
Availability of cost-effective energetics	2		2
Sector organization	1		1
Electric technology good performance in urban routes	1		1
Differentiate incentives		1	1
Financial analysis of costs	1		1
Change of commercial model from sale to rent	1		1
Investment of charging stations	1		1
Perform measurement of emissions	1		1
Market carbon offsets	1		1
Excess of regulation		1	1
Availability of new truck technologies	1		1
More collaboration		1	1
More entrepreneurship, more access to credit		1	1
More knowledge		1	1
Barrier	**14**	**36**	**50**
Lack of knowledge	4	3	7
High Cost of new technology	1	5	6
Access to credit		5	5
Investment of charging stations	1	3	4
Autonomy of electric trucks	1	2	3
Electric technology good performance in urban routes	3		3
Limitations on number of charging stations		2	2
Availability of new truck technologies		2	2
Natural Gas technology low performance in mountainous routes	1	1	2
Commitment on NetZero	1	1	2
Paying market carbon offsets	1	1	2
Electric technology good performance in mountainous routes	1		1

Sector organization		1	1
More entrepreneurship, more access to credit		1	1
Increase Incentives		1	1
COVID19		1	1
Financial analysis of costs		1	1
Specific regulation of zero emission		1	1
Availability of cost-effective energetics		1	1
Increase Carbon Tax		1	1
More collaboration		1	1
Improve fuel production		1	1
Improving actual fleet		1	1
Total general	**73**	**65**	**138**

Among the most representative barriers were cited: a) lack of knowledge, b) high cost of new technology, c) access to credit and d) Investment of charging stations. The problem of these barriers is that are external to each organization, then to overcome them must be set a collaborative agenda, especially at early stages in order to create an organized ecosystem to provide a big support for low and zero emissions technologies. These results are presented in Table 5.

6. Discussion

Policies, regulations, and directives have toughened up since the signing of Colombia the COP20 agreement of Paris. Though these policies were modest in terms of their ambition in comparison to the 2020 goals set by the Colombian Government. In order to achieve 2050 goals, these goals should be updated to incentivise the adoption of new technologies classified as zero emissions technologies and impose restrictions to fossil technologies, either old trucks already operating or new trucks with fossil fuels including diesel or natural gas.

As Figure 2, drivers and barriers are connected in the cause-and-effect Sankey diagram. The strongest relationships are highlighted in green colour, e.g. Commitment on NetZero helps to reduce emissions. In this way, each barrier and driver have an effect and some of them will help to reduce emissions. Drivers and barriers mixed very easily when analysing that cause and affect relations. From this analysis, it can be concluded that vehicle technology is the most crucial issue to decarbonize road freight transport, as one stakeholder expressed that *"There will be a time in history, in which I will not contract your company if you are not friendly and sustainable with the environment, it can even be something social, it must be a commitment of everyone"*. After this commitment, the availability and feasibility of trucks with zero emissions technologies is another important issue, which requires the activation of both demand and supply portfolios.

To achieve technological change, investment should be put in place in charging infrastructure and access to renewable energy, i.e., having electric and hydrogen charging stations, and availability of electricity and hydrogen. This is crucial for the roll-out of the sector's 2050 NetZero roadmap. As the representative from the association of energy producers said, *"from the electricity generation sector, we have the goal of not polluting, and not expanding the energy matrix at the cost of higher emissions, it makes no sense to generate electricity with coal, oil, natural gas without a capture system, since we would only be changing emissions from the mobility sector by the electricity generation sector without achieving a net improvement",* and also added: *"Nobody wants to replace the use of diesel with electricity if it has a higher price and is not available 24/7".*

