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Assessing total and renewable energy in Brazilian automotive fuels. A life cycle inventory (LCI) approach

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ABSTRACT

This article uses a first approach LCI procedure to evaluate total and renewable energy and CO_2 emissions in Brazilian automotive fuels life cycle (LC). The LC model is structured and modular, capable of being successively refined if necessary. The procedure is applied to passenger car use in urban traffic, comparing three fuels used in Brazil (gasoline with 25% ethanol, pure ethanol and compressed natural gas), considering their use in urban traffic in the city of Rio de Janeiro. An in deep research was made to collect representative and unpublished data of Brazilian automotive fuels LC reality, what is considered a main contribution. The results show where specific advantages occur, particularly in the use of renewable fuels made from biomass, an option already practiced and appropriate for Brazilian reality. The use of gasoline with 25% ethanol shows the lowest total energy consumption for the LC, with similar performance to that of compressed natural gas and 36% better than ethanol from sugarcane. However, the last alternative has the advantage of depending almost exclusively on renewable energy (93%) and producing less net CO_2 emissions.

Contents

1. Introduction

Energy consumption for transportation in Brazil grew 17% between 1996 and 2005, of which 90% was due to roadway transportation, involving petroleum derivatives (81%), compressed natural gas (CNG) (4%) and ethanol from sugarcane (15%), all widely available alternatives [1]. However, the growing social awareness of sustainable development implies making informed choices among these alternatives considering their energy efficiency and the amount of renewable energy (RE) along the entire supply chain, not just in their final use, as is the current practice [2].

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Table 1
Summary of the references chosen on application of LCA to energy sources for road transport

Authors	Year	Place	Application of the technique	Objective/application	Scope						Functional unit	Allocation criterion	Categories of impacts
					Dimensions			Extent					
					Width	Length	Depth	Temporal	Geographic	Technological			
Furuholt [4]	1995	Norway	Complete: 4 phases of the LCA	Gasoline, gasoline with MTBE and diesel oil	1st level	Supply chain	Energy, CO_2, NO_X, SO_X, COV	Short-term (year of the study)	Proprietary data	Usual technology on the study date	Liters	Energy equivalent	5 categories[2]
Wang et al. [5]	1997	USA	Partial: LCI and interpretation	E85, E10 and gasoline	1st level	Supply chain and final use	Energy, CO_2, CH_4, N_2O	Short-term (year of the study) and long-term (not defined)	Mean national and regional values	Improved technology for production of ethanol in the long term	Btu/mile	Not specified	Not considered
Sheeran et al. [6]	1998	USA	Partial: LCI and interpretation	B100, B20 and diesel oil	1st level	Supply chain and final use	Energy, GHG, local atmospheric pollutants	Short-term (year of the study)	Mean national and international values	Usual technology on the study date	bhp-h	Mass equivalent	Not considered
International Energy Agency [3]	1999	EC	Partial: LCI	Gasoline, diesel oil, LPG, CNG, M100, E100, B100, HC, DME	1st level	Supply chain and final use	Energy, CO_2, NO_X, HCNM, MP	Short-term (1–5 years) and long tern (5–25 years)	Mean values of OECD countries.	Usual technology on the study date	GJ	Not specified	Not considered
Armstrong and Akhurst [7][1]	2000	EC	Not disclosed	Gasoline, diesel oil, LPG, CNG, M100, E100, B100, HC, electricity	1st level	Supply chain and final use	Energy, CO_2	Medium-term	Mean values of EC countries	Usual technology on the study date	MJ/km	Not specified	Not considered
Berr et al. [8]	2001	Australia	Complete: 4 phases of the LCA	Premium gasoline w/o sulfur, E85, E10, LPG, CNG, LNG, B100, diesohol, diesel oil and GTL diesel oil	1st level	Supply chain and final use	Energy, GHG and local atmospheric pollutants	Short-term	Mean national values	Usual technology on the study date	g/t km	Energy and mass equivalent	Not considered
Hackney and Neufville [9]	2001	USA	Partial: LCI	Gasoline, reformulated gasoline, diesel oil, M85, E85, M100, E100, LPG, CNG, LNG, HC, electricity	1st level	Supply chain and final use	Energy, CO_2, NO_X, HCNM, MP	Medium-term (12 years of vehicle lifetime)	Mean national values	Usual technology on the study date	Energy in 12 years of vehicle life	Mass equivalent	Not considered
Kadam [10]	2002	India	Complete: 4 phases of the LCA	E10	1st level	Supply chain and final use	Energy, CO2, CO, NO_X, SO_X, HC and MP	Short-term (year of the study)	Mean national values	Usual technology on the study date	1 metric ton of dry bagasse	Not specified	6 categories[3]
Kreith et al. [11]	2002	USA	Partial: LCI	CNG, HC, diesel oil GTL, M100, electricity	1st level	Supply chain and final use	Energy	Short-term (year of the study)	Mean national values	Usual technology on the study date	Not disclosed	Not specified	Not considered
Hu et al. [12]	2004	China	Partial: LCI	E85, gasolina	Not specified	Supply chain and final use	Energy, CO_2, CO, HC, NO_X, MP e custos	Short-term (year of the study)	Mean national and international values	Usual technology on the study date	200,000 km	Not specified	Not considered
Wang et al. [13]	2005	China	Partial: LCI	Metanol, gasolina e hidrogenio	Not specified	Supply chain and final use	Energy, CO_2, CO, HC, NO_X, MP, SO_X e custos	Short-term (year of the study)	Mean national and international values	Usual technology on the study date	200,000 km	Not specified	Not considered
Collela et al. [14]	2005	USA	Partial: LCI	Gasolina, oleo diesel, hidrogenio	1st and 2nd levels	Supply chain and final use	Energy, CO_2, CO, HC, NO_X, MP, SO_X, CH_4	Short-term (year of the study)	Mean national values	Usual technology on the study date	1 year operation	Not specified	Not considered

USA – United States; EC – European Community; MTBE – methyl *tert*-butyl ether; E*X* – blend with *X*% ethanol and 100-*X*% gasoline, M*X* – blend with *X*% methanol and 100-*X*% gasoline; B*X* – blend with *X*% biodiesel and 100-*X*% diesel oil; LPG – liquefied petroleum gas, CNG – compressed natural gas, LNG – liquefied natural gas; CH – compressed hydrogen; DME – dimethyl ether; GTL – gas to liquid. *Notes*: 1 – The work does not make clear what the stages of the supply chain are for each alternative, 2 – Consumption of fossil fuels, global warming, photochemical oxidants, acidification and generation of solid wastes, and 3 – Consumption of fossil fuel, global warming, acidification, eutrophization, human toxicity and malodorous air.