



# Global Environment Facility

**MOHAMED T. EL-ASHRY**  
CHIEF EXECUTIVE OFFICER  
AND CHAIRMAN

November 10, 2000

Dear Council Member:

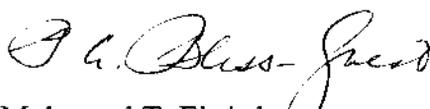
I am writing to notify you that UNDP, the Implementing Agency for the project entitled, *Brazil: Hydrogen Fuel Cell Buses for Urban Transport*, has submitted the proposed project document for CEO endorsement prior to final approval of the project in accordance with UNDP procedures.

Over the next four weeks, the Secretariat will be reviewing the project document to ascertain that it is consistent with the proposal included in the work program approved by the Council in December 1999, and with GEF policies and procedures. The Secretariat will also ascertain whether the proposed level of GEF financing is appropriate in light of the project's objectives.

If by December 8, 2000, I have not received requests from at least four Council Members to have the proposed project reviewed at a Council meeting because in the Member's view the project is not consistent with the Instrument or GEF policies and procedures, I will complete the Secretariat's assessment with a view to endorsing the proposed project document.

We have today posted the proposed project document on the GEF website at [www.gefweb.org](http://www.gefweb.org). If you do not have access to the Web, you may request the local field office of UNDP or the World Bank to download the document for you. Alternatively, you may request a copy of the document from the Secretariat. If you make such a request, please confirm for us your current mailing address.

Sincerely,

  
for Mohamed T. El-Ashry  
Chief Executive Officer  
And Chairman

cc: Alternates, Implementing Agencies, STAP



**United Nations Development Programme**  
GLOBAL ENVIRONMENT FACILITY (GEF)



6 October 2000

Dear Mr. El-Ashry,

Subject: **BRA/99/G32/A/1G/99 - Brazil: Hydrogen Fuel Cell Buses for Urban Transport**

I am pleased to enclose the project entitled "Brazil: Hydrogen Fuel Cell Buses for Urban Transport" approved by the GEF Executive Council in December 1999. Also enclosed is the response to technical comments provided by GEF Secretariat and Council Members.

As per paragraph 29 and 30 of the GEF Project Cycle, we are submitting this project to you for circulation to the Executive Council Members for comments and, subsequently, for your final endorsement.

Thank you in advance for expediting the review and approval of this project.

Yours sincerely,

Emma Torres  
Officer-in-Charge and  
Deputy Executive Coordinator

Mr. Mohamed El-Ashry  
Chief Executive Officer  
Global Environment Facility  
Room G6005  
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Washington, D.C. 20433  
PM

**Brazil: Hydrogen Fuel Cell Buses for Urban Transport  
Response to Comments from Council Members**

<b>Council Member</b>	<b>Comment</b>	<b>Response</b>
France	“Financing expensive prototypes ...poses a number of problems of principle. Impact on development is weak and sustainability is uncertain. Moreover, UNEP does not appear to be equipped to monitor and develop such programs”.	UNDP has worked closely with the proponents in EMTU to develop a monitoring program for the project. Indicators are included in project document. Moreover, as part of programmatic intervention, other developments in FCB market worldwide will be monitored and used to inform future decisions. In addition, World Bank/IFC will be asked to engage in joint monitoring and supervision missions to ensure follow-on.
Switzerland	1) North will have to invest in technology 10 times faster than South. For Phase III to be effective, more private-sector cofinancing will have to be sought, and should be encouraged for Phase II.	1) Present estimates indicate that over 60 buses are being produced for use in OECD countries to the 8 being targeted for Brazil alone. If indeed GEF decides to support a Phase III, which is a decision yet to be taken and will depend upon success of demonstration projects and progress in the technology and in the market worldwide, it is expected that private financing will cover more than 50% of costs. In addition, Brazilian authorities are seeking ways to increase private sector support for this activity through the bidding process. Industry investments in the technology are huge (hundreds of millions of dollars). The GEF contribution will help steer future resource flows to the needs of developing country markets.
	2) GEF contribution is steep at \$1.5 m per bus. Given that requirements will be large for Phase III, why is UNDP taking the lead in Phase II.	2) UNDP is taking the lead in Stage II Demonstrations as the countries have requested that UNDP do so. Once the technology reaches further stages of commercialization where near-commercial credits are justified, then IFC, World Bank and other regional banks will be asked to play a role. To date, the World Bank and IFC have expressed no interest in fuel-cell bus applications as they are still at a demonstration stage, but instead are interested in the stationary applications which are nearer to commercial prices, but are not at present driving the market. The Bank /IFC will be systematically appraised of progress on the demonstration stage and will be asked to jointly monitor activities so that they can make an informed decision on Stage III involvement.
	3) STAP reviewer has pointed out that GHG benefits will depend on design of system-wide H2 supplies to minimize GHG emissions.	3) This demonstration will have a very positive GHG balance, on a system-wide basis as the electricity to be used will be drawn from hydro. In addition, for Stage III, a number of options have been investigated, including steam reforming of natural gas, hydro and biomass as hydrogen sources. All of these can supply H2 at a favorable system-wide GHG balance. Costs and resource flows in the future will determine which of these options is most suitable for supplying H2 to the Phase III operations.
Germany	GEFSEC should be involved in early stages of project planning in order to assure adequate attention to risks; a step-by-step approach should be utilized whereby innovative technology projects start in one country and then move on when experience has been gained.	The GEFSEC has been involved in this project preparation since early 1999 and have been involved in formulating, organizing and chairing the workshops held to develop the draft FCB strategy. The Operational Program foresees repeated investments as the way to reduce technology costs. The Brazil project is the first of a series of demonstration projects. The remaining submissions to Council have been phased out over several years to create greater sharing of lessons. The Vancouver demonstration, which lagged the Chicago demonstration by 6 months, benefited from lessons learned in the earlier demonstration

## PROJECT DOCUMENT

### 1. IDENTIFIERS

<b>PROJECT NUMBER:</b>	<b>BRA/99/G32</b>
<b>PROJECT NAME:</b>	<b>Brazil: Hydrogen Fuel Cell Buses for Urban Transport</b>
<b>DURATION:</b>	5 years
<b>IMPLEMENTATION:</b>	United Nations Development Programme
<b>EXECUTING AGENCY:</b>	Ministry of Mines and Energy EMTU/SP (Empresa Metropolitana de Transportes Urbanos de São Paulo S/A)
<b>REQUESTING COUNTRY:</b>	Brazil
<b>ELIGIBILITY:</b>	Brazil ratified the FCCC on 28 February 1994
<b>GEF FOCAL AREA:</b>	Climate Change
<b>GEF PROGRAMMING FRAMEWORK:</b>	Sustainable Transport, Operational Programme No. 11

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**2. SUMMARY:** This project is designed to stimulate the development and utilization of fuel cell buses by supporting a significant operational test of fuel cell buses in the greater São Paulo Metropolitan Area. It will assist the Brazilian Government and the Empresa Metropolitana de Transportes Urbanos de São Paulo S/A in obtaining and operating 8 fuel cell buses in order to provide feedback to the technology developers and to gain meaningful experience in the operation and management of buses powered by fuel cell drive trains. This project will both pave the way for further GEF projects in Brazil that will be required for fuel cell buses to be commercially produced and provide experience and increased demand for the fuel cell buses. Thus, it will contribute to cost-reductions, making the technology more available to other developing countries over the long run. The project is designed to be consistent with the terms of both GEF Operational Program 11.

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### 3. COSTS AND FINANCING (MILLIONS US\$)

<b>GEF:</b>	-Project:	US\$	12.274
	-PDF:	US\$	0.324
<b>Subtotal GEF:</b>		<b>US\$</b>	<b>12.598</b>
Co-financing:	-EMTU/SP in-kind	US\$	1.306
	-Fares	US\$	1.000
	-Government – FINEP	US\$	5.000
	-Government – PDF	US\$	0.263
	-Private Sector	US\$	1.600
<b>Total Project Cost (including PDF)</b>		<b>US\$</b>	<b>21.767</b>

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### 4. OPERATIONAL FOCAL POINT ENDORSEMENT

Name: Antonio Gustavo Rodrigues	Title: Secretario Adjunto de Assuntos Internacionais
Organization: Ministerio Do Planejamento, Orcamento	Date: 29 September 1999
E Gescao Secretaria de Assuntos Internacionais	

**5. IA CONTACT:** Nick Remple, Regional GEF Coordinator UNDP/RBLAC/ GEF

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## BACKGROUND AND CONTEXT

### a. The environmental aspects

Diesel-powered urban buses are major contributors to air pollution in mega-cities, particularly in developing countries, which represent 75% of world bus markets. They also make a significant and growing contribution to GHG (greenhouse gas) emissions. Trolley buses, with their all-electric drive-lines, offer only a limited solution to these problems. Their overhead wire networks restrict their flexibility, and the cost of these networks limits them to high-density routes.

Despite major efforts over three decades to tackle atmospheric pollution, the São Paulo Metropolitan Region (SPMR) continues to have major problems with air quality, which drops below acceptable standards during 140 days per year. Diesel engines in trucks and buses account for a significant contribution to toxic emissions, according to CETESB (Companhia de Tecnologia de Saneamento Ambiental) report (1997):

- Over 25% of carbon monoxide;
- 20% of unburned hydrocarbons;
- 80% of nitrogen oxides;
- 75% of sulfur oxides; and
- 30% of particulates.

Diesel buses are one of the major contributors to the air pollution in the region. The average diesel bus is operated for about 78,000 km each year. For every kilometer traveled, a diesel bus in São Paulo is estimated to emit 18 g of CO; 13 g of NO; 1.2 g of SO; 2.9 g of HC's; and 0.8 g of particulates. As detailed in Table I-2, this will result in emissions of 17 tones of carbon monoxide; 12 tones of NO<sub>x</sub> emissions; 1.1 tones of SO<sub>x</sub> emissions; 2.7 tones of HC emissions; and 1560 tones of CO<sub>2</sub> emissions. In addition to these local pollutants, diesel buses emit approximately 1.1 kg of CO<sub>2</sub> for each km driven (or 300 grams C per km).

In addition, although concentrations of some pollutants have been reduced, those for particulates have remained relatively high over the last 20 years. This situation has led to governmental policies to strengthen controls, and to a commitment to proposed measures for reducing bus emissions, by establishing "low", "very low", and "ultra-low" emission standards for urban buses with a schedule for their introduction in São Paulo. These "ultra low" emissions standards are met only by hydrogen fuel cell buses and trolleybuses.

Although diesel-powered buses make up only a small part of the SPMR vehicle fleet, they make a significant contribution to toxic emissions – up to 6% of the total in the case of nitrogen oxides. Diesel buses contribute over 50% of air-borne particulate matter found in the bus corridors. The SPMR bus fleet is estimated to release more than 1.5 million tons of carbon dioxide per year. The São Paulo State Government is committed to extending the use of renewable, non-polluting energy resources for powering public transportation in SPMR. As part of this, both SPTrans and EMTU/SP operate extensive electric trolley-bus networks, both on city streets and within the dedicated corridors. Large-scale further extension of these networks is inhibited, however, by the heavy fixed costs of the overhead lines. Although the costs of these can be economically justified on routes with a high density of traffic, reliance on these overhead lines inherently limits

the flexibility of operation.

The total incremental cost of getting hydrogen fuel cell buses to the level of production volume where they become commercially competitive with clean, diesel buses has been estimated at about US\$ 970 million. Conversion of the SPMR bus fleet, 25,000 strong, to run on electrolytic hydrogen, would avoid 3.1 million tons of CO<sub>2</sub> emissions per year (0.845 m tons C). (Eliminated tailpipe CO<sub>2</sub> emissions would account for 90% of the total and avoided emissions during diesel production account for 10%.) Even if fossil fuel (natural gas) were the source of the hydrogen, the improvement in conversion efficiency alone would yield substantial savings in GHG emissions, reducing CO<sub>2</sub> emissions by 1.6 million tons per year (0.436 m tons C). (This assumes efficiency for the fuel cell buses of 8 kg H<sub>2</sub> per 100 km, which has recently been demonstrated at the prototype level).

The carbon emission reductions from replacing all diesel buses in developing countries in, say, 2025 with fuel cell buses operating on hydrogen produced from natural gas would be some 440 million tons of CO<sub>2</sub> per year (120 m tons of C). (This assumes that the number of buses per capita in Brazil today and the fuel economy and annual mileage of Brazilian buses are representative of the average in developing countries in 2025. With this assumption, there would be 6.75 million buses in developing countries in 2025, diesel-bus emissions avoided would be 131 tCO<sub>2</sub> per bus-year (35.7 t C), and emissions associated with hydrogen fuel cell buses would be 66 tCO<sub>2</sub> or 18 t C per bus-year).

The SPMR is capable of absorbing 500 high-technology buses per year, as part of its normal fleet renewal program in the next 10 years (diesel buses are currently replaced every 8 years, with sophisticated new diesel and trolley-buses being introduced). EMTU/SP, the lead institution for the proposed project, is a highly-sophisticated operator with the capability to develop and provide garaging, maintenance and repair facilities for hydrogen fuel cell buses and to operate their fuelling systems. Thus, the SPMR and the actions planned within it in the near future offer among the most favorable combinations of demand and infrastructure in the world for enabling the early large-scale launch of a system which can make a major contribution to reducing both toxic pollutants and GHG emissions.

Brazil has embarked on an ambitious program of environmental regulation and is attempting to move to cleaner public transport. However, every option tried so far--including CNG--emits significant amounts of carbon. The Government and the Municipal authorities are interested in the fuel-cell bus technology as it potentially poses a win-win-win situation—good for the local environment; good for the global environment; and following further development of the technology, good for the economy.

## **b. Social aspects**

Brazil's largest urban region, the São Paulo Metropolitan Region (SPMR), is composed of 39 municipalities and has a population of 18 million. It relies heavily on public transport and on buses in particular, with the following breakdown of journeys:

Walking 34% (10 million daily person-trips)  
Private car 33% (9.6 million daily person-trips)  
Bus 25% (7.7 million daily person-trips)

Commuter rail and Metro 8% (2.4 million daily person-trips)

The large share of journeys made by car and on foot suggests a potential for further expansion of public transport, notably by bus and by efficient integration of the different transport modes. Also, the intensive use of private cars shows the necessity of quality improvements in the buses and the public transportation services. The SPMR has a well-developed, integrated public transport system, for which further major extensions are planned, under the PITU 2020 (Plano Integrado de Transportes Urbanos) long-range transport plan. Public bus operations are dominated by SPTrans (São Paulo Transporte S/A), managing service contractors operating over 10,000 buses and trolley-buses within the city of São Paulo, and EMTU/SP (Empresa Metropolitana de Transportes Urbanos de São Paulo S/A), operating on a similar scale in the periphery. EMTU/SP has created a network of dedicated bus/trolley-bus corridors, as a cost-effective alternative to fixed rail systems, where traffic density does not justify these.

### **c. Energy demand**

Considering the energy content of the automotive fuels and the total amount of electric energy demand in the considered area, it is safe to conclude that any region (SPMR, the State of São Paulo or the entire country) burns 60% more energy from the transportation fuels than the hydroelectric power consumed by the rest of activities in the same area.

It is important to remember that 2/3 of the fuel energy is wasted through the heat rejection, dictated by the thermodynamic laws. This means that those considered regions waste more energy in transportation than the required amount for all other applications. In addition, some 10% more energy is consumed to produce current automotive fuels. This is also valid for the world; thus it is safe to say that the Planet burned 50% of the fossil sources within only a century, wasting 2/3 of that! Furthermore, if the world is to solve the global warming problem, it must change fundamentally the way it uses energy.

In conclusion, the energy conversion efficiency might be of primary concern in the transportation management, as well as the renewability of resources to be used. In this sense, the use of hydrogen fuel cell vehicles represents a fundamentally new technology approach for providing transportation services with low or zero carbon emissions, and much higher efficiency in energy conversion when compared to the internal combustion engines and the theoretical limit imposed by thermodynamics. In addition, fuel cell technology opens the way to gradually increase the use of renewable energy resources without specific requirements for engine design as a function of fuel source.

This is one of the main key-points of EMTU's vision to establish the transportation systems targets, to address the transportation solutions and mobility, and environmental protection as well.

In addition, Brazil has displayed a major commitment to the use of renewable energy resources in the transportation sector through the PROÁLCOOL program. A substantial hydrogen fuel cell bus program will also have important positive multiplier effects in Brazil as a whole, for example:

- a) Reduction in oil consumption and imports;
- b) Better oil refinery mix, through reduction of diesel fuel consumption, which has grown considerably in Brazil;
- c) Potential for extension of hydrogen fuel cell drive-lines into other urban-based vehicles, such as delivery and other fleet trucks;
- d) Stimulus to the development of fuel cell powered cars and light trucks, using on-board ethanol reformers;

- e) Stimulus to the development of sources of hydrogen other than from electrolysis, such as biomass;
- f) General stimulus of demand for the development of renewable energy resources; and
- g) Reinforcement of strategies for the development of public transport.

#### **d. Fuel supply**

Compressed hydrogen is better suited for urban buses than on-board liquid fuel reforming, since their operation is centralized in a few garages.

Purchasing hydrogen from third parties could be an option. However it is out of consideration in this Project (phase II) to avoid the risk of contaminant problems in the expensive prototypes of fuel cell and due to the fact that hydrogen obtained through this process is not renewable. It may be considered in the future, if hydrogen producers decide to include renewable resources in their processes under competitive costs.

Producing hydrogen from ethanol/biomass reforming may be a good option in the future, but it is not feasible now. Thus, it is not recommendable for this Project (phase II).

Thus, the most promising alternative is the hydrogen production from water electrolysis. Considering a production plant running 20 hours per day during the off-peak period, this process is less expensive than the other ones. In addition, renewable hydroelectric power is available in Brazil (92% of electricity generation is from hydro-power), the electrolysis technology is already well known and commercially available, as well as this process assures contaminant-free hydrogen at competitive fuel costs.

#### **e. Barriers to large-scale deployment**

There are major barriers to be overcome before the large-scale deployment of fuel cell buses becomes the cost-competitive option of choice for urban bus fleets in developing countries:

- The gap between the costs of current prototype hydrogen fuel cell buses and those of conventional diesel buses is still considerable - over US\$ 2 million versus US\$ 250,000 for buses designed to North American and other international specifications. Almost all of this difference is attributable to the higher costs of the drive-line, especially the fuel cell engine, which is still not made in series production;
- A similar gap in the durability of the fuel cell stacks, which are the electricity generating heart of the engine – 4,000 hours prior to an overhaul at present versus a normal expectation of 30,000 hours before major overhaul for a diesel engine;
- The absence, to date, of a sufficient fleet of vehicles operated over a long-enough period of time for thorough de-bugging of the drive-line technology and for setting standards and guidelines for updating its design to achieve the cost reduction and durability improvement objectives;
- The lack of large-scale experience of operating, fuelling, maintaining and repairing hydrogen fuel cell vehicles;
- The necessity of a significant market, encompassing buses and cars; and
- The lack of public awareness of and support for the new technology.