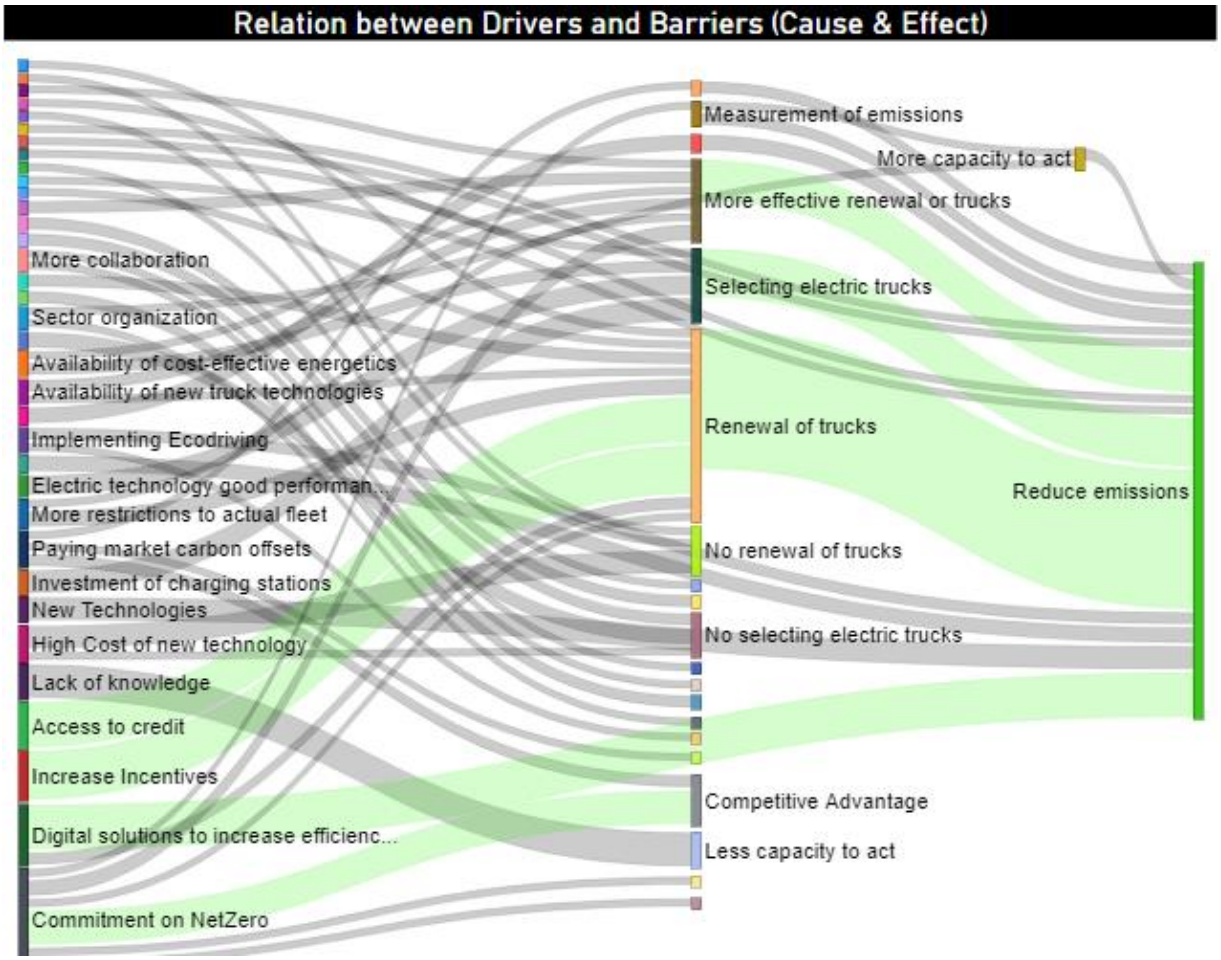

Figure 2. Relation between drivers and barriers and their causes and effects

Other driver mentioned frequently during the focus groups was strong restrictions to fossil technologies. A participate from the private sector thinks this is crucial, *"it is important that for electric, hybrid and hydrogen trucks to provide incentives, small transporters require these incentives, in this sense the national government must think in that direction so that truck owners dare to invest taking into account the costs".* A participant from the Bogota government is in accord with this view, *"the environmental regulation program is focused on companies, but the local government want to open it up and focus on the truck owner, and in the future, they will regulate on the base of the one that pollutes the most is more restricted to circulate".* Furthermore, Colombia has already set up policies for promoting fleet electrification, while scrapping old trucks, but policies are not delivering the expected results because of lack of incentives to zero emissions trucks and a poor availability of portfolio from OEM suppliers, low tax carbon allow drive the continuous use of old truck. Moreover, economic regulation must include these new technologies that are not included as current regulation, as one of the focus group participants stated, *"SICETAC (tariff table), does not included the concept of clean energy, only considers vehicles that move with DIESEL, does not consider natural gas or electric, hybrid or hydrogen".*

Another important driver is having an appropriate financing framework that gives truck owners a wider access to credit and promote savings and incentives for scrapping and renewal of their trucks. The participant from ANDI, the main association of industry stated that, "*it is essential to have the National Guarantee Fund (FOGAFIN acronym in Spanish). Most truck owners are*

not subject to credit; therefore, it is necessary to look for way to guarantee credit, because almost the only mechanism that the truck owner has access to apply for credit is their truck".

Training is a low hanging fruit to reduce fuel consumptions, reduce operative expenditures and reduce emissions. ICT and fleet management is an important driver to boost efficiencies, but is not a game changer, since it can only reduce emissions marginally.

Measurements of emissions inside companies are right now low. The recommendations to stakeholders are to the start the measurement proposed by the Global Logistics Emissions Council who proposes an indicator of gCO2/ton-km. With this indicator to reduce the emissions companies can reduce emissions per km or either increase capacity, transporting more tons in the same trucks. (Smart Freight Centre, 2019)

