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Exhaust emissions of transit buses: Brazil and India case studies

Erin Cooper [a,*,1], Magdala Arioli [b,c], Aileen Carrigan [a], Luis Antonio Lindau [b,c]

[a] EMBARQ, Washington, DC, USA
[b] EMBARQ Brasil, Porto Alegre, Brazil
[c] Laboratório de Sistemas de Transporte, Universidade Federal do Rio Grande do Sul, UFRGS, Porto Alegre, Brazil

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ABSTRACT

In order to aid fleet fuel choices, specifically in Brazil and India, this report compiles emissions testing data from in-use or real world drive cycle tests. The data is used to compare the range of emissions for four emissions that are commonly regulated by emissions standards (CO, THC, NO_x, PM) and CO_2 emissions. The combined results of the analysis show some of the best performing fuel options in Brazil and India are 20% blend Biodiesel with Diesel Particular Filter and Selective Catalytic Reduction (B20 + DPF + SCR) and Compressed Natural Gas with Three Way Catalyst (CNG + 3WC). However, other fuel or technology options provide meaningful results – CNG fuels or Hybrid buses can provide significant PM reductions or CO_2 reductions, respectively. For fleet decisions, further aspects of the local context should be considered as well, such as the impact of maintenance practices, altitude, and local driving cycles on emissions when making vehicle decisions. Also, the usual practice of covering the capital costs out of user fares may not be applicable for the introduction of cleaner buses; the use of national and international funds may be applicable, as the cleaner technologies help achieve energy consumption or emissions reduction targets.

1. Introduction

Transport is an important component of urban strategies to meet local and global environmental goals, such as air pollution and greenhouse gas (GHG) reduction targets. Mexico City, for example, was able to reduce carbon dioxide (CO_2) equivalent emissions by 4.8 million metric tons (Ecoseed, 2011) while improving the local air quality (ICLEI, 2010). Transport was a major contributor, including the use of cleaner vehicles (An, Earley, & Green-Weiskel, 2011). While focus is often on light-duty vehicles, freight and sometimes buses, are responsible for more CO_2 emissions in low and middle income countries (Schipper, Fabian, & Leather, 2009). The situation is similar with air pollutants that result in health problems (Walsh, 2012).

Knowing that cleaner transit vehicles can contribute to important air pollutant and CO_2 reductions begs the question, which fuel type is the best? Though there is abundant information regarding the impact of alternative fuels and technologies on emissions (UNEP, 2009), it is often difficult for transit agencies to determine which is the best fuel and technology to reduce emissions in their specific location. The reports and information that are available often reflect conditions in the US or Europe, and within a specific city and set of operating conditions, which is not directly transferable to cities worldwide. This report aims to interpret the available data for use in a variety of cases.

The question of which bus is best also goes beyond simply choosing a cleaner fuel to understanding the context of government and transit agency policies that impact fleet decisions. How fleets are operated and procured, publicly or privately, and the amount of subsidy supporting transit has an impact on the likelihood of changing to renewable fuels. Related government policies range from mandating the use of a particular fuel, to supporting renewable fuels, to developing targets which need to be achieved regardless of fuel type. One important set of policies are emissions standards. Emissions standards have been set in many countries to drive technological innovation to reduce emissions (An et al., 2011). These standards are considered technology neutral, in that any fuel or technology that can meet the standards can be used. As a result, emissions rates of regulated emissions for all fuel types are moving closer to the same value as emissions standards improve. Nevertheless, different fuels still have different emissions characteristics which also vary by country as fuel quality varies. At the same time, as sustainability becomes more important, fleet operators in the public or private sector, are

* Corresponding author. EMBARQ, World Resources Institute, 10 G St. NE #800, Washington, DC 20002, USA. Tel.: +1 202 729 7730.
E-mail address: ecooper@wri.org (E. Cooper).
[1] Presenting author.

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interested in investing in the most effective technologies to make the largest emissions reductions.

To aid fleet operators in making their fleet selection decisions, this paper looks at fuel and technology combinations that will be relevant for transit vehicles over the next decade in Brazil and India. Emissions data was collected from reports by transit agencies and research institutes reflecting on-road emissions testing or laboratory testing using real city drive cycles. The resulting analysis shows likely emissions ranges from each of the fuel and technology combinations. This information can be used to inform fleet decisions intended to reduce emissions and potentially meet air quality and GHG reduction targets as they are developed.

2. Theory

For decades, fuel combustion in vehicles has been linked to air quality and health problems. Air pollution is a major environmental health problem affecting people worldwide. According to the World Health Organization (WHO), more than two million premature deaths each year can be attributed to the effects of urban outdoor air pollution, at least partly caused by fuel combustion (WHO, 2006). More recently, the relationship between these issues and specific pollutants, listed below, has become clearer through research. Another major concern of vehicle exhaust is the impact of greenhouse gas emissions on global climate change. Roughly 23% of GHG emissions energy related are produced by the transport sector (IPCC, 2007).