What is needed to break down these barriers to full-scale deployment is an initial market of sufficient scale to justify the investments in further development of fuel cell engines and in the scaling-up of production which will bring them to acceptable levels of cost, availability and

reliability. Industry projections indicate that these levels will be reached at a cumulative production level of approximately 2,000 buses and 400,000 cars.

Detailed comparisons of full life cycle costs show that hydrogen fuel cell buses, once they have achieved their series-production cost and durability targets, will be much cheaper than trolley-buses and within 30% of the cost of diesel buses (see Phase I final report). These calculations include the full costs of energy provision. They are also made on a conservative basis for the hydrogen fuel cell buses, which means that their true costs will most likely turn out to be lower. Conversely, the considerable environmental costs of diesel buses have not been factored into their life-cycle costs, which would show an even better economic advantage of fuel cell vehicles. It is worth noting that hydrogen buses will be economically competitive if their useful life is comparable to the trolley-buses --say 20 years--to compensate for the higher investment. This is also of interest to enhance bus comfort to attract car users to public transport.

#### **f. Brazilian industries capabilities for further expansion potential**

Urban bus transport plays a major role in the economic and social life of Brazil, as in many developing countries. There are several other major urban areas that will be able to follow São Paulo's lead. This is reflected in the size of the national bus fleet: 40,000 long-distance and 120,000 urban buses, with the latter sector still growing rapidly. Brazil is the world's third largest bus market, after China and India, and the largest market for buses built to Western standards. The urban bus market sector alone in Brazil requires about 11,000 units per year.

Unlike many developing countries, Brazil has a large-scale, modern, well-equipped and competitive bus industry, building up to 20,000 units a year – equivalent to the production of the whole of Western Europe. It is led by three global truck and bus manufacturers, Mercedes-Benz, Volvo and Scania, each of which has a state-of-the-art truck and bus assembly plant producing bus chassis in Brazil. They are matched by large and fully-capable body building companies, notably Marcopolo and Busscar. Brazil exports significant numbers of buses to the rest of Latin America and even to Europe.

Brazilian industry, working with EMTU/SP and SPTrans, developed a new range of trolley-buses during the past 20 years, both single-body and articulated. Brazil is one of the largest producers in the world of modern, high-technology trolley-buses, with sophisticated power electronics in their drive-lines, and makes most of the components needed for them.

This experience with electrically-powered buses gives it an exceptional capability for engineering the new hydrogen fuel cell drive-line technology into its buses, which should create the potential for competitive designs. These can more than compensate for the need to import the fuel cell membrane-electrode assemblies, which are likely to be centrally-produced outside Brazil, for reasons of production scale and cost, allowing a partnership with the Brazilian industry.

#### **Lessons learned from previous experiences**

The design of this project has benefited from the experiences of previous fuel-cell bus demonstration projects, particularly the experiences of the Chicago and Vancouver demonstrations. Because the Vancouver demonstration relies upon electrolytic hydrogen, it has more relevance to the Brazilian proposal. Much of the design work; experience data; and costing of the hydrogen refueling system for the Brazilian proposal are based upon the experiences in Vancouver.

From Chicago, several lessons have been learned. First, it is not advisable to have fewer than 3 buses in a demonstration set, as statistically, it is impossible to tell whether any one operational problem is attributable to the individual unit or to the overall design. Second, availability has so far been at about 30% of the availability of diesel buses. This figure is increasing with time both within the cohort of buses used in this initial demonstration and between the cohorts in this generation of fuel-cell stacks and that of future ones. Thirdly, fuel-cell stack-life in the current generation of fuel-cells is running at about 4000 hrs between rehabilitation. With new generations, this figure is expected to rise dramatically as well. In short, all of the design parameters and assumptions used in the preparation of this project have been drawn from one of the previous demonstration projects and have incorporated expectations for future improvements in the technology.

The design of this project has also benefited from the EMTU's experience of developing trolley buses for use in the São Paulo Metropolitan area. These buses were developed over a number of years through an iterative process. One lesson from this experience is that it is more important to gain the initial experience with a bus-propulsion technology before trying to "Brazilianize" it. For this reason, Phase III of the Brazilian program will focus on localization of the production of the fuel-cell buses—pushing both the testing and indigenization of the production into the initial phase has proven too cumbersome a task to undertake all at once. A second lesson from the trolley-bus development experience is that it is essential to operate the vehicles under commercial conditions.

Fuel cell technology is revolutionary in its potential for environmental gains and urban buses are the most attractive and accessible-applicant on of them. While a number of different fuel cell technologies exist, proton exchange membrane fuel cells (PEMFC) are the leading candidate for road traction applications. Fuel cell/electric (FC/E) drivelines are inherently more efficient converters of chemical energy into mechanical energy than internal combustion engines (ICEs). Their drive-lines are at their most efficient at part loads and low speeds – precisely the opposite characteristic of diesel engines. Their energy conversion efficiency in urban traffic can be twice as high. They emit far less heat and noise than a diesel bus, no toxic emissions and no carbon dioxide. They can carry enough compressed hydrogen in their tanks to operate 400 km per day – more than enough for urban transit operations. Their tanks can be replenished overnight at their home maintenance garage, which removes the need for a dispersed hydrogen re-fuelling infrastructure. They offer the benefits of electric propulsion without the need for overhead power cables

#### **g. Development objective and expected optimize costs**

The development objective of the project is to reduce GHG emissions through the introduction of a new energy source and propulsion technology for urban buses based upon fuel-cells operating on hydrogen. This project is designed to initiate and accelerate the process of the development and commercialization of fuel cell buses in Brazil. Together with similar future initiatives in other countries, it is intended to provide a major push to the accelerated development of relatively clean technology in the mega-cities of developing countries.

Over the longer term, assuming that this project and its successors perform as designed, this project will lead to an increased production in fuel cell propelled buses, and eventually, the reduction in their costs to the point where they will become commercially competitive with

conventional, diesel buses. It has been designed to be consistent with GEF Operational Program 11 “Promoting Sustainable Transport”.

The project is concentrated in the State of São Paulo and the SPMR, which both face some of the most serious environmental and public transportation challenges, and have the best capacity and capabilities to take advantage of the new technology. The STM (Secretaria de Estado dos Transportes Metropolitanos – State Secretary of Metropolitan Transport) is strongly supportive of the project in the context of its efforts to reduce air pollution from the public transport system in São Paulo.

The FCBs cost cannot be lower than the present used Diesel buses in Brazil, because they don't have the necessary quality requirements and does not compare to bus international standards and costs. On the other hand, to assure future viability, the FCBs cannot be more expensive than the present Brazilian trolleybuses, which comply with the best international quality standards and are much less expensive.

Considering the possibility of having a joint venture between a fuel cell system producer and a Brazilian bus manufacturer, it was assumed that the future cost of a Brazilian FCB might be similar to the sum of the costs of a Brazilian trolleybus and an international fuel cell system.

Based on such considerations, it was determined some basic requirements to assure economic competitiveness, to be pursued in this fuel cell bus Project (phase II).

The evaluation of the FCBs feasibility and viability in the future, focused the bus life-cycle operation costs compared between Diesel, trolleybus and fuel cell powered buses, taking the cost of trolleybuses and Diesel buses according to the existent systems characteristics and operational costs as the baseline.

Regarding electric energy supply, the estimation was done under realistic costs, according to the presently available tariff in São Paulo, considering 20h/day operation, out of peak hours, to optimize costs of demand (nominal power) and energy consumption.

Complementing the energy cost, hydrogen production from electrolysis has an investment cost for the electrolyzer and storage tanks, which was estimated on the Canadian experience basis taken from Vancouver demonstration program. However, these costs are far below the grid network included in the trolleybus case.

Regarding the fuel cell bus itself, the feasibility study focused the future international costs of fuel cell engine + e-drive assembly expected for 2007 (the start of series production) and the vehicle cost was based on the present costs of a Brazilian trolleybus, which is one of the most competitive in the international market. This approach led to competitive operational life-cycle costs for the fuel cell buses, provided two important conditions are imposed to the future implementation:

- 20 years or 1.0 million km is the minimum durability requirement, to allow higher initial investments amortization;
- vehicle manufacturers might participate in the Brazilian FCBs construction in order to bring their costs to competitive levels.

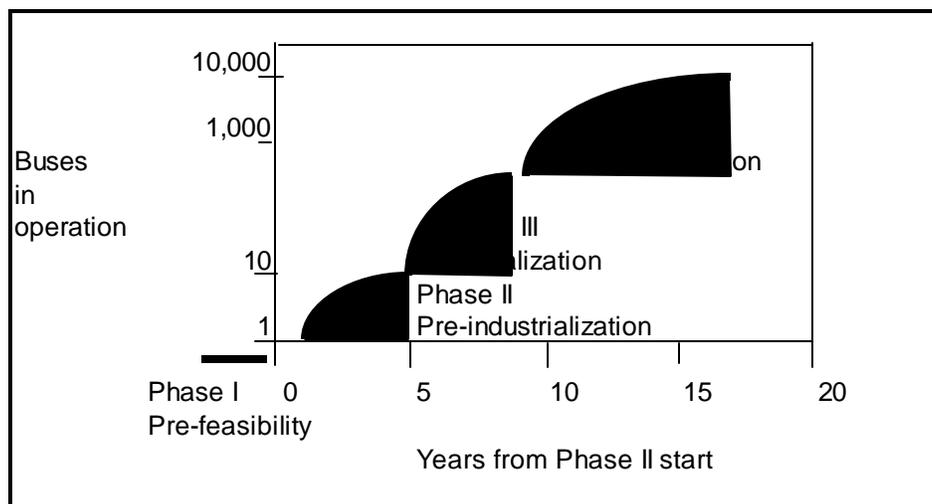
This is the basic distinction between the Brazilian demonstration project when compared to those made in Chicago and Vancouver: future FCBs must comply to durability requirements of 20 years or 1 million km driven to have total operational costs competitive to trolleybuses. This point is one of the important targets to be considered in this Project (phase II).

## **h. The overall hydrogen fuel cell bus program**

This project is the second step- Phase II - of a complete program – Environmental Strategy for Energy: Hydrogen Fuel Cell Buses for Brazil, the phases of which are summarized in the Figure 1 below:

- a) The Phase I feasibility study and Proposal for Phase II has been completed. (*The arguments presented in Section 1 of this project are condensed from the Phase I final report*);
- b) Phase II – the subject of this project - involves running a fleet of 8 buses from one bus garage in the SPMR for 4 years in order to obtain 1,000,000 vehicle-km of experience. This is not a project to be considered purely in isolation as a technology demonstrator. Its outputs will include both the preparation of the local operating infrastructure for Phase III and invaluable feedback into product development;
- c) Phase III will involve converting a complete bus garage to operating fuel cell electric buses, with a fleet of some 200 buses. The SPMR has 52 garages in its network, ranging in size from 50 to 650 buses. 33 are in the range of 101-300 buses. Buses supplied for Phase III are expected to be built in Brazil, by adaptation of a Brazilian trolley-bus chassis, in order to take advantage of existing national capabilities.
- d) Phase IV will involve wider deployment in the SPMR and other Brazilian metropolitan areas, series production of the buses on a commercial basis, and the start of exports to Latin America and other regions and/or licensed production outside Brazil. By this stage, it is expected that fuel-cell buses should be economically competitive with diesel buses on a life-cycle basis.

**Figure 1: Phases of the program**



*Source: Phase I final report*

### **i. Size, duration and location of the project (Phase II)**

The size, duration and location of the project (Phase II) are dictated by the need to ensure statistically valid results:

- 1) 1 million vehicle-kilometers is the minimum cumulative volume of operation needed to ensure that all likely failures in service are encountered, their causes understood and remedied, and opportunities to reduce costs and increase reliability and durability are identified – the life expectancy for an electric-drive bus being 15-20 years and 1.5 million kilometers, which is currently practiced in Brazil;
- 2) Diesel buses in the SPMR run an average of 84,000 km per year. It is prudent to assume half this, i.e. 42,000 km per year, with a new drive-line technology and the need to familiarize operators and maintenance personnel with it. It is assumed that the availability of the buses will increase from 50% of the availability of a diesel bus in the first year to 60% and 70% of the availability in the second, third and subsequent years of operation;
- 3) Achieving 1 million vehicle-km therefore requires 27 vehicle-years of operation;
- 4) Fulfilling this in 1 year with 27 buses would be extravagantly expensive in capital costs and unachievable until bus production could be ramped up (requiring other markets to be exploited beforehand). Individual buses would not remain in operation long enough for all potential faults to be detected;
- 5) Spreading the experience over several years (3 buses for 9 years, for example) would be an impractical length for a trial period. The feedback from operations would mainly come too late to influence the design and updating of the technology by the producers of fuel cell engines, thereby making Phase II's outputs irrelevant to the rest of the program;
- 6) 3 buses over 3 years will not give adequate results, as these buses will still have semi-prototype engines, which will vary in characteristics from one to the other. A minimum sample size of 8 is needed to ensure the statistical validity of the experimental results and the coverage of 1 million km, at least;
- 7) The 8 buses need to be in the hands of 1 operator, in order to ensure consistency of measurements and results. São Paulo contains more than enough opportunities to test the buses in different conditions: corridors and city streets; continuous operation and stop-and-go; fully- and partly-loaded; flat terrain and steep hills. Dispersing them among more than one city will both compromise the integrity of the test program and duplicate the investments in fuelling infrastructure and training; and
- 8) São Paulo also has the best-qualified bus operator, EMTU/SP, and a substantial government/academic technology infrastructure.

The best compromise between effectiveness and cost-effectiveness--taking into account the objectives of the project and the delivery capability of the suppliers canvassed--is therefore to run an initial batch of 3 buses for 4 years, (anticipating one rehabilitation of the fuel-cells to extend their useful life), and a second batch of 5 buses for the last 3 of these 4 years. However, it does pose additional risks on the project, as discussed below.

Therefore, this procedure has the following advantages:

- 1) to accumulate over 1 million km, the minimum timelife required for future buses, which is a very good target for evaluating MTBF (minimum time between failures) and FMA (failure mode analysis), at the end of the 4<sup>th</sup> operational year
- 2) to make each bus run a total of 80,000 to 120,000 km, which is 2 or 3 times the objective for MTBF, and therefore sufficient to detect likely failure modes.
- 3) to identify bus and driveline design and manufacturing problems.

#### **j. Benefits of hydrogen fuel cell urban buses**

The project will demonstrate significant additional local benefits in terms of reduced emission of pollutants dangerous to human health and habitat. In particular, the project will reduce the emission of NO<sub>x</sub>, SO<sub>x</sub>, CO, HC and particulates, as detailed in the incremental cost matrix. As detailed in the text, there are also significant benefits to the global community, the automotive industry, and the technology providers.

The immediate beneficiaries will be the population of the SPMR and eventually the population of other Brazilian cities who will benefit from reduced local air pollution. The private sector will also benefit through the creation of new markets and employment based upon the deployment of new technology and skills. Finally, the global community will benefit from both a reduced cost of a GHG-neutral energy technology and the resulting reduction in global CO<sub>2</sub> emissions.

Although the boundary for this immediate project is the Brazilian urban transport sector, the project will support and draw upon resources from the global automotive industry. It should also provide important feedback for public transport agencies in other parts of the developing world. One of UNDP GEF' s roles is to ensure that the information gathered and experience gained can be shared across national and commercial boundaries. In that context, this project is important internationally for the experience to be gained and shared.

## **2. PROJECT OBJECTIVE, ACTIVITIES AND EXPECTED RESULTS**

### **a. Project Objective**

The **immediate objective** of the project is to demonstrate the operational viability of fuel cell drives in urban buses, together with the requisite re-fueling infrastructure, under Brazilian conditions. It will begin the process of commercialization and adaptation of the fuel-cell buses in Brazilian markets.

### **b. Project outputs and activities**

The results of the project are expected to be:

**Output 1:** A significant demonstration of the operational viability of fuel cell drives in urban buses and their refueling infrastructure under Brazilian conditions;

**Output 2:** A cadre of bus operators and staff trained in the operation, maintenance, and management of fuel cell buses;

**Output 3:** The accumulation of a substantial body of knowledge about reliability, failure modes and opportunities for improving the design of fuel cell buses for Brazil;

**Output 4:** Assessment of the performance of the electrolysis unit;

**Output 5:** A proposal for Phase III of the Brazilian Fuel-cell Bus program that lays the foundation for the expansion of the market for and use of fuel cell buses and increases the involvement of local engineering and production of buses; and

**Output 6:** Increased awareness and support of the public for an increased role for fuel cell buses in Brazil's urban transport system.

In order to achieve the results listed above, sixteen activities are being proposed. The outputs and respective proposed activities are listed below:

## **Output 1**

Activity 1.1: Specification of technical performance targets for the buses – The project team will specify the characteristics of the buses and the fuelling system, such that they will meet the needs of the project. The current assumption is that complete fuel cell electric buses will be procured (as opposed to component procurement and assembly in Brazil), in order to reduce the specification and procurement time and effort, and – most crucially – to minimize the technological risks.

Activity 1.2: Issue call for tenders and select vendor to supply the buses—Tenders from different combinations of fuel cell engines and bus chassis/body manufacturers will be sought and encouraged. The expectation is that a single vendor will be required to contract for the whole system – buses and fuelling system – with appropriate sub-contracting arrangements. The vendor(s) will be selected on the basis of lowest cost for the complete Phase II period, subject to meeting the specified technical and performance requirements.

Activity 1.3: Install, operate and maintain the refueling infrastructure – As part of the main contract, the primary contractor will oversee the installation, operation, and maintenance of the hydrogen generation and refueling system. Its placement will have to precede the arrival of the initial set of three buses.

Activity 1.4: Place initial set of 3 buses in operation—Once a vendor is selected, the next activity will involve placing the initial batch of 3 buses in service for 4 years, operating in revenue service under realistic operating conditions.

Activity 1.5: Place second set of 5 buses in operation—The same vendor will then be expected to place a second batch of 5 buses in service for 3 years, under similar conditions.

## **Output 2**

Activity 2.1: Hold on-the-job training seminars for drivers and maintenance staff—This activity must ensure the training of sufficient numbers of operating and maintenance personnel to ensure

both the execution of Phase II and the preparation of Phase III.

