Annex 53: Sustainable Bus Systems

Project Duration	November 15–December 2017
Participants **Task Sharing** **Cost Sharing**	Canada, Chile, Finland, Israel, Sweden, United States
Total Budget	$600,000 US (Estimated Budget)
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Purpose, Objectives, and Key Question

Some of the biggest cities in Latin America are facing the renewal of their bus fleets. It is essential that, at this juncture, energy-efficient, low-polluting, and soot-free buses be introduced into their bus transport systems. In this context, advanced technologies require an appropriate characterization of the advantages of clean and energy-efficient buses in terms of emissions, operational costs, and fuel economy. These characteristics vary, however, depending on local operating conditions, emission regulations, fuel quality, and type of service the buses provide. Verified performance data are needed, as well as test and assessment methodologies that reflect local needs and conditions.

The main objective of Annex 53 is to develop a methodology for establishing requirements for clean and energy-efficient buses that can be used in the tendering process for public transportation operators in developing regions. Such a methodology includes guidance and recommendations on control and follow-up of the buses in operation. A methodology to assess emission stability over time will also be considered. Only original equipment manufacturer products will be considered; no retrofit solutions will be addressed.

Activities

Activities include analysis of the performance of existing buses, evaluation of the operational conditions in pilot regions, comparison of these with existing test cycles, development of a common test methodology, execution of tests with selected fuels and vehicles, data analysis, and, finally, the development of guidelines for buses in sustainable bus transport systems. To facilitate the analysis, the project included a work exchange between European and South American researchers.

Key Findings

Annex 53 started with an analysis of the performance of existing buses and the evaluation of operational conditions in the public transportation system of Santiago, Chile. The Ministry of Transport, in cooperation with the Ministry of Energy and Centro Mario Molina Chile, conducted a comprehensive analysis of bus fleets and routes to obtain a preliminary sample of 19 routes that total more than 800 km. The routes were selected based on average speed, length, rate of occupancy, and number of bus stops.

In cooperation with the Technical Research Center of Finland (VTT), 5 of the 19 routes were selected for vehicle instrumentation. During April 2016, data on time, speed, position, altitude, rate of occupancy, and bus condition were collected for each selected route. These data were used to analyze how well existing international bus driving cycles represent conditions in the city of Santiago de Chile. From this, a representative Santiago driving cycle was developed, in which a micro-trip approach was used. The driving cycle was separated into phases representing different kinds of routes. On the basis of the transport system, there are three main types: Only Bus, Corridor, and Mixed. “Only Bus” is a road not physically segregated for transport operations, such as the Corridor type, but with restrictions on private vehicle usage. These roads represent about 4.4% of the public transport road network. “Corridor” is a road type physically segregated for urban buses. It is similar to Bus Rapid Transit road, and about 2.5% of the public transport road network is Corridor. Finally, “Mixed” is a road type where there are no restrictions on private vehicles, taxis, motorcycles, or bicycles. Mixed routes represent about 92% of the public transport road network. Figure 1 shows the cycle profile for the City of Santiago.

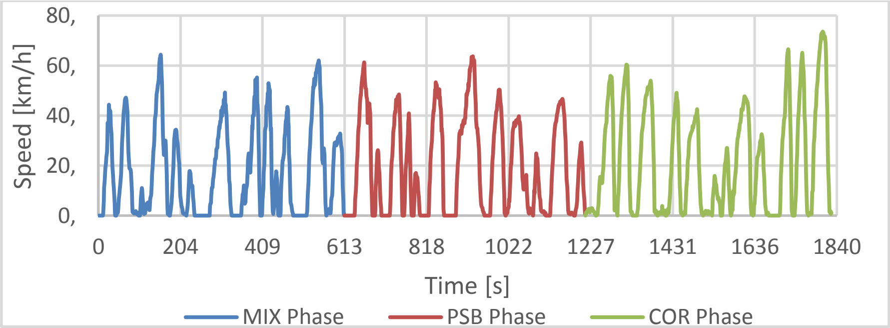

Fig. 1 Santiago Driving Cycle

Different driving conditions were evaluated to determine the parameters for the Santiago driving cycle. As a result of this analysis, the test is conducted under a warm start, with a 50% load and 0/1.4% slope. During 2016 and 2017, dynamometer tests were conducted at the VTT and Center for Vehicle Control and Certification (3CV) laboratories. At the VTT laboratory, buses with Diesel Euro V, Diesel Euro VI, CNG Euro VI, and electric technology/standard were tested. At the 3CV labs, battery electric and Diesel Euro VI buses were tested (see Figures 2 and 3). In addition, with Argonne National Laboratory’s support, Centro Mario Molina (CMMCh) carried out energy consumption models using the Autonomie modeling framework, where the performance of different bus technologies and operation conditions were simulated under diverse driving cycles. The main results of these tests show that for local pollutants, the bus testing program operating in the conditions of a developing city, such as Santiago, may have higher emissions. For electric buses, the results show that these are significantly more efficient than conventional technology buses, even in demanding operating conditions during the Santiago bus cycle. Independent of this advantage, the energy consumptions are greater than those observed in other cycles with less demanding operating conditions; however, these differences may vary depending on the technology used by the electric bus.

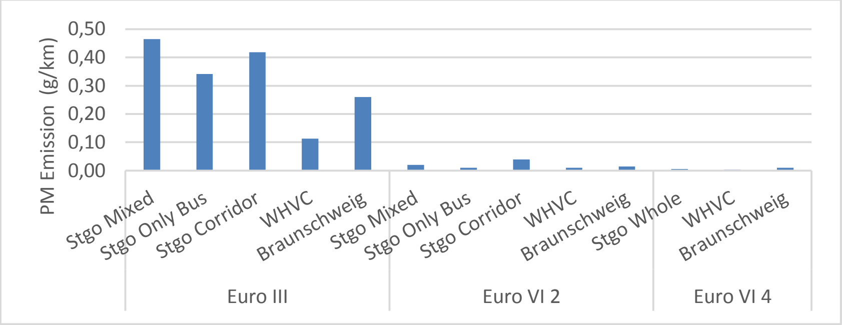

Fig. 2 Particulate Matter Emissions for Different Driving Cycles

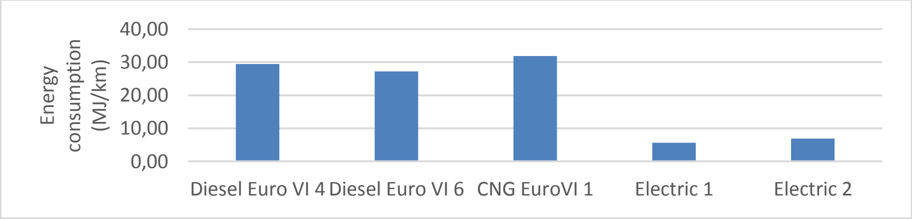

Fig. 3 Energy Consumption for Urban Buses, Santiago Driving Cycle (1.4% gradient)