AUTOMOTIVE TRANSPORT DECARBONIZATION USING HYDROGEN FUEL CELL VEHICLES IN ARGENTINA DEMAND COSTS

CUSTOS DE DEMANDA, PARA A DESCARBONIZAÇÃO DO TRANSPORTE AUTOMOTIVO NA ARGENTINA, ATRAVÉS DE VEÍCULOS A CÉLULA DE COMBUSTÍVEL À BASE DE HIDROGÊNIO

COSTOS DE LA DEMANDA, PARA LA DESCARBONIZACIÓN DEL TRANSPORTE AUTOMOTOR EN ARGENTINA, MEDIANTE VEHÍCULOS DE CELDAS DE COMBUSTIBLE EN BASE A HIDRÓGENO

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Palabras clave: Descarbonización del transporte, hidrógeno, costos reducción emisiones GEI.

INTRODUCTION

During ENARCIV2020 Congress [1] carbon pricing for public transport buses for hydrogen bid decarbonization costs was stablished. The hypothetical case, applied to Rosario City, with a potential technological change from buses with internal combustion engine (ICE) to Fuel Cell Electrical Buses (FCEB) running on hydrogen gas. The avoided GHG from a life cycle assessment (LCA) based on ISO 14040-ISO 14044 standard (Iannuzzi, 2018) was applied, considering hydrogen production costs for adaption and the supply for urban buses from filling stations (Bierregaard, 2020).

In this case, the previous study expanded in order to be able to establish the complete carbon pricing technology change [2] (Langholtz et al.) starting from a Total Cost of Ownership (TCO) substracting the TCO reference technology, in order to be able to stablish the total differential cost of the chosen decarbonization technology. The final objective was to reach a viable economic automotive transport decarbonization in Argentina in order to comply with the Paris Memorandum [3] country commitments for 2030.

The fuel bid cost was considered as an additional TCO component, named Demand Total Cost, focused on the costs that a hypothetical FCEB bus company must assume, based on a functional unit FU defined as 100 km traveled by the bus, considering "Green Hydrogen" [4] production or a GHG low level emissions passing thru the complete LCA of the hydrogen generated. Chosen technology in this study (biomass derived from fast-cutting densified poplar plantations gasification) allows more than 70% of GHG reductions in relation to ICE Buses [5].

METHODOLOGY

Considering international ICE and FCEB vehicles TCO data and values [6], hydrogen production costs [7] and international gas costs, total carbon pricing for transport decarbonization for a hypothetical FCEB local company was calculated:

Bus TCO calculation formula:

$$\frac{\text{TCO}}{100\text{ km}} = \frac{(\text{Bus Purchase Cost} + \text{Bus Operating Cost})}{100\text{ km}}$$

Bus Purchase Cost /100 km = (Gross Margin + Components Mark Up + Drive System + Energy Storage + Remaining Propeller Components) / 100 km

Bus Operating Cost /100 km = (Fuel Cost + Filling Station Operation and Maintenance + Bus Maintenance + Spare Parts Replacement + Others) / 100 km

Decarbonization TCO calculation:

$$\frac{\textbf{Decarbonization TCO}}{100\text{ km}} = \frac{(\text{Replacement TCO} - \text{Reference TCO})}{100\text{ km}} = \frac{(\text{TCO FCEB} - \text{TCO ICE})}{100\text{ km}}$$

$$\frac{\text{Avoided Emissions for AEGEF 0,40 kg CO } 2eq/kWh}{100\text{ km}} = \frac{(\text{GHG ICE} - \text{GHG FCEB})}{100\text{ km}}$$

$$\frac{\text{Avoided Emissions for AEGEF 0,10 kg } CO2eq\ /kWh}{100\text{ km}} = \frac{(\text{GHG ICE} - \text{GHG FCEB})}{100\text{ km}}$$

AEGEF: Argentine Electrical Grid Emission Factor

Total carbon pricing or decarbonized TCO calculation:

$$\textbf{Descarbonized TCO Carbon Pricing} = \left(\frac{\text{Decarbonization TCO}}{\text{Avoided Emissions Ton CO2eq}}\right)$$

Comparison literature information Table 1 shows purchase bus and operative bus costs percentage as part of the Bus TCO for each technology.

Table 2 shows bus purchase cost in detail and Table 3 the bus purchase breakdown costs.

Table 1. Bus Purchase Distribution Costs and Bus Operating Costs.

Technology	Bus Purchase Cost /100 km (%)	Bus Operating Cost/100 km (%)	Bus TCO U$D/100 km
Bus with Internal Combustion Engine (ICE)	44	56	124,96
Bus with Hydrogen Electrical Fuel Cell (FCEB)	46	54	243,37

Source: Deloitte [6]

Table 2. 2019 Bus Purchase Cost.