### **Output 3**

Activity 3.1: Formulate guidelines for quarterly reporting on in-service performance of the buses—It is expected that through a consultative process, the project team will develop a protocol for issuing quarterly reports on the technical operations of the bus fleet (e.g., in-service reliability, failure modes, energy consumption, etc.).

Activity 3.2: Collect, analyze, and evaluate the operating data on reliability, failure and potential improvements — The project team will engage in systematic logging, analysis and interpretation of operating parameters paying particular attention to reliability, failure modes and potential improvements in design and operation of the buses. These data will serve as the basis for annual progress reports; proposals for further product development; and improvements for Phase III (see below). The inputs from bus users obtained via surveys or focus groups will also be incorporated into the design process.

Activity 3.3: Exchange experiences with Chicago, Vancouver, and other users of fuel cell buses-  
- In this activity, it will be important to give special emphasis to interactions with other GEF fuel cell bus projects and other non-GEF FCB projects. The experiences of these other cities should also be taken into account in formulating future Brazilian projects.

### **Output 4**

Activity 4.1: Systematic logging, analysis and interpretation of operating parameters.

Activity 4.2: Opportunities identified for potential improvements of performance and cost reductions.

Activity 4.3: Evaluation of safety aspects.

Activity 4.4: Establishment of operating standards for the electrolysis unit.

### **Output 5**

Activity 5.1: Develop initial Brazilian bus design for hydrogen-powered fuel cell buses in Brazil — The project team will then develop the initial bus design, operation, and maintenance guidelines, and specifications. It will also involve strengthening Brazilian capacity to manage the integration of new transport technologies.

Activity 5.2: Provide feedback to the vendors to improve future bus designs — The data collected in the above activities will then be fed back to the vendor(s) in order to demonstrate the need for modifications to hardware and control software.

Activity 5.3: Formulate Brazilian standards for hydrogen fuel cell buses for urban transport — The project team will develop standards for hydrogen fuel cell buses for Brazilian cities based upon the knowledge and experience gained during Phase II. This will also involve an

independent

Activity 5.4: Prepare proposal for Phase III Project—Taking into account the Phase II experience and the independent evaluation, the project team will prepare a proposal for a Phase III project. (GEF resources will not be devoted to this activity). Phase III is expected to involve the procurement and operation of an entire garage (100-200 buses) of fuel cell buses. This will also involve developing proposals for the organization of Phase III (such as selection of garage, number of vehicles, preferred routes, financing options, etc).

### **Output 6**

Activity 6.1: Hold workshops and seminars to publicize results of Phase II project— : The project team will participate in national and international meetings on hydrogen fuel cell technology and applications in order to make the results widely known among transport sector professionals.

Activity 6.2: Use information media to publicize result of Phase II project as well as plans for future projects-- In order for the entire program to be a success, the public must be supportive of the initiative. Through this activity, the project team will publicize the results of the project and inform the public of the advantages of fuel cell buses in order to gain widespread public support for the expansion of the program. This activity must result in enhanced public awareness and support in São Paulo, Brazil as a whole, and internationally.

## **3. IMPLEMENTATION ARRANGEMENTS**

The National Executing Agency is the Federal Ministry of Mines and Energy, which will also be responsible for disseminating the experience resulting from the project into the other States of Brazil. The overall coordinating agency is DNDE (Departamento Nacional de Desenvolvimento Energético - National Department of Energy Development).

The National Implementing Agency is the EMTU/SP by delegation from the above, because of its direct experience in handling new-technology bus projects and because the implementation of the project will be based in its facilities. Its main responsibilities are:

- a) To set the product specifications, negotiate the procurement of equipment and manage the project as a whole;
- b) To promote the new technology in the SPMR, elsewhere in Brazil and world-wide; and
- c) To make the results of Phase II available to the world operator and vendor community.

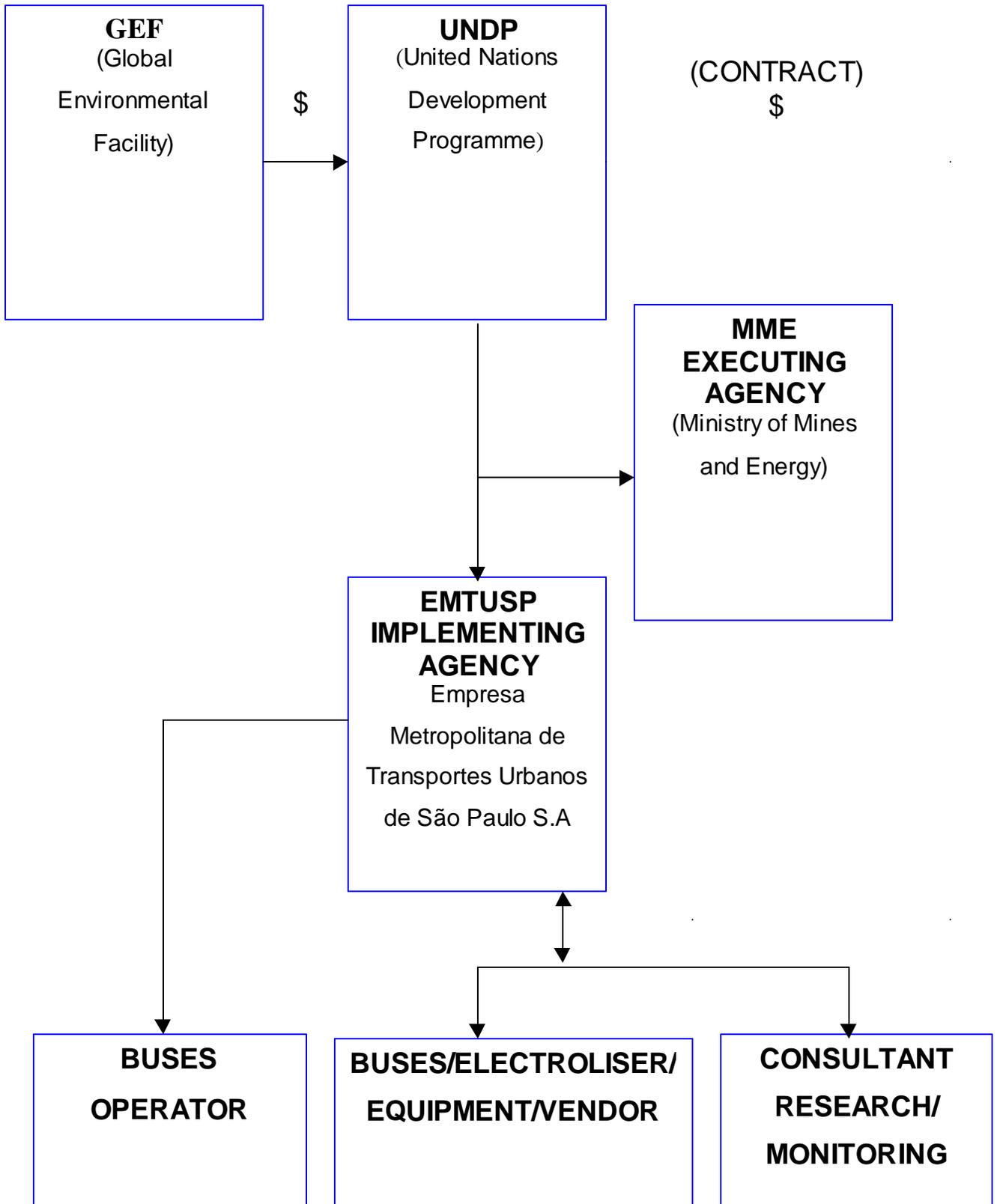
The UNDP ( United Nations Development Programme ) has as mains responsibilities:

- a- To be responsible for receiving and managing the GEF financial resources to the project;
- b- To publish the tender for buying equipment for the project; and
- c- To organize meetings with ABC/UAP for following-up the project development

In addition to the above agencies, USP (the University of São Paulo) will provide technical

backstopping, eventually, UNICAMP (University of Campinas), FATEC (São Paulo Faculty Technology) and COPPE (Coordination of post graduated engineers of Federal University of Rio de Janeiro) will provide technical support and IPT (Institute for Technological Research) will develop materials and equipment tests.

# ORGANOGRAM



## **4. INPUTS**

### **a. Executing Agency Inputs - MME**

The executing agency will place at the disposal of the project its own technical and administrative personnel for the execution of tasks provided for in this document at no cost to the project, except for travels undertaken by such personnel for services to the project.

The executing agency will provide adequate facilities for project consultants, technical personnel and technical team. Telephone services, fax, computer, postal service and other support services will be available for project execution.

### **b. Implementing Agency Inputs – EMTU/SP**

The implementing agency will place at the disposal of the project its own technical and administrative personnel for the execution of tasks provided for in this document at no cost to the project, except for travels undertaken by such personnel for services to the project.

The implementing agency will provide adequate facilities for project consultants, technical personnel and technical team. Telephone services, fax, computer, postal service and other support services will be available for project execution.

EMTU will also supply the following:

- garage for parking and maintenance of the buses:
- local in the garage for installation of the electrolyser:
- work hand to operate the buses (with training and supervision to be given by the vendor);
- work hand for the maintenance of the buses (with training and supervision to be given by the vendor);
- electric energy and water for production of the hydrogen;
- replacement pieces had gone of to warranty and that they have suffered natural waste during its use, such as, brake systems, tires, shocks absorber, etc (the replacement pieces of the system fuel cell are not included in this item);
- body repair works.

All the inputs of EMTU described above corresponds the contribution in-kind of US\$1.306 m, plus the contribution of US\$0.392 m in the form of future fares from fuel cell buses operation.

### **c. UNDP Inputs**

#### **i. Technical Support**

UNDP will, jointly with the project national executing agency, undertake program support activities, provide advice on planning and implementation as well as carry out technical, substantive, monitoring and evaluation missions in the course of project execution (utilizing resources allocated for that purpose under budget line 16.71). UNDP will collaborate in the identification and selection of project professional personnel, who, upon approval by the project coordination, will be hired by UNDP.

## **ii. Support to National Execution**

Upon request of the national executing agency, UNDP will place at its disposal mechanisms for the acquisition of goods and services for the benefit of the project, in accordance with the corresponding approved budget (and under the appropriate budget lines).

The provision of the said physical and human inputs shall be made according to procedures for national execution of technical cooperation projects, agreed upon by the Brazilian Government and UNDP, and may include:

- Recruitment and hiring of national and international consultants and experts, including administration of the corresponding contracts;
- Analysis of personnel terms of reference;
- Subcontracting of public and private sector services;
- Analysis of the technical specifications of equipment;
- Support in the conduct of competitive bidding procedures;
- Evaluation and adjudication of competitive bidding;
- Financial monitoring of projects.

The hiring of project professional personnel shall not exceed the duration of the project, and shall not, under any circumstances, constitute an employment link with the executing agency.

The rules and procedures for contracting of services, acquisition of non-disposable material and hiring of consultants as well as the regulations on project execution are described in a specific annex to this document. These rules, procedures and regulations comply with those contained in the UNDP National Project Execution Manual.

The above mentioned assistance not only for technical support but also for support to national execution may be requested by the National Project Director or proposed by the UNDP Resident Representative, as required within the scope of the project document agreed upon with the Government. The financial resources for such assistance are to be provided by the project and its implementation shall likewise follow UNDP financial rules and regulations and, in operational terms, national execution procedures.

## **d. Vendor Inputs**

The selected vendor(s) will contribute their technology, engineering and production know-how. This will include:

- a) Initial supply of hardware and software, including bearing the partial cost of the buses to be supplied;
- b) Continuous provision of technical and training support to the Brazilian operator during the course of the project;
- c) Willingness to respond to problems and suggestions for modifications and improvements, during and after Phase II; and
- d) Commitments to pursue major cost reductions and improvements in fuel cell stack durability.

In return, they will gain:

- a) Invaluable experience and a strong reference in the application of their technologies;
- b) Unique feedback into their product and process development;
- c) Accelerated product and process development, with reduced risk;
- d) A possible head-start in bidding for Phase III involvement; and

e) A reinforced positioning against other opportunities in Brazil and elsewhere.

#### **e. Incremental Costs And Financing Arrangements**

The incremental cost calculations are discussed in detail in Annex A of this project document. The incremental costs of the project are measured by assessing the costs that would be encountered by Brazilian authorities in operating a fleet of diesel-buses for one million vehicle-km over the four-year demonstration period. As detailed in Annex A Table I-1, the baseline costs come to approximately US\$1.368 million. The costs of the GEF project are estimated at approximately US \$21.180m. The total incremental costs are therefore estimated at approximately US\$19.812m. Two things should be noted about the magnitude of these incremental costs. First, as this technology is still under development, the fraction of total costs that are incremental in future GEF projects should decline as the number of fuel cell drive-trains increase. Industry estimates show that with as few as 5000 fuel cell bus engines produced, the cost of a fuel cell bus will be comparable to that of a modern, diesel bus on a life-cycle basis. Over this time-period, the cost of the fuel cell is expected to fall from being about 75% of the total value of the fuel cell bus to being about 20-25% of the value of the bus, roughly similar to the fraction of a diesel bus made up by the engine. Second, even though the incremental costs represent a high fraction of total costs, GEF is not being asked to meet the entire incremental costs of the project. In fact, a financing plan has been developed to share these incremental costs between the Brazilian authorities, UNDP GEF, and the private-sector suppliers of the technology.

The following principles have been applied in developing the financing plan for the project:

- 1) The incremental element corresponds to the costs of procuring, running and maintaining the planned fleet of hydrogen fuel cell buses, compared to that of providing the equivalent transportation capacity through diesel buses;
- 2) Finance is mobilized from Brazilian national partners for the operations, maintenance, training, data gathering and analysis, communications and project management aspects;
- 3) A participation from the private sector equipment vendors is planned as an investment in anticipation of the returns they will gain from participating in the project; and
- 4) The bulk of GEF' s financial contribution is aimed at the provision of the vehicles, as their current incremental cost over that of conventional diesel buses represents the greatest barrier to the dissemination of the new technology.

The estimation of incremental costs and the application of the above principles has resulted in the following breakdown of project costs:

- 1) The MME contribution will comprise US\$ 4.597 million in cash ;
- 2) EMTU/SP will contribute US\$1.306 m (in-kind) in the form of bus operation and maintenance;
- 3) EMTU/SP will contribute US\$0.392m (in cash) in the form of future fares from the fuel cell buses;
- 4) The private sector (vendor) , in this case, the technology providers, will provide US\$2.611m as a contribution, through the residual value of the vehicles at the end of the

- 4 years test (perhaps via a lease); and
- 5) GEF will provide US\$12.274m.

The details of the budget for the Phase II project are included as follows:

**Estimated Budget Allocation for the Phase II Project**  
(US\$m)

	GEF	MME	EMTU/SP		Private Sector	TOTALS
			in-kind	Cash		
<b>Subcontract<sup>a</sup></b>	12.274	1.870	0.0	0.0	2.611	16.755
<b>Equipment</b>	0.0	0.0	0.0	0.0	0.0	0.0
<b>Training<sup>b</sup></b>	0.0	0.0	0.323	0.0	0.0	0.323
<b>Travel<sup>c</sup></b>	0.0	0.191	0.097	0.0	0.0	0.288
<b>Other<sup>d</sup></b>	0.	2.536	0.886	0.392	0.0	3.814
<b>TOTALS</b>	12.274	4.597	1.306	0.392	2.611	21.180

**Notes:**

- (a) It is assumed that subcontracts will be used to procure the buses and the hydrogen production and refueling station.
- (b) Training costs are EMTU/SP operating and maintenance staff salaries and São Paulo workshop costs.
- (c) Travel costs are for international air travel and per-diem, as indicated in the detailed cost estimate.
- (d) This includes operating costs as shown in the detailed cost estimate, except for staff training costs. It also includes salaries related to information dissemination; monitoring and evaluation; and contingencies.

**5. RISKS AND SUSTAINABILITY**

As with any development project, this one is not risk-free. There are three main assumptions that present risks to project success. These risks, and the ways that they have been mitigated against in project design, are discussed below.

The first assumption is that a demonstration fleet of fuel cell buses can be procured through commercial avenues. In this case, the risk is that fuel cell buses are still too experimental to be commercially available. Verifying the seriousness of this risk has consumed a large portion of the preparatory activities undertaken with GEF support. Through this effort, the project team has, in fact, identified several vendors whom they feel would respond to a request for proposals. The cost estimates used in the preparation of this proposal are drawn from the figures of one of the leading firms in this sector. Given the substantial work that has gone into investigating the technologies and the suppliers, this risk is considered to be relatively insignificant.

The second assumption has to do with the capabilities of the vendor involved. The vendors may not be able to deliver on cost recovery or quality improvement in the production of this technology. In this case, the best safeguard is the strength and quality of project management. Assessment of vendor capabilities and long-term commitment during the selection process will be particularly important. It is likely that the fuel cell buses for Brazil will be co-developed by the vendor and EMTU. In this context, EMTU/SP has substantial experience in procuring and developing novel equipment, particularly in the context of its trolley-bus program. To safeguard against this risk, close assessment by the Brazilian project team and scrutiny by UNDP of all transactions will be necessary to ensure that this risk remains small. To this end, it is worth noting that the Brazilian automotive industry is well integrated into the international automotive industry. Brazilian bus operators have a strong record of effective cooperation with their supplier industries, and the international suppliers welcome the opportunity to work with Brazil on this innovative initiative.

The third assumption has to do with the probability of obtaining one million vehicle kilometers of experience with a demonstration fleet of 8 buses in a short enough period of time to provide relevant feedback to the design of the next generation of fuel-cell buses and stacks. As has been discussed, if bus availability does not increase as rapidly as foreseen or performance falls short, the experience may not provide adequate insight into the design of the next generation of buses. The design of the project has been changed, reducing the size of the demonstration fleet from 10 to 8 buses in the interests of cost-effectiveness. The trade-off is that this will increase the risk that one million vehicle kilometers will not be reached within the target time-frame. The project staff can only mitigate against this by continually monitoring bus performance. If it is found that the necessary experience will not be gained from the eight buses, some adjustments to the project will have to be made while the project is under implementation.

As has been indicated in this proposal, fuel cell buses will not become financially sustainable by the end of this Phase II demonstration period. Phase III, which will focus on fitting an entire garage of about 200 buses to operate on hydrogen fuel-cells, will be required to obtain even more widespread experience with operating fuel cell buses on a commercial level. After a large number of fuel cell drives have been produced and the buses begin to be assembled in Brazil, the cost of the fuel cell buses will fall to a level that makes their life-cycle operational costs competitive with those of modern diesel buses. This project will lead to a sustainable fuel cell bus program as the cost-reduction targets of the industry are met. For these targets to be met, there will be a requirement for future GEF support in Brazil and other program countries. The scope of the required support will depend upon the success of this and other GEF-sponsored fuel-cell bus projects, as well as the share of the developmental costs borne by OECD countries.