One of the actors bring up a concluding final statement: *"A win-win model for all actors is needed, from which the user gains confidence about the new truck operability and the financial gains, the financier can allocate resources more aggressively, the government generating not only tax incentives, but a scheme of guarantees and the other actors, which are the energy distributors, the insurance companies and the manufacturers doing the same, the manufacturers guaranteeing after-sales service, guaranteeing availability of spare parts and guaranteeing that the vehicle will operate well".* This last statement is aligned with the main conclusions of (Toelke, 2021) in which governments, OEMs, freight buyers and carriers must collaborate to reform old business practices and attitudes.

Adoption of technology

To transform the RFT sector it is paramount to achieve the adoption, change and technological rise of trucks. The technological change includes the evolution of the fleet towards transition vehicles (EURO VI Diesel or EURO VI gas or hybrids) and towards zero emission trucks (electric BEV and hydrogen, FCEV), as well as the disintegration of the current fleet with technologies prior to the EURO IV.

There are different benefits and disadvantages for each of the technologies, which can be seen in the following table:

Table 6. Benefits and disadvantages of different technologies

Characteristics/ Technologies	*Biofuel- hybrids*	*Electric Battery (BEV)*	*Hydrogen fuel cells (FCEV)*
CO_2 Intensity	*Intensity depends on biomass or carbon source*	*Zero or minimal if renewable generation is used*	*Zero or minimal if green or blue H2 is used*
Air quality	*NOx and particulate matter emissions similar to Diesel*	*zero emissions*	*zero emissions*
Efficiency Well to Wheel (WTW)	*20%*	*75-85% depending on load and transmission losses*	*35% if H2 is produced with renewable energy*
Capital expenditures	*Same as current combustion engines*	*High investment cost if large batteries are required*	*High investment cost for fuel cells and auxiliary batteries*
Payload restrictions	*Same size and weight of current combustion engines*	*Weight greater than combustion engine, payload restrictions*	*Space needed for hydrogen tank*
Energy refuelling	*<15 min, depending on tank size*	*>3 hours depending on fast charge or not*	*15-30 min depending on tank size*

Infrastructure costs	*Use of current infrastructure*	*Requires charging infrastructure and network upgrades*	*Requires hydrogen filling and distribution infrastructure*

Source: (McKinsey & Company, 2021)

Currently, natural gas vehicles have a lower energy and asset price advantage over diesel (Euro V / VI standards). However, for natural gas trucks, its operating costs are higher, except for fuel, and it still does not have a sufficiently robust supply infrastructure in the country.