Harmful vehicle exhaust emissions, with a variety of affects contributing to environmental and health problems, have been identified and are regulated by improving fuel quality, by improving vehicle technology or fuel economy, or remain unregulated. This paper looks at the pollutants that are regulated through vehicle emissions standards (Carbon monoxide (CO), hydrocarbons (HC), Nitrogen oxides (NO_x), particulate matter (PM)) because of their impact and because a large amount of data is available regarding these emissions due to the fact that they are regulated. Though still unregulated in most places, this paper also looks at CO_2 emissions.

Regulation of GHG emissions is more recent in the United States and Europe. The European Union emission standard for GHG emissions currently covers only passenger cars and vans, but not heavy-duty vehicles. Because there is currently no after-treatment technology that can reduce CO_2 emissions from road vehicles, CO_2 reductions are achieved through fuel efficiency improvements (Lindqvist, 2012). In the United States, the Environmental Protection Agency (EPA) and the National Highway Traffic Safety Administration (NHTSA) have developed the first GHG regulations for heavy-duty engines and vehicles. According to EPA, the regulations will be phased in starting in 2014, and by 2018 the regulations should create an average reduction in GHG emissions per vehicle by 17 percent. The proposed standards are expected to save more than six billion barrels of oil through 2025 and reduce more than 3.1 billion metric tons of CO_2 emissions (EPA, 2012).

Interest in using alternative fuels has grown as a way of exploring possible improvements over diesel in air quality and greenhouse gas emissions. In selecting particular bus technologies, transit agencies must balance fuel and vehicle availability, local conditions, service needs, and costs. Various fuel options have been tested as part of national programs through institute testing and agency pilot programs and locally through agency testing (Cooper, Arioli, Carrigan, & Jain, 2012). Despite this testing, these results may not apply to other locations and are often not aggregated into one database where direct comparisons between fuels can be made. Also, among many possible fuels and exhaust after-treatment technology combinations, not all of these combinations will be available in the next decade in all countries and at all transit agencies. Table 1 shows the fuels currently being used by agencies in two target countries of this report. Brazil has a wide variety of fuels available. In India, as a result of a Supreme Court order, 13 major cities were required to use CNG buses starting in 2001, while diesel fuel is still available for buses in other cities (Roychowdhry, 2010).

2.1. Fuel and technology alternatives

The following is a discussion of fuels, associated technologies, and emissions characteristics. This provides background for the analysis by showing the general characteristics of fuels. However these general characteristics do not capture the full range of emissions impact of the fuel which is assessed in the analysis. This also does not discuss lifecycle emissions related to particular fuels or fuel sources. Lifecycle emissions can make a significant impact on the total GHG emissions of a fuel relative to other fuels, particularly for biodiesel and ethanol.

2.1.1. Diesel

While searching for optimal alternative fuels, it is important to understand why diesel remains an important fuel in urban transit: its high energy density allows for a smaller volume of fuel to transport a bus further. Many improvements have been made to diesel buses over decades to reduce emissions, and the most recent emissions standards in the US show that buses using any fuel type will comply with the same stringent emissions standards.

Most diesel fuel available is petroleum diesel refined from crude oil (TCRP, 2011). Individual countries offer various grades of diesel that have different sulfur contents. Diesel emissions are affected by the amount of sulfur in the diesel as well as the emission-reduction technologies. Reducing sulfur content in fuels is also a major concern (UNEP, 2007), not only for reducing air pollution related to sulfur, but also to allow for the use of exhaust after-treatment technologies. Diesel fuel in developing countries commonly have sulfur content levels above 500 parts per million (ppm); sulfur levels below this value allow for the use oxidation catalysts. Below 50 ppm, additional emissions reduction technologies are available (UNEP, 2007). Major pollutant concerns for diesel fuel are NO_x and PM emissions (Nylund, Erkkila, Lappi, & Ikonen, 2004).

There are many technologies that help to reduce diesel emissions:

- A Diesel Oxidation Catalyst (DOC) utilizes a chemical process to break down pollutants from diesel engines in the exhaust stream, turning them into less harmful compounds. This reduces PM, HC, and CO emissions (Translink, 2006). DOC can only be used below 500 ppm sulfur content in diesel (UNEP, 2007).

Table 1
Fuels and technologies currently being used by transit agencies in Brazil and India.

		Brazil	India
Fuel	Low-sulfur diesel	x	x
	Diesel	x	x
	Ethanol	x	
	B5	x	
	B20	x	
	B100	x	
	CNG		x
Technology	Hybrid	x	
	DPF	x	x
	EGR	x	x
	SCR	x	x
	OC	x	x
	3WC		x

Low-sulfur diesel is 50 ppm.
3WC – Three-way catalyst.