## **6. MONITORING AND EVALUATION PLAN**

The monitoring and evaluation plan for the project is based on the logframe and the workplan (annex A and B ), consistent with the project objectives and procurement specifications. A set of report is listed below:

1. Quarterly reports on achievement of hours and kilometers of operation by individual vehicles and the fleet;
2. Quarterly reports on the availability of vehicles and on fuel consumption;
3. Quarterly reports on MTBF (minimum time between failures) and FMA (failure mode

- analysis), for both vehicles and the fueling system;
4. Quarterly reports on proposed engineering modifications and the communication of these to vendors, plus confirmation of actions taken;
  5. Quarterly reports on operator and maintenance personnel training and achievement;
  6. Annual review of progress towards cost reduction, reliability improvement and increased durability;
  7. Annual records of communication activities: participation in international meetings, information dissemination within Brazil, and
  8. Final report with the independent evaluation of the project.

## 7. BUDGET

**United Nations Development Programme**  
BRA/99/G32 - Hydrogen Fuel Cell Buses for Urban Transport  
Budget " A "

Main Source of Funds: 1G - Global Environment Trust  
Fund  
Executing Agency: NEX - National Execution

Sbln	Description	Impleme Funding nting	Total	2000	2001	2002	2003	2004	2005
10 PROJECT PERSONNEL									
11 International Experts & Consultants									
1111	Intern. Experts & Consult. - GEF	NEX	Net Amount						
1121	Intern. Experts & Consult. - Other	NEX	Net Amount	150,000		10,000	35,000	35,000	35,000
			Total	150,000		10,000	35,000	35,000	35,000
1199	Line Total	-----	Net Amount	150,000		10,000	35,000	35,000	35,000
			Total	150,000		10,000	35,000	35,000	35,000
13 Admin. Support Personnel									
1311	Admin. Support Personnel - GEF	NEX	Net Amount						
1321	Admin. Support Personnel - Other	NEX	Net Amount						
1399	Line Total	-----	Net Amount						
15 Duty Travel									
1511	Duty Travel - GEF	NEX	Net Amount						
1521	Duty Travel - Other	NEX	Net Amount	191,000	16,000	41,000	41,000	41,000	40,000
			Total	191,000	16,000	41,000	41,000	41,000	40,000
1599	Line Total	-----	Net Amount	191,000	16,000	41,000	41,000	41,000	40,000
			Total	191,000	16,000	41,000	41,000	41,000	40,000
16 Mission Costs									
1671	Mission Costs	NEX	Net Amount	50,000		10,000	10,000	10,000	10,000
			Total	50,000		10,000	10,000	10,000	10,000
1699	Line Total	-----	Net Amount	50,000		10,000	10,000	10,000	10,000
			Total	50,000		10,000	10,000	10,000	10,000
17 National Professionals									
1711	National Professionals - GEF	NEX	Net Amount						
1721	National Professionals - Other	NEX	Net Amount	1,650,000	42,000	330,000	330,000	330,000	330,000
			Total	1,650,000	42,000	330,000	330,000	330,000	330,000
1799	Line Total	-----	Net Amount	1,650,000	42,000	330,000	330,000	330,000	330,000
			Total	1,650,000	42,000	330,000	330,000	330,000	330,000
19 PROJECT PERSONNEL TOTAL									
		-----	Net Amount	2,041,000	58,000	391,000	416,000	416,000	415,000
			Total	2,041,000	58,000	391,000	416,000	416,000	415,000
20 SUBCONTRACTS									
21 Subcontract A									
2111	Subcontracts - GEF	NEX	Net Amount						
2121	Subcontracts - Other	NEX	Net Amount	415,000		60,000	95,000	95,000	90,000
			Total	415,000		60,000	95,000	95,000	90,000
2199	Line Total	-----	Net Amount	415,000		60,000	95,000	95,000	90,000
			Total	415,000		60,000	95,000	95,000	90,000

		Total	415,000		60,000	95,000	95,000	90,000	75,000
29 SUBCONTRACTS TOTAL	-----	Net Amount	415,000		60,000	95,000	95,000	90,000	75,000
		Total	415,000		60,000	95,000	95,000	90,000	75,000
40 EQUIPMENT									
45 Local Procurement of Equipment									
4511 Expendable Equipment - GEF	NEX	Net Amount							
4512 Non-Expendable Equipment - GEF	NEX	Net Amount	12,274,000		6,532,000	5,742,000			
		Total	12,274,000		6,532,000	5,742,000			
4513 Operations - GEF	NEX	Net Amount	506,130	1,740	224,490	201,690	29,430	29,250	19,500
		Total	506,130	1,740	224,490	201,690	29,430	29,250	19,500
4521 Expendable Equipment - Other	NEX	Net Amount							
4522 Non-Expendable Equipment - Other	NEX	Net Amount	30,000		30,000				
		Total	30,000		30,000				
4599 Line Total	-----	Net Amount	12,810,130	1,740	6,786,490	5,943,690	29,430	29,250	19,500
		Total	12,810,130	1,740	6,786,490	5,943,690	29,430	29,250	19,500
49 EQUIPMENT TOTAL	-----	Net Amount	12,810,130	1,740	6,786,490	5,943,690	29,430	29,250	19,500
		Total	12,810,130	1,740	6,786,490	5,943,690	29,430	29,250	19,500
50 MISCELLANEOUS									
53 Sundries									
5311 Sundries - GEF	NEX	Net Amount							
5321 Sundries - Other	NEX	Net Amount	1,604,870		243,770	268,310	440,570	440,750	211,400
		Total	1,604,870		243,770	268,310	440,570	440,750	211,400
5399 Line Total	-----	Net Amount	1,604,870		243,770	268,310	440,570	440,750	211,400
		Total	1,604,870		243,770	268,310	440,570	440,750	211,400
59 MISCELLANEOUS TOTAL	-----	Net Amount	1,604,870		243,770	268,310	440,570	440,750	211,400
		Total	1,604,870		243,770	268,310	440,570	440,750	211,400
99 BUDGET TOTAL	-----	Net Amount	16,871,000	59,740	7,481,260	6,723,000	981,000	975,000	651,000
		Total	16,871,000	59,740	7,481,260	6,723,000	981,000	975,000	651,000

**United Nations Development Programme**  
**BRA/99/G32 - Hydrogen Fuel Cell Buses for Urban Transport**  
**Budget " A "**

**Main Source of Funds: 1G - Global Environment Trust Fund**

Executing Agency: NEX - National Execution

Sbln	Donor	Funding	Total	2000	2001	2002	2003	2004	2005	
101										
10101	NEX	NEX	Net Contrib.	4,597,000	58,000	951,000	981,000	981,000	975,000	651,000
			Total	4,597,000	58,000	951,000	981,000	981,000	975,000	651,000
10199			Net Contrib.	4,597,000	58,000	951,000	981,000	981,000	975,000	651,000
			Total	4,597,000	58,000	951,000	981,000	981,000	975,000	651,000
109	C/S Total	-----	Net Contrib.	4,597,000	58,000	951,000	981,000	981,000	975,000	651,000
			Total	4,597,000	58,000	951,000	981,000	981,000	975,000	651,000
999			Net Contrib.	12,274,000	1,740	6,530,260	5,742,000	0	0	
			Total	12,274,000	1,740	6,530,260	5,742,000	0	0	

United Nations Development Programme

C/S Schedule of Payments

Project BRA/99/G32/A/99 Hydrogen Fuel Cell Buses for  
 Urban Transport  
 Main Source of Funds GEF  
 AOS Source of Funds 1G  
 Executing Agency NEX - National  
 Execution  
 Budget Currency USD

Subline	Donor	Year	Date	Budgeted Amount	Scheduled Amount	Balance		
103.01	MIF	2000	15/10/2000	58,000.00	58,000.00	0.00		
							58,000.00	
		2001	15/05/2001			500,000.00	0.00	
			15/10/2001		951,000.00	451,000.00		
		2002	15/05/2002			500,000.00	0.00	
			15/10/2002		981,000.00	481,000.00		
		2003	15/04/2003			500,000.00	0.00	
			15/10/2003		981,000.00	481,000.00		
		2004	15/04/2004			500,000.00	0.00	
			15/10/2004		975,000.00	475,000.00		
		2005	15/04/2005			300,000.00	0.00	
			15/10/2005		651,000.00	351,000.00		
		Grand Total				4,597,000.00	4,597,000.00	0.00

**LIST OF ANNEXES**

<b>Annex A</b>	<b>Table I 2 Incremental Cost Matrix</b>
<b>Annex B.</b>	<b>Logical Frame work</b>
<b>Annex C.</b>	<b>Work Plan / Timetable</b>
<b>Annex D</b>	<b>Terms of Reference</b>

## Annex A

### Incremental Costs

#### Broad Development Goal

The broad development goal being pursued by the Government of Brazil and the EMTU/SP is the provision of public transport services to its urban inhabitants.

#### Baseline

Under the baseline situation, the EMTU/SP would provide urban bus transport services to its population through the continued reliance on diesel or CNG-powered buses and electric-powered trolley buses. The baseline to this project is the provision of urban bus service through diesel fueled buses. There are some 25,000 buses in service in the Sao Paulo Metropolitan area. Of this total, 17,500 operate on diesel fuel.

Diesel buses are one of the major contributors to the air pollution in the region. The average diesel bus is operated for about 78,000 km each year. For every kilometer travelled, a diesel bus in Sao Paulo is estimated to emit 18 g of CO; 13 g of NO<sub>x</sub>; 1.2 g of SO<sub>x</sub>; 2.9 g of HC's; and 0.8 g of particulates. As detailed in Table I-2, this will result in emissions of 17 tonnes of carbon monoxide; 12 tonnes of NO<sub>x</sub> emissions; 1.1 tonnes of SO<sub>x</sub> emissions; 2.7 tonnes of HC emissions; and 1560 tonnes of CO<sub>2</sub> emissions. In addition to these local pollutants, diesel buses emit approximately 1.1 kg of CO<sub>2</sub> for each km driven (or 300 grams C per km).

Brazil has embarked on an ambitious program of environmental regulation and is attempting to move to cleaner public transport. However, every option tried so far—including CNG—emits significant amounts of carbon. The Government and the Municipal authorities are interested in the fuel-cell bus technology as it potentially poses a win-win-win situation—good for the local environment; good for the global environment; and following further development of the technology, good for the economy.

#### Global environmental objectives

The global environmental objective is the reduction of greenhouse gas (GHG) emissions from the urban transport sector in Brazil. Over the immediate term of the project, this will involve the demonstration and testing of fuel cell buses fueled by electrolytic hydrogen. Over the longer term, assuming that this project and its successors perform as designed, this project will lead to an increased production in fuel cell propelled buses, and eventually, the reduction in their costs to the point where they will become commercially competitive with conventional, diesel buses.

This project has been prepared to be consistent with GEF Operational Program 11 “Promoting Sustainable Transport”. GEF project activities

The GEF project described in this proposal is Phase II of a four Phase process. The project is designed to develop and operate a demonstration fleet of eight fuel cell buses in São Paulo, Brazil. These buses will be procured in two batches (the first of three and the second of five buses). They will be designed to operate commercially under Brazilian conditions and will

provide the Brazilian EMTU/SP with detailed operating experience of 1,000,000 vehicle-km. This operating information will be used as feedback both to the bus suppliers and the EMTU/SP so that future fuel cell bus activities can successfully build upon the initial activities of this project.

With respect to the broader technological scope of the project, there are unique conditions in Sao Paulo to develop a complete set of specifications to define the bus, the fuel-cell system and the power-train for use in all mega-cities of the world.

In order for the long-term programmatic goal of this project to be achieved in the proposed four stages, not only must GEF support be sought for Phase III of the Brazilian initiative, but fuel cell buses must be produced for use in other contexts. According to industry projections, after a total of 5000 fuel cell buses have been produced, the costs should fall to where fuel cell buses will be roughly competitive on a lifecycle basis with modern, clean diesel buses.

### Global Environmental Benefits

The deployment of fuel-cell buses in Brazil will lead to significant reduction in carbon emissions from the transport sector. In Sao Paulo alone, this amounts to nearly 1.5 million tons of CO<sub>2</sub> annually (or 409 thousand tons of carbon). As the technology is further developed and deployed, these significant global benefits will continue to multiply as fuel-cell buses are deployed around the world.

The immense potential for reducing global carbon emission can be demonstrated in the following example. If all diesel buses in developing countries in operation in the year 2025 were replaced by fuel-cell buses operation from hydrogen produced from natural gas, the emission of nearly 440 million tons of CO<sub>2</sub> would be reduced per year (120 m tons of C). (Assuming that the number of buses per capita in Brazil today and the fuel economy and annual mileage of Brazilian buses are representative of the average in developing countries in 2025.) With this assumption, there would be 6.75 million buses in developing countries in 2025, diesel-bus emissions avoided would be 131 tCO<sub>2</sub> per bus-year (35.7 t C), and emissions associated with hydrogen fuel cell buses would be 66 tCO<sub>2</sub> or 18 t C per bus-year. If the hydrogen were drawn from renewable sources, as is the case in this project, the emission reductions would be even greater.

### Costs

The costs of the baseline course of action are measured by the costs of operating conventional diesel buses for one million vehicle-kilometers. These are estimated at US\$1.368m over the five-year project lifespan. The costs of the proposed project activities are estimated at US\$21.18m, of which US\$19.8m are considered incremental (see Table I-1). These incremental costs are shared between the GEF, Brazilian sources, and the private sector providers of the technology (see Section 6 in main body of this brief).

### System boundary

Although the boundary for this immediate project is the Brazilian urban transport sector, the project will support and draw upon resources from the global automotive industry. It should also provide important feedback for public transport agencies in other parts of the developing world.

One of UNDP GEF's roles is to ensure that the information gathered and experience gained can be shared across national and commercial boundaries. In that context, this project is important internationally for the experience to be gained and shared.

#### Additional benefits

The project will demonstrate significant additional local benefits in terms of reduced emission of pollutants dangerous to human health and habitat. In particular, the project will reduce the emission of  $\text{NO}_x$ ,  $\text{SO}_x$ , CO, HC and particulates, as detailed in the incremental cost matrix. As detailed in the text, there are also significant benefits to the global community, the automotive industry, and the technology providers.



TABLE I - 1

## BRAZIL - HYDROGEN FUEL CELL BUSES FOR URBAN TRANSPORT PROJECT (PHASE II) - BUDGET

(1000 US\$ - Nov. 1998) (See costs notes)

Estimation of Costs ,Incremental Costs and Financing	BASELINE	Project	Sources of Finance				Classification to Budget (UNDP)	
	COSTS	Costs	Brazilian Sources			Private	GEF	Description
		(TOTAL)	EMTU	Fares	MME			
			In-kind					
<b>Investment</b>								
Vehicles (amortization)(a)	275	13.285				2.611	10.674	Non-Expendable Equipment
Electrolyzers(b)		1.300					1.300	Non-Expendable Equipment
H2 storage ( c )		300					300	Non-Expendable Equipment
Garage modifications(d)		40			40			Subcontracts
Additional power equip.(e)		30			30			on-Expendable Equipmen
Monitoring, etc(f)								
Data collection		600			600			National Technical Personnel
Analysis		630			630			National Technical Personnel
Report preparation		420			420			National Technical Personnel
Independent project review		150			150			International Experts & Consultant
<b>SUBTOTAL</b>	<b>275</b>	<b>16.755</b>	<b>-</b>	<b>-</b>	<b>1.870</b>	<b>2.611</b>	<b>12.274</b>	
<b>Operating costs</b>								
Diesel fuel	141							
Electric power(g)		233		233				Expendable Equipment
Electrolyzer maint.(h)		40		40				Operation and Maintenance of the Equipment
Vehicle maint.(parts)(i)	67	119		119				Operation an Maintenance of the Equipment
Operating personal(j)	776	776	776					National Technical Personnel
Administration(k)	66	66	66					National Project Assistant
Staff training(salaries)(l)		323	323					National Technical Personnel
Facilities amortization(m)	44	44	44					Operation and Maintenance of the Equipment
<b>SUBTOTAL</b>	<b>1093</b>	<b>1.601</b>	<b>1.209</b>	<b>392</b>	<b>-</b>	<b>-</b>	<b>-</b>	
<b>Info.Dissem. &amp; exchange</b>								
National seminars(n)								
Salaries		55	55					National Technical Personnel
Registration fees		23			23			Travel
International seminars(o)								
Salaries		23	23					National Technical Personnel
Travel & expenses		108			108			Travel
Other international travel(p)								
Salaries		19	19					National Technical Personnel
Travel & expenses		60			60			Travel
Workshops São Paulo(q)		75			75			Subcontracts
Advertisement ( r )		300			300			Subcontracts
<b>SUBTOTAL</b>		<b>663</b>	<b>97</b>		<b>566</b>	<b>-</b>	<b>-</b>	
<b>SUBTOTAL</b>	<b>1368</b>	<b>19.019</b>	<b>1.306</b>	<b>392</b>	<b>2.436</b>	<b>2.611</b>	<b>12.274</b>	
Contingency (s)		2.161			2.161			Sundries
<b>TOTAL</b>	<b>1368</b>	<b>21.180</b>	<b>1.306</b>	<b>392</b>	<b>4.597</b>	<b>2.611</b>	<b>12.274</b>	
		<b>100%</b>	<b>6%</b>	<b>2%</b>	<b>22%</b>	<b>11%</b>	<b>58%</b>	

## Notes on Project Costs

- (a) Purchase of 3 buses at 1.97 million and 5 buses \$1.475 million, based on communication with Ballard Automotive. Costs are assumed to include all supplier costs, including training, warranties and procurement. Under the baseline, \$275,000 refers to the amortization (capital cost (-) salvage value) of Padron diesel buses attributable to 1 m km of use.
- (b) Estimated installed cost for a 1.5 MW electrolyzer, based on communication with Stuart Energy Systems.
- (c) Installed cost for on-site gaseous hydrogen storage for one day's H<sub>2</sub> supply for 8 buses, based on communication with Stuart Energy Systems.
- (d) Based on Vancouver demonstration project experience, as communicated by Stuart Energy Systems.
- (e) Cost of equipment required to handle additional 1.5 MW power supply to the existing garage.
- (f) Assuming \$50K per month for project monitoring: data collection, analysis, report preparation, etc. This will enable supplier-collected data and analysis to be checked and assimilated by EMTU/SP. Within this budgetary allocation, provision will be made for an independent project review.
- (g) Average electricity price of \$0.0373/kWh, which includes energy and demand charges based on early -1999 tariff schedule of Eletropaulo (13.8 kV, off-peak), the utility that serves the proposed host garage.
- (h) Based on communication from Stuart Energy Systems indicating cost of \$2.5 per bus filling (29 kg H<sub>2</sub>).
- (i) Based on EMTU/SP experience with trolley buses and information provided by Ballard Automotive.
- (j) Based on EMTU/SP system-wide average cost per bus-km for operating and maintenance personnel for 1 million bus-km of operation.
- (k) Based on EMTU/SP system-wide average administrative costs per bus-km for 1 million bus-km of operation.
- (l) Training relating to fuel cell bus operation and maintenance. Assuming 1 week training for all 430 drivers operating out of the proposed host garage, 2 weeks training for all 126 mechanics, and 2 months training of all 12 specialized electronic technicians.
- (m) Average depreciation and cost of capital for a typical EMTU/SP garage.
- (n) Participation in three seminars per year in Brazil (each 3 days long) for 3 years. Attendance by 10 persons = 270 person-days, or 9 person-months, at salary of \$3000/mo = \$27,000. Seminar registration of \$750/person = 30x750 = \$22,500. Preparation of 2 papers per seminar @ 150 hrs/paper = 900 hours total = 5.6 months at salaries of \$5000/month = \$28,000.
- (o) Participation in three seminars per year for 3 years, each attended by 2 persons. One week time commitment, with salary = \$5000/mo:  $3 \times 3 \times 2 \times 5000 / 4 = \$22500$ . Air tickets plus per-diem = \$4000/person-trip. Total travel expenses = \$72000. Seminar registration @ \$2000/person per seminar = \$36,000.