These benefits and limitations allow us to conclude that both Euro VI Diesel and Euro VI Natural Gas technologies reduce emissions (especially particulate matter PM) compared to any old fleet and emission standards lower than Euro V (as is the case in Colombia), especially those related to respiratory diseases. But natural gas trucks are not long-term solutions since they do not ostensibly improve greenhouse gas GHG emissions or air quality and, on the contrary, they should be seen as transitional solutions in the meantime technological change can be achieved with vehicles zero emissions. Additionally, it must be taken into account that the country's energy security is also at stake. According to the Colombian Government, the country's hydrocarbon reserves, mainly gas, have decreased over the last 10 years, which means less availability to serve a future local demand for gas and diesel for trucks and its consequent risk on the certainty of supply required for the transition (ANH, 2020).

In the decade 2020 to 2030, hybrid and electric vehicle technology is already available for light trucks. In 2022, electric trucks with a capacity of 10.5 tons to 17 tons that operate in urban areas will be marketed, for the other options the fleet will be distributed between Euro VI Diesel and Euro VI Natural Gas[4].

Table 7. First decade: Technologies available in the 2020-2030 decade

Technology according to weight (GVW) and autonomy (km range)	*Urban (< 100 km)*	*Regional (100 to 200 km)*	*National (more than 400 km)*
Light trucks (0 - 10,5 ton)	*Electric (BEV)/ Diesel (EURO VI)/ Hybrid*	*Electric (BEV)/ Diesel (EURO VI)/ Hybrid*	*Diesel (EURO VI)/ Hybrid*
Medium-Duty Trucks (10,5 ton - 17 ton)	*Electric (BEV)/ Diesel (EURO VI)*	*Diesel (EURO VI) [5]/Gas Natural Gas (EURO VI)[6]*	*Diesel (EURO VI)/ Natural Gas /EURO VI)*
Heavy Duty Trucks (10,5 ton - 76 ton)[7]	*Diesel (EURO VI)/ Natural Gas /EURO VI)*	*Diesel (EURO VI)/ Natural Gas /EURO VI)*	*Diesel (EURO VI)/ Natural Gas /EURO VI)*

[4] Law 1972 of 2019 establishes in article 4 that from 2023 only Euro VI technologies may be sold in Colombia for national operating range of vehicles with a diesel engine.

[5] Diesel trucks with EURO VI emission standards have been approved emission limits since 2009 when other catalyst systems had not been yet developed and were modified in 2011 and 2014. Even more rigorous limits have been established for emissions of NOX, CH4, non-combusted hydrocarbons (HC) and PM. Likewise, new limits have been established for the number of particles, ammonium and stricter requirements than previous technologies (ICCT, 2016).

[6] Studies have found that gas trucks do not significantly reduce emissions when compared to Euro IV Diesel standards, in terms of greenhouse gases or in terms of air pollutants and that on some occasions it may have higher emissions of disease-causing particulates than Euro VI Diesel trucks. (Transport&Environment, 2021)

[7] Including the maximum weights of the vehicle configurations of the Resolution 20213040062005 of 2021 Ministry of Transportation, which regulates the configurations for High Capacity Vehicles

Source: ***GIRO ZERO Roadmap 2022***

In the long term, for the second and third decade between 2030 to 2050, the industry of heavy-duty vehicle manufacturers has unveiled the zero-emission technologies that will be available on the market, where electric trucks (BEV) will play an important role between short distances and light loads, while hydrogen trucks will have a greater application in long-distance and heavy-load operations[8].