Bus Purchase Components	ICE	FCEB
Gross margin	14%	14%
Components MarkUp	0%	34%
Drive System	6%	2%
Energy Storage	1%	13%
Other Components	79%	37%
Total U$D/100 km	54.42	112,49

Fuente: Deloitte [6] Costos del bus de MCI: 76.880 U$D. Costo del bus de FCEB: 314.290 U$D.

Tabla 3. 2019 Bus Operating Cost.

Operating Costs Components	MCI	FCEB
Fuel Costs	49%	55%
Filling Station Operation and Maintenance	0%	5%
Bus Maintenance	31%	15%
Parts Replacement	6%	9%
Others (Insurance)	14%	16%
Total U$D/100 km	70,54	130,82

Source: Deloitte.[6] Hydrogen Cost= 8U$D/kg [7]. Gas Cost=0.79U$D/litre.

RESULTS AND DISCUSSION

Decarbonization TCO Carbon Pricing was set, Table 4 for two Argentine Electric Grid Emission Factor (AEGEF) scenarios, expressed at the consumption point AENEF of 0,40 and 0,10 kg CO2eq/kWh, respectively.

Table 4. Descarbonization TCO Carbon Pricing.

Factor de Emisión de la Red Eléctrica Argentina (AENEF) en el punto de consumo	Carbon Pricing del TCO Descarbonizante de un Bus FCEB U$D/Ton CO_{2eq} evitados	Carbon Pricing de la oferta de Hidrógeno U$D/Ton CO_{2eq} evitados	Carbon Pricing Oferta H_2/Carbon Pricing TCO Descarbonización %
AEGEF 0,40 kg CO_{2eq}/kWh	1096	95.1	8.7
AEGEF 0,10 kg CO_{2eq}/kWh	834	72,1	8.7

Source: Own Elaboration.

Table 4 results show incremental actual cost of transport decarbonization for conventional buses with ICE (Mixed 90% Gas and 10% Biodiesel), for FCE buses represents 1096 U$D/Ton of avoided CO_{2eq} for a 0,40 kg CO_{2eq}/kWh AEGEF and 834 U$D/Ton of avoided CO_{2eq} for a 0,10 kg CO_{2eq}/kWh AEGEF.

CONCLUSION

Carbon pricing of the hydrogen bid related to the TCO carbon pricing decarbonization with FCE buses represents 8,7% of the total ICE buses decarbonization cost. This is a key information to understand total costs implications in order to promote a decarbonization process for a disruptive technology change in the actual economy context of the country.

Considering that promotion policies and incentives could lead to an important reduction of actual international prices for the hydrogen bid, specially it's energy component cost and FCEB prices, hydrogen has a great potential to achieve vehicle transport decarbonization process.

The methodology used allows to set and compare the complete carbon pricing from other decarbonization technologies. It provides objective information in order to generate the necessary criteria for a decarbonization planning and prioritization, subject to effective cost guidelines.

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REFERENCES

1. R. C. Leonardo Iannuzzi, Roy Bierregaard, Jorge Antonio Hilbert, Electo Silva Lora, Marcelo Ferrando y Raúl Comelli, "COSTOS PARA LA DESCARBONIZACIÓN DEL TRANSPORTE AUTOMOTOR EN ARGENTINA MEDIANTE VEHÍCULOS DE CELDAS DE COMBUSTIBLE EN BASE A HIDRÓGENO. ENARCIV 2020 | IX Encuentro Argentino de Ciclo de Vida VIII Encuentro de la Red Argentina de Huella Hídrica. Presentado." https://analisisciclodevida.wixsite.com/inicio (accessed Mar. 22, 2021).
2. M. Langholtz *et al.*, "The Economic Accessibility of CO2 Sequestration through Bioenergy with Carbon Capture and Storage (BECCS) in the US," *Land*, vol. 9, no. 9, p. 299, 2020, doi: 10.3390/land9090299.

3. “Acuerdo de París | Argentina.gob.ar.” https://www.argentina.gob.ar/ambiente/cambio-climatico/acuerdo-de-paris (accessed Mar. 02, 2021).
4. “certifhy.” https://www.certifhy.eu/ (accessed Mar. 08, 2021).
5. L. Iannuzzi, J. Antonio Hilbert, and E. Eduardo Silva Lora, “Life Cycle Assessment (LCA) for use on renewable sourced hydrogen fuel cell buses vs diesel engines buses in the city of Rosario, Argentina,” 2021, doi: 10.1016/j.ijhydene.2021.01.065.
6. “Fueling the Future of Mobility Hydrogen and fuel cell solutions for transportation Volume 1 Deloitte China.” https://www2.deloitte.com/content/dam/Deloitte/cn/Documents/finance/deloitte-cn-fueling-the-future-of-mobility-en-200101.pdf (accessed Apr. 11, 2021).
7. R. prepared by the IEA and J. for the G20, “The Future of Hydrogen.” Accessed: Jan. 27, 2021. [Online]. Available: https://webstore.iea.org/download/direct/2803.