- (p) Assumes 5 person-trips (1 week each) per year for 3 years @ \$4000/p-trip for expenses. Salary is \$1250/person-week.
- (q) Workshops organized and held at EMTU/SP to share project information with national and international organizations and individuals. One workshop per year for 3 years.
- (r) Estimated to be 1.3% of total project cost.
- (s) Assumed to be 10% of total project cost. This accounts for exchange rate changes, among other uncertainties.

**Table I-2 Incremental Cost Matrix**

	Baseline	GEF Project	Increment
National impact	<ul style="list-style-type: none"> <li>Public transit in Sao Paulo continues its heavy reliance on diesel buses.</li> <li>Diesel fuel consumption continues.</li> <li>Emissions from Diesel Buses: CO emissions = 18 g/km NO<sub>x</sub> emissions = 13 g/km SO<sub>x</sub> emissions = 1.2 g/km HC emissions = 2.9 g/km Particulates = 0.8 g/km</li> </ul>	<ul style="list-style-type: none"> <li>Commercial development of FCB's accelerated through GEF support.</li> <li>Brazilian assimilation of FCB technology accelerated.</li> <li>Zero CO, HC, NO<sub>x</sub>, SO<sub>2</sub> and particulate emissions per vehicle-km.</li> <li>Reduced wasted heat emission</li> </ul>	<ul style="list-style-type: none"> <li>Commercial development of FCB's accelerated through GEF support.</li> <li>Brazilian assimilation of FCB technology accelerated.</li> <li>Diesel fuel use reduced.</li> <li>Avoidance of CO, HC, NO<sub>x</sub>, SO<sub>x</sub>, and Particulate emissions from diesel bus traffic.</li> </ul>
Global impact	<ul style="list-style-type: none"> <li>Diesel Bus Emission: CO<sub>2</sub> emissions = 1,100 g/km or 300 g C/km.</li> </ul>	<ul style="list-style-type: none"> <li>Zero CO<sub>2</sub> or Carbon emissions.</li> <li>Fuel cell bus cost reduction and commercialization accelerated.</li> <li>"Southernization" of fuel cell bus technology accelerated.</li> </ul>	<ul style="list-style-type: none"> <li>Significant quantities of CO<sub>2</sub> or Carbon emissions avoided.</li> <li>Fuel cell bus cost reduction and commercialization accelerated.</li> <li>"Southernization" of fuel cell bus technology accelerated.</li> </ul>
Cost	<ul style="list-style-type: none"> <li>EMTU/SP in-kind = \$1.305 million</li> <li>EMTU/SP cash = \$0.063 million</li> </ul> <p><b>Total = \$1.368 million</b></p>	<ul style="list-style-type: none"> <li>EMTU/SP in-kind = \$1.306 million</li> <li>EMTU/SP cash = \$1.000 million</li> <li>Brazilian local = \$5.000 million</li> <li>Private sector = \$1.600 million</li> <li>GEF = \$12.274 million</li> </ul> <p><b>Total = \$21.180 million</b></p>	<ul style="list-style-type: none"> <li>EMTU/SP in-kind = 0</li> <li>EMTU/SP cash = \$0.937 million</li> <li>Brazilian local = \$5.000 million</li> <li>Private sector = \$1.600 million</li> <li>GEF = \$14.474 million</li> </ul> <p><b>Total = \$19.812 million</b></p>



## Annex B

**Table 2.1 The logical frame work (logframe) matrix**

	(1) Program or project summary	(2) Indicators	(3) Means of verification	(4) External factors (assumptions and risks)
Development Objective	To reduce GHG emissions via the introduction of a new energy source and propulsion technology for urban buses	CO <sub>2</sub> emissions from São Paulo buses decreased by 1560 tones over the project' s life-time		
Immediate objective	To demonstrate the operational viability of fuel cell drives in urban buses and their refueling infrastructure under Brazilian conditions	Eight buses are operated for one million vehicle-km so that operational statistics can be gathered	Final project report	
Output 1  Activities	<p>Significant demonstration of the operational viability of fuel cell drives in urban buses and their refueling infrastructure under Brazilian conditions</p> <p>1.1 Specify technical performance targets</p> <p>1.2 Tender and select vendor for bus provision</p> <p>1.3 Install, operate and maintain refueling infrastructure</p> <p>1.4 Place initial set of 3 buses in operation</p> <p>1.5 Place second set of 5 buses in operation</p>	<p>Buses operate according to pre-specified levels (hrs or km per year) –</p> <p>Refueling station operates satisfactorily to supply sufficient H<sub>2</sub> at reasonable cost</p> <p>Breakdowns are limited in frequency to acceptable levels (&lt; 50,000 km between breakdown)</p>	<p>Annual and final project reports</p> <p>Vehicle log books and records</p>	<p>Assumption: Fuel-cell buses can be produced from commercial vendors at satisfactory cost</p> <p>Risk of vendor failure</p>
Output 2  Activities	<p>Cadre of bus operators and staff trained in the operation, maintenance, and management of fuel cell buses</p> <p>2.1 Hold on-the-job training seminars for drivers and</p>	<p>Number of operators/maintenance staff trained</p> <p>Enrollment in training seminars</p>	Quarterly and annual project reports	



<p>Output 5</p> <p>Activities</p>	<p>Proposal for Phase III of the Brazilian Fuel-cell Bus program</p> <p>5.1 Develop initial Brazilian bus design for hydrogen-powered fuel cell buses in Brazil</p> <p>5.2 Provide feedback to vendors to improve future bus designs</p> <p>5.3 Formulate Brazilian standards for hydrogen fuel cell buses for urban transport</p> <p>5.4 Prepare proposal for Phase III Project</p>	<p>Satisfactory preparation of Phase II proposal based upon Phase II experience, reconfigured bus designs, Brazilian standards and continued dialogue with vendors</p>	<p>Quarterly, annual and final project reports</p>	
<p>Output 6</p> <p>Activities</p>	<p>Increased awareness and support of the public for an increased role for fuel cell buses in Brazil's urban transport system</p> <p>6.1 Hold workshops &amp; seminars to publicize results</p> <p>6.1 Use media to publicize results of project and future plans</p>	<p>Number of local, national and international workshops / seminars held and attended</p> <p>Number of professional publications produced</p> <p>Number of reports in media</p>	<p>Project reports</p> <p>Project files</p> <p>Publications produced</p>	
<p>Inputs</p>	<p>4-year, 8-bus test.</p> <p>Based in a single bus garage in São Paulo</p> <p>Electrolytically-generated hydrogen fuel, based on renewable hydraulic energy resource</p> <p>Cost: Approximately US\$21m</p>			

**Annex C**

**Brazil : Hydrogen Fuel Cell Buses for Urban Transport**

**National Executing Agency: MME  
National Implementing Agency: EMTU/SP**

**Work Plan**

<p><b>Phase II (this project) objectives</b></p>	<p>To demonstrate the operational viability of the use of fuel cell buses and their refueling infrastructure under Brazilian conditions, by running 8 of them in special conditions, in Phase II, starting in 2001, for 4 years. To begin the process of commercialization and adaptation of fuel cell buses in Brazilian markets.</p>
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## Brazil : Hydrogen Fuel Cell Buses for Urban Transport

**National Executing Agency: MME**  
**National Implementing Agency: EMTU/SP**

### Work Plan Development Objectives

<b>1. Main development objectives</b>	
Short-term objectives	<p>To demonstrate the operational viability of the use of fuel cell buses and their refueling infrastructure under Brazilian conditions, by running 8 of them in special conditions, in Phase II, starting in 2001, for 4 years.</p> <p>To begin the process of commercialization and adaptation of fuel cell buses in Brazilian markets.</p>
Medium-term objectives	<p>A fleet of 200 of them, in Phase III, starting in 2005, for 5 years, converting a complete bus garage to operating fuel cell electric buses.</p> <p>Series production of the buses on a commercial basis, in Phase IV, starting in 2010, involving wider deployment in São Paulo Metropolitan Region and other Brazilian metropolitan areas.</p>
Long-term objectives	<p>To reduce global warming by lowering CO<sub>2</sub> emissions and by reducing emission of pollutants dangerous to human health and habitat, which otherwise would be produced by conventional diesel oil buses that burn fossil fuel. In particular, to reduce the emission of NO<sub>x</sub> , SO<sub>x</sub> , CO, HC and particulates.</p> <p>To increase production in fuel cell propelled buses, and eventually, the reduction in their costs to the point where they will become commercially competitive with conventional, diesel buses.</p>
<b>2. Social and environmental objectives</b>	<p>To serve as the basis for developing a broad action plan to substitute zero emission buses that use advanced technology - the fuel cells - , for diesel oil buses in Brazil. To provide a powerful incentive for mass transport systems more modern than the conventional ones, as an answer to the perception of the threat of global warming that results, to a great extent, from consumption of fossil fuels.</p>
<b>3. Technology development objectives</b>	<p>To represent a powerful push for the use of fuel cell technology and fuel supply technology in the automotive industry and its utilization in mass transportation. To create a substantive increase in competitiveness, within the automotive industry and transit authority.</p>

## Brazil : Hydrogen Fuel Cell Buses for Urban Transport

**National Executing Agency: MME**  
**National Implementing Agency: EMTU/SP**

### Work Plan

Output I: Significant demonstration of the operational viability of fuel cell drives in urban buses and their refueling infrastructure under Brazilian conditions

N°	Activity/Sub-Activity	Description	Input
I.1.	Specification of technical performance targets. I.1.1. Specification of characteristics of the buses. I.1.2. Specification of technical performance targets. I.1.3 Specification of characteristics of the fuelling system.		
I.2.	Issue call for tenders and select vendor to supply the buses and the fuelling system – Requirements for a single vendor to contract for the whole system - buses and the fuelling system. I.2.1. Encouragement of tenders from different combinations of fuel cell engines and bus chassis/body manufacturers. I.2.2. Preparation of tender call and its presentation to UNDP. I.2.3.Publication of tender call in international journal. I.2.4. Follow-up of Procurement Process. I.2.5. Judgement of proposals and selection of the vendor. I.2.6. Contract to supply buses and fuelling system.	Arrangements for appropriate sub-contracts.	Project Implementation Team (PIT) * and UNDP

\* PIT is a technical team that will be defined by the EMTU/SP.

## Brazil : Hydrogen Fuel Cell Buses for Urban Transport

National Executing Agency: MME  
National Implementing Agency: EMTU/SP

### Work Plan

Output I: Significant demonstration of the operational viability of fuel cell drives in urban buses and their refueling infrastructure under Brazilian conditions

N°	Activity/Sub-Activity	Description	Input
I.3.	Install the refueling infrastructure.	As part of the main contract, the primary contractor will oversee the assigned area, installations, power and water supply necessary for the installation of the electrolytic hydrogen production and refueling system.	Vendor and sub-contractor/ PIT
I.4.	Operate and maintain the refueling infrastructure.	As part of the main contract, the primary contractor will oversee the operation and maintenance of the hydrogen production and refueling system.	Vendor and sub-contractor/ PIT
I.5.	Implement operation of initial set of 3 buses.	Initial batch of 3 buses placed in service for 4 years, operating in revenue service under realistic operating conditions.	Vendor/PIT
I.6.	Implement operation of second set of 5 buses.	Second batch of 5 buses placed in service for 3 years, under similar conditions.	Vendor/PIT

## Brazil : Hydrogen Fuel Cell Buses for Urban Transport

National Executing Agency: MME  
National Implementing Agency: EMTU/SP

### Work Plan

Output II: Cadre of bus operators and staff trained in the operation, maintenance, and management of fuel cell buses

N°	Activity/Sub-Activity	Description	Input
II.1.	Hold on-the-job training seminars for drivers and maintenance staff. II.1.1. Training of operating and maintenance personnel for Phase II development. II.1.2. Training of operating and maintenance personnel for Phase III.		Vendor/PIT

## Brazil : Hydrogen Fuel Cell Buses for Urban Transport

**National Executing Agency: MME**  
**National Implementing Agency: EMTU/SP**

### Work Plan

Output III: Accumulation of a substantial body of knowledge about reliability, failure modes and opportunities for improving the design of fuel cell buses for Brazil

Nº	Activity/Sub-Activity	Description	Input
III.1.	Formulate guidelines for quarterly reporting on in-service performance of the buses and reliability of the buses and electrolyzer.	Protocol for issuing quarterly reports on the technical operations of the bus fleet (e.g., in – service reliability, failure modes, energy consumption, etc.) and electrolyzer.	TORs 1, 2, 3 and vendor
III.2.	<p>Follow-up of hydrogen bus operation.</p> <p>III.2.1. Systematic logging, analysis and interpretation of operating parameters – special attention to reliability, failure modes and potential improvements and operation design and operation of the buses, considering project files and history.</p> <p>III.2.2. Opportunities identified for potential improvements and cost reductions.</p> <p>III.2.3. Evaluation of safety aspects.</p> <p>III.2.4. Establishment of operating standards.</p>		TORs 4, 5 and 6
III.3.	<p>Exchange experiences with Chicago, Vancouver, and other users of fuel cell buses.</p> <p>III.3.1. Exchange experience with Chicago Transit Authority, in Chicago, and British Columbia Transit, in Vancouver.</p> <p>III.3.2. In these exchange experiences, special emphasis given to interactions with other GEF fuel cell bus projects and other non-GEF FCB projects.</p>		<p>Travel and DSI for EMTU participant/PIT</p> <p>Travel and DSI for EMTU Participant/ PIT</p>

**Brazil : Hydrogen Fuel Cell Buses for Urban Transport**

**National Executing Agency: MME  
National Implementing Agency: EMTU/SP**

**Work Plan**

**Output IV: Assessment of the performance of the electrolysis unit**

<b>N°</b>	<b>Activity/Sub-Activity</b>	<b>Description</b>	<b>Input</b>
IV.1.	Follow-up of electrolytic hydrogen production. IV.1.1. Systematic logging, analysis and interpretation of operating parameters. IV.1.2. Opportunities identified for potential improvements of performance and cost reductions. IV.1.3. Evaluation of safety aspects. IV.1.4. Establishment of operating standards for the electrolysis unit.	Special attention to collect, analyze and evaluate the operating data mostly on reliability and failure.	TOR 5

## Brazil : Hydrogen Fuel Cell Buses for Urban Transport

National Executing Agency: MME  
National Implementing Agency: EMTU/SP

### Work Plan

#### Output V: Proposal for Phase III of the Brazilian Fuel-cell Bus program

N°	Activity/Sub-Activity	Description	Input
V.1.	Develop initial Brazilian bus design for hydrogen-powered fuel cell buses in Brazil. V.1.1. Initial bus design, operation, and maintenance guidelines, and specifications. V.1.2. Strengthening of Brazilian capacity to manage the integration of new transport technologies.		Vendor dialogues, TOR 6
V.2.	Provide feedback to the vendors to improve future bus and electrolyzer designs.	Feeding back the data collected to the vendor(s) in order to demonstrate the need for modifications to hardware and control software.	Vendor dialogues, TOR 6
V.3.	Formulate Brazilian standards for hydrogen fuel cell buses for urban transport. V.3.1. Development of standards for hydrogen fuel cell buses for Brazilian cities, based upon the knowledge and experience gained during Phase II. V.3.2. Development of standards for hydrogen purity and production for fuel cell applications.		Vendor dialogues, TOR 6

## Brazil : Hydrogen Fuel Cell Buses for Urban Transport

National Executing Agency: MME  
National Implementing Agency: EMTU/SP

### Work Plan

#### Output V: Proposal for Phase III of the Brazilian Fuel-cell Bus program

N°	Activity/Sub-Activity	Description	Input
	V.3.3. Independent evaluation of the Phase II project.		
V.4.	Prepare proposal for Phase III Project. V.4.1. Involvement of the procurement and operation of an entire garage (100 - 200 buses) of fuel cell buses. V.4.2. Development of proposals for the organization of Phase III, such as selection of garage, number of vehicles, preferred routes, financing options, etc.		Quarterly, annual and final project reports

## Brazil : Hydrogen Fuel Cell Buses for Urban Transport

National Executing Agency: MME  
National Implementing Agency: EMTU/SP

### Work Plan

Output VI: : Increased awareness and support of the public for an increased role for fuel cell buses in Brazil' s urban transport system

N°	Activity/Sub-Activity	Description	Input
VI.1.	<p>Hold workshops and seminars to publicise results of Phase II project.</p> <p>VI.1.1. Participation of the project team in national and international meetings on hydrogen fuel cell technology and applications in order to make the results widely known among transport sector professionals.</p> <p>VI.1.2. Workshop I organization for dissemination of results of Phase II project.</p> <p>VI.1.3. Workshop II organization for dissemination of results of Phase II project.</p> <p>VI.1.4. Workshop III organization for dissemination of results of Phase II project.</p> <p>VI.1.5. Workshop IV organization for dissemination of results of Phase II project.</p>		Marketing Agency, TOR 7

## Brazil : Hydrogen Fuel Cell Buses for Urban Transport

National Executing Agency: MME

National Implementing Agency: EMTU/SP

### Work Plan

Output VI: : Increased awareness and support of the public for an increased role for fuel cell buses in Brazil' s urban transport system

N°	Activity/Sub-Activity	Description	Input
VI.2.	Use information media to publicize results of Phase II project as well as plans for future projects.	Use media to publicize the results of Phase II project and future plans. Inform the public of the advantages of fuel cell buses. Gain widespread public support in São Paulo, Brazil as a whole, and internationally, for the expansion of the program.	PIT and Marketing Agency



## **Annex D**

### **TOR 1 Terms of Reference**

Project Number and Title - **Brazil : Hydrogen Fuel Cell Buses for Urban Transport**

**Post Title :** Consultant on guidelines for quarterly reporting on in-service performance of the buses.

**Starting date :**

**Duration:**

**Honoraria/fees:**

**Consultancy covers:** Output III, Activity III.1

**Budget line:** 011.21

**Place of work :**

#### **A. Project background:**

This Project will show practical applications of fuel cells for generating energy in electrical buses, utilizing hydrogen. This is an advanced technology that through an electrochemical process generates energy with high efficiency without pollutants. Phase II of this Project will have a decisive role because it will purchase, implant and operate 8 buses in the São Paulo Metropolitan Area. Moreover, an assessment of this technology will be made and research will be developed for defining Brazilian hydrogen fuel cell buses specifications, taking into account the technological experience gained in this country related to trolleybus building (engines, chassis, accessory systems, electronic controls, etc.) and joining this to the international technology for making fuel cells.