Table 8. Technologies that will become widespread in the second and third decade 2030 - 2050

Technology according to weight (GVW) and autonomy (km range)	*Urban (< 100 km)*	*Regional (100 to 200 km)*	*National (more than 400 km)*
Light trucks (0 - 10,5 ton)	Electric (BEV)[9]	Electric (BEV)	Electric (BEV) / Hydrogen (FCEV)
Medium-Duty Trucks (10,5 ton - 17 ton)	Electric (BEV)	Electric (BEV)	Electric (BEV) / Hydrogen (FCEV)
Heavy Duty Trucks (10,5 ton - 76 ton)	Electric (BEV)	Electric (BEV) / Hydrogen (FCEV)	Hydrogen (FCEV)[10]

Source: ***GIRO ZERO Roadmap 2022***

It is also considered important to highlight that the evaluation of technological change and advancement must be carried out in an integrated manner, considering the characteristics of the market, the routes and the products to be transported.

7. Concluding remarks

[8] There are several zero-emission technologies for heavy-duty vehicles: Battery Electric Vehicles (BEV), Hydrogen Fuel Cell Electric Vehicles (FCEV) and Hydrogen Internal Combustion Engine Vehicles (H2). Hybrids and gas engines represent technologies that, as mentioned above, reduce emissions, but do not reach zero emissions by themselves. In the same way, it must be taken into account if the hydrogen or electricity consume by these trucks are produced from fossil fuels or from a clean energy source.

[9] Truck electrification may require one or more fast charges per day and faces a risk of less capacity of payload to be transported due to the additional weight of the batteries. However, there may be savings in energy consumption (around 35%) and in operation and maintenance costs. The initial purchase cost is higher than a diesel or gas truck, but this difference can be reduced to almost 50% by 2030 as technologies advance. (Fleming et al, 2021). Likewise, there may be battery exchange systems in specific operations so that the trucks` batteries can be replaced in a few minutes, trucks that are capable of transporting more than 20 tons are currently considered a challenge to electrify by several industry experts. (Crooks, 2020).

[10] Great opportunities for hydrogen have been identified globally and in the same way in Latin America and it is important for governments not only to highlight their vision in the technological change of trucks but also to attract private investment and create accelerated mechanisms for the implementation and for development of storage and infrastructure charging networks, as well as ensure access to financing for equipment and increase support for own research (ABD, 2021). Hydrogen is the energy source with the highest logistics operational reliability in which the restrictions are related to the work cycles, weight, refueling times and payload of RFT (DFT, 2021).

The literature has provided projections of road freight transport emissions and proposed useful frameworks as TIMBER (technology, infrastructure, market, behaviour, energy and regulation) that aligned with this study. The findings show strong evidence that the Colombia road freight transport sector has already designed specific policies to face the reduction of emissions, but these policies are not aligned with the new 51% emissions reduction commitment by 2050. Thus, this research has the potential to influence the sector putting a special focus on low and zero carbon technologies, and the barriers and drivers that need to be considered for their adoption. Outputs from this research can be used as a guide for policy making and practice for transport decarbonisation.

Furthermore, this paper highlights the wide discussion among stakeholders in an early stage of their decarbonisation journeys. The stakeholders included in the study have interested in reduction of emissions and have a basic knowledge of sustainability, of sustainable transportation and logistics practices, and are taking some basic steps to start to measure GHG emissions and adopting some CO_2e reduction initiatives. Although there is divergence on the ideas around decarbonisation, the actors predominant think that commitment to NetZero is the first and most important step, and then public and private sector should define incentives and restrictions to promote access to credit that will encourage NetZero technological transition. Colombia must take advantage of a clean energy matrix to focus on decarbonizing transportation in early stage by the use of electric and hydrogen when feasible in freight transportation.

Further research is needed on the analysis of qualitative approach in complex future scenarios and evaluating size of incentives for new technologies and restrictions to fossil trucks, and pilots and validation of technology to electrify road freight transportation.

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