The role of EMTU/SP (Empresa Metropolitana de Transportes Urbanos de São Paulo S.A.) and MME (Ministry of Mines and Energy) in this Project is the one of maintaining Brazil's competitiveness in the mass transit sector, in the most promising technological context in the near future, using the knowledge they have now as a counterpart for an important international association, using Brazilian technical specifications. The main objective is to have a better energy efficiency and the reduction of air pollution, now very critical in mass transit operations, that will be significant in the development of the project.

GEF is interested in the Brazilian technological counterpart and the bus market in this country, aiming at cost-reductions in the utilization of this technology worldwide, making it available as well to other developing countries over the long run.

The fuel cell bus Project has also the important role of paving the way to other research projects in the area of special materials, hydrogen management and storage, electrodes and further developments that will be useful in universities and research institutes.

**B. Project objectives:**

To demonstrate the operational viability of the use of fuel cell buses and their refueling infrastructure under Brazilian conditions.

**C. Objectives of consultancy:**

**Guidelines defined for quarterly reporting on in-service performance of the buses. Analysis and approval of the bus project and electrolyser. Analysis and approval of the procedures of tests that will be used in the phases of building, acceptance and operation, aiming at testing the quality of the buses, as well as the collection of necessary data for the study of their performance, and eventual modifications for better performance.**

**D. Activities described:**

Protocol made for issuing quarterly reports on the technical operations of the bus fleet and electrolyser. Reports will be as follows:

- 1) Report 1, containing:
  - a) check of the buses and electrolyser delivered to the project according to specifications of the procurement process;
  - b) possible improvements in them, aiming at better in-service performance conditions.
- 2) Report 2, containing:
  - a) achievement of hours and kilometers of operation by individual vehicles and the fleet;
  - b) in-service reliability;
  - c) fuel consumption;
  - d) electrical energy consumption; and
  - e) identification of main parameters that should be monitored during the buses operation for the performance evaluation (e.g. temperature, pressure, speed, acceleration, etc.).
- 3) Report 3, containing:
  - a) failure modes analysis (FMA), for both the vehicle and the fuelling system; and
  - b) mean time between failures (MTBF).
- 4) Report 4, containing:
  - a) potential improvements in design, engineering, and operation of the buses and feedback of these improvements to the vendor(s); and
  - b) operator and maintenance personnel training and achievement.

**E. Expected results of consultancy or output:**

Document according to specifications in item Objectives of Consultancy above.

**F. Professional qualifications:**

10 years experience and published papers on automotive industry and market entry of new technology such as fuel cells. Experience in follow-up of tests. Bachelor in Engineering or

Chemistry.

**G. Input:**

PHF

**H. Special considerations:**

The guidelines specified in objectives of Consultancy above will be complemented by the assessments and considerations made by the Brazilian Project Implementation Team and by the two Brazilian consultants on Guidelines.

**I. Contact at Project level:**

Marcio Rodrigues Alves Schettino

Manager of the Hydrogen Project

EMTU/SP (Empresa Metropolitana de Transportes Urbanos de São Paulo S.A.)

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São Bernardo do Campo – SP

Telefax: 759-6727 / 759-1110

## **TOR 2**

### **Terms of Reference**

Project Number and Title - Brazil : Hydrogen Fuel Cell Buses for Urban Transport

**Post Title:** Consultant on guidelines for quarterly reporting on in-service performance of the buses.

**Starting date :**

**Duration:**

**Honoraria/fees:**

**Consultancy covers:** Output III, Activity III.1

**Budget line:** 017.21

**Place of work:** São Paulo and São Bernardo do Campo.

#### **A. Project background:**

#### **B. Project objectives:**

To demonstrate the operational viability of the use of fuel cell buses and their refueling infrastructure under Brazilian conditions.

#### **C. Objectives of consultancy:**

**Guidelines defined for quarterly reporting on in-service performance of the buses. Analysis and approval of the bus project and electrolyser. Analysis and approval of the procedures of tests that will be used in the phases of building, acceptance and operation, aiming at testing the quality of the buses, as well as the collection of necessary data for the study of their performance, and eventual modifications for better performance.**

#### **D. Activities described:**

Protocol made for issuing quarterly reports on the technical operations of the bus fleet and electrolyser. Reports will be as follows:

- 1) Report 1, containing:
  - a) check of the buses and electrolyser delivered to the project according to specifications of the procurement process;
  - b) possible improvements in them, aiming at better in-service performance conditions.
  
- 2) Report 2, containing:
  - a) achievement of hours and kilometers of operation by individual vehicles and the fleet;
  - b) in-service reliability;

- c) fuel consumption;
  - d) electrical energy consumption; and
  - e) identification of main parameters that should be monitored during the buses operation for the performance evaluation (e.g. temperature, pressure, speed, acceleration, etc.).
- 3) Report 3, containing:
- a) failure modes analysis (FMA), for both the vehicle and the fuelling system; and
  - b) mean time between failures (MTBF).
- 4) Report 4, containing:
- a) potential improvements in design, engineering, and operation of the buses and feedback of these improvements to the vendor(s); and
  - b) operator and maintenance personnel training and achievement.

**E. Expected results of consultancy or output:**

Document according to specifications in item Objectives of Consultancy above.

**F. Professional qualifications:**

10 years experience and published papers on automotive industry and market entry of new technology such as fuel cells. Experience in follow-up of tests. Bachelor in Engineering or Chemistry.

**G. Input:**

PHF

**H. Special considerations:**

The guidelines specified in objectives of Consultancy above will be complemented by the assessments and considerations made by the Brazilian Project Implementation Team and by the international consultant on Guidelines.

**I. Contact at Project level:**

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### **TOR 3**

#### **Terms of Reference**

Project Number and Title - Brazil : Hydrogen Fuel Cell Buses for Urban Transport

**Post Title:** Consultant on guidelines for quarterly reporting on in-service performance of the buses.

**Starting date :**

**Duration:**

**Honoraria/fees:**

**Consultancy covers:** Output III, Activity III.1

**Budget line:** 017.21

**Place of work:** São Paulo and São Bernardo do Campo.

#### **A. Project background:**

#### **B. Project objectives:**

To demonstrate the operational viability of the use of fuel cell buses and their refueling infrastructure under Brazilian conditions.

#### **C. Objectives of consultancy:**

**Guidelines defined for quarterly reporting on in-service performance of the buses. Analysis and approval of the bus project and electrolyser. Analysis and approval of the procedures of tests that will be used in the phases of building, acceptance and operation, aiming at testing the quality of the buses, as well as the collection of necessary data for the study of their performance, and eventual modifications for better performance.**

#### **D. Activities described:**

Protocol made for issuing quarterly reports on the technical operations of the bus fleet and electrolyser. Reports will be as follows:

- 1) Report 1, containing:
  - a) check of the buses and electrolyser delivered to the project according to specifications of the procurement process;
  - b) possible improvements in them, aiming at better in-service performance conditions.
  
- 2) Report 2, containing:
  - a) achievement of hours and kilometers of operation by individual vehicles and the fleet;
  - b) in-service reliability;
  - c) fuel consumption;

- d) electrical energy consumption; and
- e) identification of main parameters that should be monitored during the buses operation for the performance evaluation (e.g. temperature, pressure, speed, acceleration, etc.).

3) Report 3, containing:

- a) failure modes analysis (FMA), for both the vehicle and the fuelling system; and
- b) mean time between failures (MTBF).

4) Report 4, containing:

- a) potential improvements in design, engineering, and operation of the buses and feedback of these improvements to the vendor(s); and
- b) operator and maintenance personnel training and achievement.

**E. Expected results of consultancy or output:**

Document according to specifications in item Objectives of Consultancy above.

**F. Professional qualifications:**

10 years experience and published papers on automotive industry and market entry of new technology such as fuel cells. Experience in follow-up of tests. Bachelor in Engineering or Chemistry.

**G. Input:**

PHF

**H. Special considerations:**

The guidelines specified in objectives of Consultancy above will be complemented by the assessments and considerations made by the Brazilian Project Implementation Team by the international consultant on Guidelines.

**I. Contact at Project level:**

Marcio Rodrigues Alves Schettino

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**TOR 4**  
**Terms of Reference**

Project Number and Title - Brazil : Hydrogen Fuel Cell Buses for Urban Transport

**Post Title:** Consultant on opportunities identified for potential improvements for the second set of buses.

**Starting date :**

**Duration:**

**Honoraria/fees:**

**Consultancy covers:** Output III, Activity III.2, Sub-Activity III.2.2.

**Budget line:** 017.21

**Place of work:** São Paulo.

**A. Project background:**

**B. Project objectives:**

To demonstrate the operational viability of the use of fuel cell buses and their refueling infrastructure under Brazilian conditions.

**C. Objectives of consultancy:**

**Modifications identified for being introduced in the second set of buses and specifications for the Brazilian buses.**

**D. Activities described:**

Interpretation of operating parameters. Analysis of operating data on reliability and failure modes. Potential improvements in design and operation of the buses. Proposals for further product development. Proposed engineering modifications and communication of these to vendors.

**E. Expected results of consultancy or output:**

Document according to specifications in item Objectives of Consultancy above.

**F. Professional qualifications:**

10 years experience and published papers on automotive industry or buses maintenance, and market entry of new technology such as fuel cells. Bachelor in Engineering or Chemistry.

**G. Input:**

PHF

**H. Special considerations:**

**I. Contact at Project level:**

Marcio Rodrigues Alves Schettino

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**TOR 5**  
**Terms of Reference**

Project Number and Title - Brazil: Hydrogen Fuel Cell Buses for Urban Transport

**Post Title:** Consultant on follow-up of the performances of fuel cell stacks and the electrolysis unit.

**Starting date :**

**Duration:**

**Honoraria/fees:**

**Consultancy covers:** Output III, Activity III.2, and Output IV.1.

**Budget line:** 017.21

**Place of work:** São Paulo.

**A. Project background:**

**B. Project objectives:**

To demonstrate the operational viability of the use of fuel cell buses and their refueling infrastructure under Brazilian conditions.

**C. Objectives of consultancy:**

**Performances systematically evaluated of the fuel cell stacks and electrolysis unit.**

**D. Activities described:**

Follow-up of data collected on performance of the fuel cells and electrolyser. Systematic analysis and interpretation of operating parameters, of performance curves, with special attention to reliability, failure and other aspects indicated by the vendor. General technical backstopping.

**E. Expected results of consultancy or output:**

Document according to specifications in item Objectives of Consultancy above.

**F. Professional qualifications:**

10 years experience and published papers on electrochemistry. Experience in fuel cells. Bachelor in Chemistry.

**G. Input:**

PHF

**H. Special considerations:**

**I. Contact at Project level:**

Marcio Rodrigues Alves Schettino

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**TOR 6**  
**Terms of Reference**

Project Number and Title - Brazil : Hydrogen Fuel Cell Buses for Urban Transport

**Post Title :** Technician for making follow-up of the performance of the buses.

**Starting date :**

**Duration:**

**Honoraria/fees:**

**Consultancy covers:** Output III, Activity III.2.

**Budget line:** 017.21

**Place of work:** São Bernardo do Campo.

**A. Project background:**

**B. Project objectives:**

To demonstrate the operational viability of the use of fuel cell buses and their refueling infrastructure under Brazilian conditions.

**C. Objectives of consultancy:**

**Systematic follow-up made on the performance of hydrogen fuel cell buses operating in experimental revenue-earning service for data collection. Systematic follow-up made on the performance of the electrolyser.**

**D. Activities described:**

Systematic follow-up of the performance of buses and electrolyser for data collection that will be used for analysis. Interpretation of operational parameters, with special attention to reliability, failure modes, and identification of potential improvements in the project and operation of the buses, taking into account data files and history. Follow-up of tests during building, if possible.

**E. Expected results of consultancy or output:**

Document according to specifications in item Objectives of Consultancy above. Weekly reports with results of the follow-up of tests.

**F. Professional qualifications:**

Bachelor in Engineering or Technician. 10 years experience in follow-up of tests and equipment manufacturing in the area of public transportation or mass transit.

**G. Input:**

PHF

**H. Special considerations:**

**I. Contact at Project level:**

Marcio Rodrigues Alves Schettino

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EMTU/SP (Empresa Metropolitana de Transportes Urbanos de São Paulo S.A.)

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São Bernardo do Campo – SP

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**TOR 7**  
**Terms of Reference**

Project Number and Title - Brazil : Hydrogen Fuel Cell Buses for Urban Transport

**Post Title :** Consultant on Workshop.

**Starting date :**

**Duration:**

**Honoraria/fees:**

**Consultancy covers:** Output VI, Activity VI.1, Sub-Activity VI.1.2.

**Budget line:** 017.21

**Place of work:** São Paulo.

**A. Project background:**

**B. Project objectives:**

To demonstrate the operational viability of the use of fuel cell buses and their refueling infrastructure under Brazilian conditions.

**C. Objectives of consultancy:**

**Workshop organized for dissemination of partial results of Phase II Project and to inform the public of the advantages of fuel cell buses. Moreover, it will create enhanced public awareness and understanding of the potential role of fuel cell buses.**

**D. Activities described:**

Workshop organized with the audience of mass transit authorities of different states, automotive industries, governmental institutions and non-governmental ones, that will be potentially beneficiaries of the Project in the future.

**E. Expected results of consultancy or output:**

Document according to specifications in item Objectives of Consultancy above.

**F. Professional qualifications:**

10 years experience on Workshop organization.

**G. Input:**

PHF

**H. Special considerations:**

**I. Contact at Project level:**

Marcio Rodrigues Alves Schettino

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**TOR 8**  
**Technical Specifications for an Electric Buses System Powered by Hydrogen Fuel Cells**  
**Basic Specifications For Suppliers**

**1 – INTRODUCTION**

This document refers to a pilot project for the trial, demonstration and operation of electric buses powered by hydrogen fuel cells, as well as the technological update of Brazil, in harmony with programs in progress for the implementation of new technologies and the use of low pollutive potential alternatives in the urban transportation, funded by GEF - Global Environmental Facilities, through the UNDP – United Nations Development Program (Ref. BRA/97/G 41) and from FINEP – Funding Provider for Studies and Projects, as well as with the co-funding from the Brazilian Government, from the Government of the State of São Paulo, from manufacturers and other entities interested in the development of the technologies related to electrical vehicles powered by hydrogen cells.

The project is being developed in two stages, the first one dedicated to its conceptualization and to the identification of suppliers of parts, vehicles and fuels or energy input, and the second, with the purpose of implementing a trial lot, developing the National capacitation and technological options that are better suited to Brazil.

In order to achieve that, the UNDP, the Brazilian Government and the Government of the State of São Paulo intend to introduce the use of such technology in the RMSP - the Metropolitan Area of São Paulo, targeting four main strategic stages:

- 1) studies and definitions of the project, starting from consultancy works and commercial information achieved by means of a public consultation, concluded in June 1999;
- 2) a 3 or 4-year pilot trial with 8 buses in order to evaluate the concepts and the development of the Brazilian vehicle (trial or development stage), to be performed from 2000 up to 2004;
- 3) the implementation and operation of a model garage, operating at full capacity, with 200 serial production vehicles, provided with its own hydrogen production plant, with a four-year follow-up and evaluation, starting from 2005;
- 4) the definitive industrialization at market prices and in compliance with the environmental, energy and transportation policies resulting from the project to be provided for 2008.

This Invitation to Bid has in view the immediate purchase of a complete system of hydrogen-powered vehicles comprising the following subsystems:

- electric buses with hydrogen fuel cells;
- equipment for the production of hydrogen;
- equipment for storage and fueling the vehicles with hydrogen.

This Invitation to Bid shall identify qualified suppliers, whose appraisal will be performed by means of technical criteria and by the assessment of their ability to ensure the technical support required to conduct the project.

The co-responsibility of the suppliers of hydrogen fuel cells buses in the fuel quality and cost is also required. For that reason the supplies will be mandatorily performed by one sole bidder or

consortium, which will be responsible for the whole system. Subcontracting of specialized companies to supply part of the system will also be accepted, up to the limit of 30% of the full price, as long as those companies and their products are included in the proposal and appraised in the bidding process, under the exclusive responsibility of a sole bidder. In that sense, the technical and costing proposals must comprise the whole supply and focus each one of the subsystems separately.

Along the whole process, the explanations that may be required by the bidders shall be requested to the UNDP Environment Unit Coordination or to EMTU-SP Project Coordination.

In this project, the hydrogen production alternatives will also be discussed, starting from necessarily renewable sources, by water electrolysis utilizing secondary electric power (preferably), by means of the reform of liquid or gas fuels “in loco” or the acquisition of hydrogen produced by third parties, because of its quality versus the requirements of the hydrogen fuel cells and their catalyzers, as well as the availability of such alternatives.

With this process, we intend to disclose the Program’s purposes, the supplier’s familiarization with the technology and qualification to supply the vehicles and equipment required to the development stage, which contemplates the following subsystems:

- buses
- hydrogen electrolytic production unit(s);
- vehicles storage and fueling unit;
- vehicles maintenance equipment, including safety devices.

We also accept a technologic alternative for the second item, provided that the hydrogen production is performed from renewable sources and by means of a commercially established technology.

Since it concerns a vehicle with special features and production, we intend to estimate the costs for the development and implementation of a hydrogen fuel cells transportation system with electrical buses, contemplating the acquisition of the vehicles, or their subsystems, as well as the fixed fueling subsystems. In that stage, therefore, EMTU-SP will purchase, through the UNDP, by way of trial and demonstration, 8 buses and other facilities required to start the operation in 2001, in the Metropolitan Area of São Paulo, under EMTU-SP management, making the resulting information available to other cities that may be interested in the innovation.

Taking into account the interest in the partnership with the industry for the technological development of Brazil, the suppliers will follow the trial results, which will be public, and will utilize the prototypes and replaced parts in the benefit of their own products’ development. For that reason, the bidders shall propose an interest of at least 20% of the project’s costs, being accepted that the supplier(s) of vehicles and other systems that are object of development be the owner(s) of the respective product(s), on the whole or in part, so that they may be able to evaluate the assemblies and parts after the tests and the components replaced in the course of the operation. In all cases, any evaluation that may be performed during or after the tests must be followed by EMTU/SP technicians, consultants and other participants of the project’s technical team, and the results may be freely utilized by EMTU-SP and the UNDP.

With that purpose, the UNDP and EMTU/SP intend to develop the following stages:

- a) identification of companies and/or consortia which are able to supply buses or their subassemblies separately (chassis, body, fuel hydrogen cells system, motor, electronic control, auxiliary equipment), hydrogen production subsystems, gas storage and fueling subsystems and vehicle maintenance facilities provided with the safety equipment required;
- b) development of the bid process among the qualified companies or consortia, in order to purchase at least eight buses and other systems required to the development stage;
- c) acquisition of a complete system, that is, 8 buses, as it is described in item 5 – Basic Technical Specifications of the Vehicle, the related subsystems and infrastructure items, as described in item 6 – Basic Technical Specifications of the Hydrogen Production Subsystems, or, optionally, item 7 – Fuel Supply by units outside the garage;
- d) a technical and economical follow-up of the test vehicles performance, aiming to the evaluation of the vehicles and related subsystems, and of the nationalization levels that may be achieved;
- e) development, based on the experience achieved, of the specifications required to prepare an Invitation to Bid or pre-qualification for the supply of 200 buses and the related subsystems required to the implementation of a hydrogen cell powered bus transportation system;
- f) start or stimulate a transportation operator to start the acquisition of a 150 up to 200-buses lot and related subsystems required to the implementation of a hydrogen fuel cells powered buses model garage.

Since EMTU-SP is preparing the bid for the operation of all the metropolitan lines under concession, it intends to generate favorable conditions so that one of the future operators will be responsible for the acquisition and operation of the aforementioned 200 vehicles, providing, that way, continuity to the stages of the Project in commercial scale.

## **2 – TECHNICAL DOCUMENTATION FOR THE BID**

The companies interested in the bid shall provide technical specifications and documentation for themselves, for the manufacturers, suppliers and sub-suppliers of the vehicles and related subsystems, equipment, components and materials, comprising at least the following topics:

- A handbook with the fitting procedures and requirements, where applicable.
- A handbook with the operation procedures.
- A Maintenance Handbook and preventive maintenance program (vehicle, equipment and components of the vehicle and of the related subsystems).
- A Parts and Tools Handbook (including the special ones).
- Handbook/Warranty Term (vehicle, components, materials, equipment and related subsystems).
- A Training Program for EMTU-SP technicians.
- Technical Designs (vehicle and related subsystems, combined, interior lay-out and painting).
- Methodology and results of the tests performed (chassis, body and vehicle components, as well as the related subsystems).
- A list containing the description and minimum quantities of spare parts (in floppy disk or CD), being mandatory the delivery of at least a full set of extra supply fuel cells.

- In the case of fuel cells and their catalyzers, the manufacturers shall specify the hydrogen minimum quality requirements needed to achieve a good operation and durability of the components.
- The subcontracted suppliers that do not take part in consortia for the supply of the whole system requested in this Invitation to Bid shall declare explicitly that they accept the specifications of the related subsystems, assemblies, subassemblies and materials that take part in this Invitation to Bid, and that the performance of their products will not be impaired if the specifications are complied with, in case EMTU-SP opts later for the supply of the various subsystems by independent suppliers.

Before the manufacture of the subsystems, subassemblies, equipment or materials, EMTU-SP shall conduct the analysis of the designs, specifications and compatibilities with the full system, such as the basic plan of the vehicle (dimensions, inner distribution of the passengers compartment, doors location, inner and outer visual communication, among others); the compatibility of subassemblies provided by different suppliers, the installation plan of the fixed equipment and other requisites and requirements of the system and their implementation. In case of incompatibilities, the supplier(s) shall change its (their) specifications as required and according to the establishment of new criteria from EMTU-SP, or the company shall be able to choose another supplier for the items at issue.

Once it is approved, a “Compliance Term” shall be issued for each design, which will cause it to be a “standard model” to be followed for the compliance with the specifications from the Project Implementation Team – PIT.

The bidders disagreeing with the specifications contained in this Invitation to Bid shall inform EMTU-SP on the fact, along with their justifications and suggestions, within 30 days after their publication, so that EMTU-SP shall be able to analyze and eventually revise the specifications, at its exclusive discretion.

### **Costs**

The suppliers of vehicles shall present realistic cost estimates for each stage of the project (with specific amounts for the purchase of 3 vehicles in the first year and 5 additional vehicles in the second one), taking into account the introduction of the fuel cells technology, and that the development of such products as a result of the project will comprise new future business opportunities, and they shall propose separately their interest percentages in those costs, as companies interested in the ownership of the prototypes and in the access to the results of the project.

As to the costs of the imported materials or items, they must indicate separately the total amounts to be paid, FOB, freight and incurring taxes.

The costs shall also be indicated for each subsystem, as defined and specified in this Invitation to Bid.

### **Supply Terms**

The minimum terms for the supply of the vehicles and equipment for the trial stage shall be presented, followed by the respective implementation schedules.

### **Characterization of the bidder or supplier**

The companies and consortia interested in the supply that is object of this Invitation to Bid shall describe the characteristics qualifying them as suppliers and the items (assemblies, subassemblies or even special components) that they intend to supply or to purchase from other companies subcontracted by them.

Those descriptions shall be clear and detailed, defining the limits of the supply intended and the way of integration of their product in the full system of hydrogen fuel cell-powered buses and/or the complementary subsystems of production and storage of the fuel.

The following items shall take part in the characterization and qualification of the supplier:

- a) total practice time in the manufacture and supply of buses in Brazil;
- b) total practice time in the development and supply of the items offered, considering their participation in similar applications in Brazil;
- c) total of investments made in the technologic development of the items offered;
- d) built area and number of people involved in the technologic development and production of the items offered;
- e) characterization and quantification of similar supplies and applications already performed, indicating the durability of the items offered and of the items in operation.

### **3 – TECHNICAL RULING**

All the Resolutions, Technical Guidelines and Legislation specific to the manufacture industry must be complied with, in addition to those mentioned below, starting from their inclusion in this document, taking into account, however, that in case of doubt or disagreement, the original text description of such technical ruling shall prevail.

#### **3.1 – OF INTERNATIONAL NATURE**

- 3.1.1.IEC 165/73 guideline, on the insulation of electric circuits.
- 3.1.2.IEC 349 guideline, providing for trial methods for the insulation of electric circuits.
- 3.1.3.IEC 77 guideline, providing for rules for electric traction equipment.
- 3.1.4.UL 198K guideline, providing for fuses for semiconductors.
- 3.1.5.ISO/FDIS 14687: 1998 (E) guideline, providing for the fuel hydrogen specifications.
- 3.1.6.Technical guidelines applicable to the hydrogen storage and handling, pressurized chambers (300 bar), pressure reductive equipment and its accessories.

#### **3.2 - OF FEDERAL NATURE**

- 3.2.1.Law n° 9.503/97, instituting the Brazilian Traffic Code.
- 3.2.2.Law 8.078/90, instituting the Consumer Defense Code.
- 3.2.3.Executive Act 98.933/90, providing for the Law of Cargo per Shaft (law of the Scale).
- 3.2.4.CONAMA Resolutions n° 01/93 and 08/93, providing for the external noise level.
- 3.2.5.CONMETRO Resolution 01/93 providing for the internal lights.
- 3.2.6.CONTRAN Resolution 777/93, providing for the adoption of ABNT Guidelines as a trial method and the minimum requirements for the evaluation of the brake system.

- 3.2.7.CONTRAN Resolution 784/94, ruling on the use and establishing requirements for safety glasses.
- 3.2.8.CONTRAN Resolution 811/96, establishing safety requirements for collective transportation.
- 3.2.9.ABNT NB 1253, NB 1254, NB 1255, MB 3160 and MB 3161 guidelines, providing for a trial method and the minimum requirements for the evaluation of the vehicles braking system.
- 3.2.10.ABNT NBR 5096/82 guideline, providing for the requirements of the printed circuit plates.
- 3.2.11.ABNT NBR 5117/82 guideline, providing for the features of synchronous machines.
- 3.2.12.ABNT NBR 5410/90 guideline, providing for low voltage electric fittings.
- 3.2.13.ABNT NBR 6056/80 and its amendments, providing for the anthropometric range for drivers.
- 3.2.14.ABNT NBR 6606/80 and its amendments, providing for the ergonomic standards.
- 3.2.15.ABNT NBR 8171, 8172, 8173 and 8174, 8175/83 guidelines, providing for mechanic, electric and other characteristics to be considered in printed circuit plates.
- 3.2.16.ABNT NBR 8179/81 guideline, providing for trial methods for vehicles with electric traction motors.
- 3.2.17.ABNT NBR 8188/83 guideline, providing for the specification, manufacture and use of printed circuit plates.
- 3.2.18.ABNT NBR 8365/79 guideline, providing for requirements of the electronic equipment utilized in railroad movable material.
- 3.2.19.ABNT NBR 9112/85 guideline providing for the basic features of converters to semiconductors.
- 3.2.20.ABNT NBR 9158/85 guideline, providing for the terms employed in electric traction.
- 3.2.21.ABNT NBR 9314/85 guideline, providing for splices and terminals for power cables with insulation for voltages from 1 kV up to 35 kV.
- 3.2.22.ABNT NBR 11875/92 guideline, providing for continuous power feeding systems.
- 3.2.23.ABNT NB 36 and EB 71 guideline, providing for the electromagnetic interference.
- 3.2.24.ABNT NB 161 guideline, providing for chemical powder fire extinguishers.
- 3.2.25.The applicable technical guidelines for the storage and handling of gases, pressurized chambers (330 bar), pressure reductive equipment and their accessories.

#### **4 – DEVELOPMENT AND USE OF NEW TECHNOLOGIES**

New technologies must be applied to the vehicle project as a whole or to its subassemblies, as well as to the hydrogen production, storage and fueling subsystems, in addition to the elements mentioned in this document, targeting the comfort, safety, performance, durability and optimization of the material and human resources, mainly concerning the decrease of sensitiveness of the catalyzers utilized in the fuel cells to the carbon monoxide and sulphur compounds, as well as of the electronic systems on board, enabling the self-management of the

main subassemblies taking part in the vehicle, such as suspension, steering wheel, motor, brakes, H<sub>2</sub> inventory in the vehicle, monitoring and control of the parameters related to the performance of the power generating subassembly (hydrogen fuel cells system) and of the electric motor.

Since technologies that are new to Brazil are involved, such as that of the hydrogen fuel cells, the purchase of complete buses will be necessary, as long as their subsystems are suitable to the local conditions by means of an engineering development with the highest Nationalization rate possible, and as long as they are assembled in Brazil by automotive manufacturers installed in the Country or consortia with their participation. The new technologies introduced in the project shall be submitted to the EIP previous approval.

## **5 - BASIC TECHNICAL SPECIFICATIONS OF THE VEHICLE**

This document presents the basic specifications desired, which shall be followed by the manufacturer/supplier of the vehicles, equipment, subassemblies and materials, but the manufacturer/supplier shall be free to propose the most convenient alternatives for his company, as long as they are proved and justified, which must be approved by the EIP before their adoption.

The items that are usually utilized in the vehicles, such as side mirrors, windshield wipers, kinds of tires, etc., are not specified here in order to provide freedom to the suppliers to utilize their usual production components and, that way, to avoid raising the prices of the final products. However, each supplier shall list and specify the components or subassemblies utilized, in a clear and objective way, indicating the characteristics defining the product, and prove compliance with the Brazilian legislation where applicable. The bidder shall show his level of interest in producing in Brazil, or in joining Brazilian companies to supply his products in Brazil. He shall show also the existence and the rate of his interest in co-financing the development, together with the project funds.

### **5.1 – STRUCTURE OF THE VEHICLE**

The vehicle structure shall be designed in order to meet the performance features described in this specification and may be one of the three following types:

- Monobloc.
- Structural chassis and body.
- Integrated body and platform.

The (local and globalized) rigidity shall be enough to prevent noises and vibrations impairing the comfort of the passengers.

#### **Minimum capacities**

- passengers seats: 43
- area for standing passengers: 9 m<sup>2</sup>

The integrity of the system shall be ensured under all the operation conditions in urban traffic, meeting with safety the usual requests and those resulting from overloads due to the vehicle operation, including an unusual occupation of 10 standing passengers per square meter of functional area, being able to support the dynamic load deriving from the usual operation conditions.

#### **Vehicles Life**

The transportation system by means of hydrogen fuel cell-powered vehicles was conceived for an average 20-year effective life of the buses, so that the main subassemblies shall have a higher durability than that, while other components may be less durable and their replacement and exchanges periodicity shall be previewed in the preventive maintenance plan. In principle, the following minimum values for the effective life of the main subassemblies are expected:

- Chassis and body 20  
years
- Electric and traction subassemblies 30 years or 3.000.000 km
- Hydrogen fuel cells:  
First prototypes  
3 years or 250.000 km  
Project target (\*) 8 years  
or 700.000 km

(\*) The manufacturer shall present a development schedule ensuring, at least, the target intended.

## **5.2 - ENVIRONMENTAL PROTECTION AND COMFORT**

### **5.2.1 - Exterior Noise Emission**

It shall comply with CONAMA Resolutions n° 01/93 e 08/93.

### **5.2.2 – Interior Noise Level**

The maximum noise levels allowed, with doors and windows closed, are:

- 77 dBA: Vehicle with a maximum acceleration from rest up to the maximum speed on good quality pavement.
- 60 dBA: Ventilation system of the vehicle at full charge.
- 72 dBA: Vehicle parked with all the auxiliary equipment running.
- 60 dBA: Each equipment installed under the vehicle, running under the usual conditions, except for the propulsion system.

### **5.2.3 - Electromagnetic Noise Emission**

The supplier shall ensure the protection required to prevent any interference whatsoever on the equipment in the surroundings, such as pacemakers, airbags, ABS, etc., besides describing and specifying the protection devices used with that purpose.

In the electromagnetic equipment, sensitive to the generation of electromagnetic noise that may impair the radio-reception, there must be a provision of filters suited to suppress such noise.

The levels of radio-interference (electromagnetic noise) generated by the vehicle are subject to approval by the buyer.

The elimination of electromagnetic noises shall comply with the following guidelines: ABNT.NB-36 and ABNT.EB-71.

### **5.3 – RELIABILITY, WARRANTY AND PREVENTIVE MAINTENANCE**

As a target of the project, of either the trial stage or the development one, in the project of each subassembly, the quantity of failures that may occur, implying repairs out of the maintenance interval, shall be foreseen. The vehicle shall not present failures interrupting its operation in frequency higher than once in every 50.000 km driven. The manufacturer shall indicate the reliability predicted for its project, which will be the object of scoring.

In addition, the fueling subsystem shall not present failures compromising or interrupting, even momentarily, the operation of the bus transportation system.

A Preventive Maintenance Plan shall be prepared for each subsystem, within the standards required, which shall ensure to the assembly the reliability level specified above. Therefore, for all the assemblies, subassemblies and components, there must be a specification of the replacement terms before such failures occur.

The supplier must be able to provide a 4 (four)-year warranty on the operation and be responsible for the preventive maintenance plan, including the replacement of vital parts, which ensures the subsystem operation with the reliability desired, as well as specify the terms for the replacement of components before such failures occur.

### **5.4 - CHASSIS**

#### **5.4.1 - Steering**

The steering system shall be integral hydraulic.

The mechanic and geometric features of the system shall be optimized so as to allow accuracy of control and response, high steering stability and the adequate return to the position corresponding to the rectilinear course once the steering effort ceases.

The steering mechanism shall be designed so as the moves due to the suspension action do not introduce directional effects disturbing the vehicle' s course.

The tangential effort applied by the driver, in case of a total loss of hydraulic assistance in any maneuver, shall not be higher than 500 N.

The hydraulic pump shall be vane type, activated by an electric motor and electrically insulated from the vehicle structure.

In case of failure in the electric power supply, the system shall not suffer an immediate reduction of the hydraulic assistance, which shall be maintained in the proper levels for at least 20 seconds, in order to ensure safety in the pulling over maneuver of the vehicle.

#### **5.4.2 - Suspension**

The suspension shall be fully pneumatic or pneumatic-spring combination (air and springs), with a preference for a height variation system.

The suspension shall, in all the operation conditions of the vehicle:

- a) Lessen the shocks and vibrations of the body, originated by defects on the paved surface.
- b) Ensure stability to the vehicle.
- c) Keep constant the height from the ground in relation to the shafts, so as to ensure the comfort of the passengers.

The elastic elements shall be provided with stroke limitation devices capable of, in case of total

loss of pressure or rupture of the springs, allowing the continuity of the operation without compromising the safety of the passengers and the vehicle.

### **5.4.3 - Brakes**

The brake system comprises the following subsystems:

- a) Brake: is made up by the friction brake acting on all wheels and by the electric brake.
- b) Parking brake: acts on the rear shaft, keeps the vehicle motionless and acts automatically as an emergency brake.

The friction brake system shall be drum or wheel with fully pneumatic action and made up by two independent circuits, one for the front shaft and the other for the back shaft, capable to cause a  $5,0\text{M/S}^2$  deceleration with the vehicle in the total gross weight situation.

The electric brake of the vehicle shall be activated automatically by means of the brake pedal.

The parking brake, fed by a third independent circuit, shall comprise energy accumulator cylinders acting by means of springs, integrated to the activation servomechanism of the back shaft brake.

The vehicle shall remain directionally stable, in any braking operation and under any load conditions whatsoever.

The system shall comply with the legal safety requirements applicable in the date of production.

### **5.4.4 - Shafts**

The system shall endure the vertical strains due to the vehicle weight and inertia, the horizontal strains resulting from accelerations, decelerations and pavement defects, as well as the transverse ones.

The system integrity shall be ensured in all the operation conditions of the urban traffic, meeting with safety the usual demands and those arisen from overloads, due to the operation of the vehicle, including an unusual occupation rate of 10 standing passengers per square meter of area available, being able to support the dynamic load originated from the usual operation conditions.

The supplier shall present the loads transmitted to the ground, for each shaft, in the total gross weight situation.

The transmission system shall be suited to the performance specified, and perfectly compatible with the traction system.

### **5.4.5 – Subassemblies for Propulsion, Energy Generation and Feeding of the Hydrogen Fuel Cells**

#### **Description**

##### a) Electric traction subassembly:

The electric traction equipment of the vehicle shall be designed so as to meet the performance requirements.

The propulsion subassembly shall utilize, in principle, a high-revolution CC or AC electric motor, water, air or oil cooled, with a speed reducer acting on the vehicle back wheels. Alternatives may be considered, as long as they are duly substantiated.

##### b) Cooling subassembly:

The operation temperature of the hydrogen fuel cells shall be specified and recommended by the manufacturer, and it must be maintained in those levels by a thermostatically controlled system, such as a radiator(s) with electronically controlled fan(s). If that system utilizes water as the cooling fluid, the water may also be used to moisten the air and the fuel gas flow before its entrance in the hydrogen fuel cells stacks, in case it is necessary. In that case, some device (such as a ion exchange filter, for instance) shall be proposed to keep the water pure, in order to prevent it from turning into an electricity conductor.

An auxiliary cooling system shall be provided to cool the high power electric and electronic components and the exhaustion vapors condenser, according to the manufacturers' specifications for those components.

c) Control subassembly:

The mechanical, processing and electric source subassemblies shall be coordinated and controlled by means of a device integrated with modules for the dosage of fuel and air, cooling, traction force, indicators and operation modes (ignition, warming, use and switching off). The control device utilizes the information from the interior instruments and provides responses to several components, such as motor controllers, valves and indicators, utilizing a programmable logic controller.

The acceleration control shall respond to the position of the acceleration pedal without interruptions in the intensity of the traction thrust.

d) Electric subassembly:

The electric subassembly is made up of the interfaces for the power transfer from the hydrogen fuel cells system to the electric equipment, the motor and the vehicle. The power for the main motor shall be provided with nominal values of 600 V and 400 amperes. Current switches for the protection of circuits and controllers managing the vehicle traction and the auxiliary systems shall preferably be centralized in the same place. CC to AC converters shall provide power in the different voltages required to the operation of the motor and of the other pieces of equipment in the vehicle. The high power electric components may be cooled by a liquid in order to reduce size and weight. Alternatives may be considered, as long as they are justified.

e) Hydrogen fuel feeding subassembly:

The fueling must be performed under a pressure limited to 3 (three) bar, by means of two-stage regulators. In order to ensure a uniform distribution and the full use of the fuel, as well as the moistening of the gases inside the cells, a device or a fuel cells-fed hydrogen recirculation system shall be provided.

f) Air supply subassembly:

The discharge and pressure parameters for the air supply shall be specified for the optimization of the fuel cells operation and control of the power produced, and to ensure the proper removal of the water produced by the electrochemical reaction on the electrodes.

The filtering, pressurization and control of the air flow subassemblies shall be specified and provided by the hydrogen fuel cells manufacturer, integrated to the system.

g) Hydrogen fuel cells subassembly:

The hydrogen fuel cells shall preferentially be of the "Proton Exchange Membrane" type. The number and size of the stacks of interconnected hydrogen cells, which make up the cells

subassembly, shall be specified in order to ensure the supply of the power required to all the electric systems and subsystems of the vehicle, including for the momentary surges required at the start of the motor and in short accelerations.

Labyrinths and inner galleries shall distribute the flows of fuel, air and cooling liquid, as well as collect the water produced by the fuel cells operations and assist in the removal of the heat generated in the electrodes, maintaining the cells in the proper operation temperature.

#### h) Hydrogen containers in the vehicle:

The compressed hydrogen shall be stored in pressurized cylinders, preferentially installed on top of the vehicle, so as to ensure the proper ventilation of the containers and preserve the largest interior space in the vehicle.

The supplier shall specify the Safety Guidelines utilized and demonstrate the compliance of its product with those guidelines, indicating the types of the sensors utilized and their location, as well as the conception of the monitoring and safety system concerning leakages.

#### i) Dynamic braking

The vehicle propulsion subassembly shall have characteristics allowing for the dynamic braking.

### **Hydrogen consumption targets**

12 kg/100 km for the vehicles in the development stage;

9 kg/100 km for the 200 series vehicles.

### **Performance requirements**

The manufacturer shall indicate in detail the indexes and parameters characterizing the vehicle performance, taking into account all the items required and mentioned in this document, especially the acceleration curves and the traction capacity with relation to the speed, fuel consumption, time to reach the working conditions in cold and hot starts and other requirements considered important to characterize the subsystems and the vehicle regarded as a whole.

### **Accessories**

The following items are considered components required to the vehicle operation:

- air supply subassembly;
- cooling devices;
- devices for the H<sub>2</sub> flow control;
- safety mechanisms.

### **5.4.6 – Traction Control Equipment**

The manufacturer shall describe in detail the technical specifications and guidelines utilized in the vehicle and in each subassembly, according to the following list:

#### **General Features**

- Control type (chopper or an equivalent)
- Insulation
- Ventilation

- Equipment protection
- Test points for control parameters monitoring
- The parameters monitored
- Insulation trials
- Printed circuit cards and modular units
- Cables and connectors
- Protection against external radio-interference and protection of the circuits themselves.

### **Operational and Manufacturing Features**

The traction control shall be, in principle of the chopper type, with IGBT (Insulated Gate Bipolar Transistor) technology.

The acceleration control shall act so as to meet the requirements mentioned, satisfying the performance requisites in the Total Gross Weight condition:

- the traction acceleration control shall allow for the command corresponding to the accelerator pedal position, conferring continuous characteristics, without interruption in the intensity of the traction effort. The acceleration position sensor shall be redundant.
- starting from the rest position on a horizontal pavement and in an environment with a temperature between 15°C and 25°C, the vehicle shall reach 50km/h at most in 18 seconds.
- the vehicle shall be able to reach the following accelerations on acclivities:

<b>Activity (%)</b>	<b>a (m/s<sup>2</sup>)</b>
00	1.30
05	1.20
10	0.70
15	0.30 (at the moment of start)

- the vehicle acceleration shall be limited, in whatever situation, to a maximum value of 1.3 m/s<sup>2</sup>. The acceleration variation rate shall be limited to a maximum value of 1.5m/s<sup>3</sup>, either in the moment of start of the motor or during the reapplication of the traction effort.
- the vehicle shall be started with an automatically controlled acceleration, regardless of its load and the slope, preventing the backward movement of the vehicle, allowing the motor to be exerted in the limit conditions, without detrimental surges.
- when the vehicle exceeds 55 km/h, a sound signal shall be activated. The system shall limit the maximum speed of the vehicle to 60 km/h, and a 3-digit counter shall record the number of times that speed was reached.
- for the model garage implementation stage, the EIP may change the specifications above,

in consequence of the technologic development and the results of the trial stage.

The electrical braking control shall act so as the following requirements are met, in the situation of Nominal Gross Weight, on a flat, horizontal and dry pavement, save where there are different indications:

- deceleration rate regardless of the vehicle load and the slope, as long as it is not overloaded;
- the control equipment shall promote a maximum deceleration (as a component of the electric braking) between  $1.0\text{m/s}^2$  and  $1.3\text{m/s}^2$ , adjustable according to the brake pedal stroke, in the Total Gross Weight condition, starting from any speed whatsoever up to  $10\text{km/h}$ ;
- the deceleration variation rate (jolt) shall be limited to the maximum value of  $1.5\text{m/s}^3$ , either in application or in the reapplication of the electric braking;
- the electric brake shall be activated immediately after the idle course of the brake pedal, besides having continuous characteristics, with no steps, and the maximum effect of the electric braking shall be reached at the beginning of the performance of the air braking;
- for the dynamic electric braking, the bidder shall specify the systems it intends to offer.

The whole equipment shall be designed modularly in order to ease the maintenance.

The supplier shall describe the control equipment or control logic, which shall be designed with the purpose of interpreting and processing the signals produced by means of the accelerator and brake pedals, monitoring and activating the maneuver equipment, controlling the current in the traction motor and the air and hydrogen flows and pressures on the cells, controlling their auxiliary equipment and performing the protection functions.

It is desirable that the control device have diagnostic indicators of defects, hydrogen leakages and other safety items and that there are integrated control and supervision circuits.

The traction equipment shall not allow for a backward movement of the vehicle when it departs on a slope.

#### **5.4.7 - Low Voltage Electric Equipment**

The low voltage electric subassembly shall operate at a 24 Vcc nominal voltage, supplying the power required to meet the vehicle interior lighting level, as well as the other equipment and accessories.

That subassembly shall be fed by two sets of sealed batteries, both 24 V. The first one will supply power to the conventional equipment of the vehicle, and the second one will feed the electronic systems of the clippers. Each set of batteries will have its own static charger, fed from the inverters.

The equipment shall be fitted with an overall checking system that will be able to provide an optical indication on the Dashboard, in the case of critical failures.

#### **5.4.8 – Auxiliary Electric Subassembly**

The Auxiliary Electric Subassembly shall provide power to activate the following systems and subsystems:

- hydraulic steering pump;

- ventilation/exhaustion of the passengers compartment;
- air conditioning;
- compressor(s) to activate the suspension, brakes, doors, etc.;
- the ventilation motor of the semiconductors box;
- batteries charger (24Vcc);
- the motor for induced cooling ventilation of the traction motor, hydrogen cells and other equipment, where applicable.

There shall be an optical indicator on the Dashboard to indicate whatever failure in the subassembly.

The access for checking and maintenance of all parts and components shall be easy.

The supplier shall specify in detail its conception of the auxiliary electric subassembly.

#### **5.4.9 - Lubrication**

The lubrication subassembly will be centralized and automatic for all the lubricative parts of the chassis/platform, ensuring a specified dosage at regular intervals, keeping a renewed grease, regardless of the type of work, preventing the early wear of the parts caused by a lack of the proper lubrication. The manufacturer shall determine the grease substitution/addition periodicity for lubrication.

### **5.5 - BODY**

#### **Dimensioning**

The design of the vehicle shall provide the smallest weight possible and its dimensioning shall be performed based on a static load equal to the vehicle full of passengers, utilizing an occupation rate of 10 standing passengers per square meter of area available.

#### **Dimensions of the steps, the floor and doors:**

The following specification table refers to the parked vehicle condition, with a nominal gross weight:

Maximum height of the first step	= 350 mm
Maximum height between steps	= 275 mm
Minimum depth of the steps	= 300 mm
Maximum height of the floor at the doors area	= 920 mm
Minimum internal height in circulation areas	= 2.000 mm
Maximum inclination with relation to the floor	= 5%
Free space of the doors = 1.100±10 mm	

Note.: Steps along the floor between the doors will not be allowed. In case of low floor bodies, that requirement may be reevaluated.

#### **Vehicle floor:**

All the unprotected structural parts below the floor, including the inner part of the body valance of the body, if they are built with materials subjected to corrosion, shall be adequately protected with the use of compounds and sealants, besides the conventional anti-noise treatment.

The floor shall be covered with a rubber blanket or other antiskid material ensuring the electric insulation, with no indentations, waterproof and with no metallic bands on the coating.

All corners must be round and protected by rubber or plastic bands, with no rough edges or projections that could harm the passengers. The rubber blanket shall be fixed with the suitable glue, and the use of nails, rivets or other perforating means is not allowed.

The floor shall be watertight when submitted to washing operations. The equipment on it shall not, in any way, be affected during those operations.

### **Service Doors**

- a) The vehicle shall be provided with 2 (two) disembark doors and 1 (one) embark door. Configurations with doors on the right side and/or on the left side of the vehicle may be required.
- b) The doors shall be operated exclusively by the driver.
- c) The activation shall be electro-pneumatic, with compressed air valves near each door, fitted with mufflers. Alternatively, the electric activation of the doors may be proposed.
- d) Near each door there shall be a device allowing for the valves pressure easing, to be manually activated in case of emergency, with an easy access and safe from accidental activation by the passengers.
- e) The system shall allow for the opening and closing of the doors between 2 and 5 seconds.
- f) The entrance door shall be located as near the vehicle front as possible.
- g) All doors shall have a 2,000 mm minimum free height.
- h) The doors shall have 2 (two) blades, opening in such a way that their inner side is turned to the passengers and, when open, they shall not protrude more than 20 mm outside the body of the vehicle. Alternatively, a one-blade door shall be proposed, sliding outside the vehicle.
- i) The steps shall have the smallest trimmings possible, so that they will not present any risk to the passengers.
- j) The edges of the blades that are side-by-side when the doors close shall be provided with a soft material stripe ensuring their sealing and with a minimum 50 mm width.
- l) The entrance door shall be fitted with glass so that, with the door closed, the driver is able to see a point at the height of 200 mm from the ground and 400 mm from the vehicle side. The other doors shall have at least 2 (two) upper halves fitted with glass covering the widest area possible on the panels.
- m) The glass fitting on the doors shall be made with safety glasses (NBR-9491).
- n) The vehicle shall have an electric interlocking between the control circuits of the doors and traction, so that, in regular conditions, it will not be able to move with the doors open.
- o) A key shall be fitted in the outer side of the vehicle to open the front door, so that the driver is able to get into it.

- p) A bypass switch shall be fitted near the doors mechanism, on the front door, which will allow for the regular moving of the vehicle in the case of defect of the interlocking with the traction.
- q) The compressed air feeding system for the doors cylinders shall have a properly dimensioned container, in order to keep the system uniform, and it shall have a pressure reduction valve at its entrance.

### **Steps**

- a) The structure of the steps shall be designed taking into account the cyclic loading effect, from the embarking and disembarking of the passengers and which may cause possible fatigue problems.
- b) The steps and their connection with the rest of the structure shall support six people, weighing 640 N each.
- c) All parts of the steps that may be touched by the passengers, being in contact with the ground, shall be electrically insulated from the rest of the vehicle.
- d) There shall be 2 (two) steps, at most, between the vehicle and the ground.
- e) The inner corners of the steps shall be rounded to prevent the accumulation of dirt, and the edges shall not have clasps in order to prevent the passengers from stumbling
- f) The steps shall be coated with antiskid material.

### **Windows, windshields and rear windshields**

- a) All glasses utilized in the windows and fixed must be tempered, except for the front and rear windshields, which shall be laminated, with a 70% minimum transparency.
- b) All windows, windshields and fixed glasses must be protected from water dripping from the roof in the case of rain.
- c) The frames of the movable part of the window shall allow for a smooth sliding with an effort lower than 20N, and that characteristic shall not suffer any change due to the constant use. They shall be coated with a fabric in similar material so as to reduce the vibration and noise levels.
- d) The height of the front windshield shall allow for a visual angle higher than 20° (twenty degrees) for drivers within the anthropometric range specified in the ABNT NBR 6056/80 guideline and its complementaries.
- e) The back windshield must be ample, with its bottom immediately above the back of the rear seat and its top part following the same height as the side glasses, and it shall not cause interior reflecting.
- f) It shall have emergency windows located on both sides of the vehicle and their operation shall be easy, with clear and distinct instructions on their handling, located according with the following description:
  - 2 (two) windows located on the left side of the usual vehicle, non-adjacent and distributed equally.
- g) The windows shall have a 900 mm minimum height and a 1,400 mm minimum length. Their bottom shall be located at 900 mm above the floor, at most, while their top shall be located 1.750 mm above the floor, at least.

- h) In case the vehicle is not air-conditioned, the side windows shall be divided in two equal parts in their height, with sliding panes on top and fixed panes at the bottom, except for the windows behind the back doors.
- i) A sun visor shall be provided to be used by the driver.

### **Passengers' seats**

- a) The seats shall be upholstered and provided with a head protection.
- b) The upholstery shall be anatomically shaped for a perfect pressure uniformity.
- c) All passengers' seats shall be installed forward-oriented, except for those installed on the wheel boxes, which may be back-to-back with other seats or laterally located.
- d) The seat and its back shall be independent.
- e) The seats installed on the wheel boxes shall be provided with armrests in the aisle side.
- f) All seats shall be provided with handles installed on top of the seat back.
- g) The back seat shall comprise individual or double seats, instead of a continuous seat.
- h) The whole metallic frame of the seats shall be built with an anti-corrosion material or with a material protected against corrosion by means of the proper treatment.
- i) All seats shall be at least 30 mm far from the interior sides of the vehicle body.

### **Posts, balusters, handrails and supports**

- a) The vehicle shall have support rails for the passengers, in adequate quantities, in the shape of posts, balusters, handrails and supports, and their distribution shall be done in such a way that the passenger, when moving along a crowded vehicle, may always have a support within his/her reach.
- b) Balusters, handrails and posts, as well as their connections with the vehicle frame, shall endure the pressures of the everyday utilization without presenting permanent deflections.
- c) The handrail height shall remain constant along the vehicle.
- d) The posts, balusters and handrails located near the doors shall be electrically insulated from the rest of the vehicle body.
- e) The top handrails, located above the single seats shall be installed with their axis at 1,850 mm above the floor.
- f) The top handrails aligned with the sides of the seats, as well as their extensions in the regions where the aisle is wider, shall be located approximately 1,900 mm above the floor.
- g) All the variations in height and direction of the top handrails shall be slightly curved.
- h) All the top handrails and balusters shall end in a curve fastened on the ceiling and the side of the vehicle, respectively.
- i) The handrails of the steps shall have a support on the first and second steps and on the ceiling, at a height between 860 mm and 960 mm from the natural inclination of the stair.
- j) The posts, the top handrails, and the stair handrails shall be made with a round tube with a 30 or 40 mm exterior diameter, made in stainless steel or aluminum tubes with a surface treatment.

### **Panels-screens**

- a) All panels shall have round corners and edges, as well as a 40 to 60 mm distance from the floor and the ceiling, in the case of the driver' s sun visor.
- b) The vehicle shall be provided with panels-screens in front of each seat turned to the stairs and behind the driver' s seat.
- c) The panels-screens located in front of the seats that are turned to the stairs shall be as wide as the corresponding seats.
- d) The panels shall be manufactured in non-corrosion and opaque material.
- e) The finishing material shall be the same one utilized in the coating.

### **Driver' s seat**

- a) The driver' s seat (and the ticket-collector' s, if applicable) shall be provided with a safety belt, a head protection and an anatomic shape, molded in the upholstering material so as to ensure good comfort levels to an operator within the anthropometric range specified in ABNT NBR 6056/80 guideline and the complementary guidelines.
- b) The steering-wheel shall be coated.
- c) The blinker lever shall be fitted on the left side of the steering column and be provided with an automatic return.
- d) The horn shall be blown by means of a button located preferably on the steering-wheel.

### **Speedometer/odometer**

The speed indication system and at least one non-settable accumulator of the distance traveled shall be installed in a sole instrument and the unit of measure for distance shall be the kilometer (km). The speedometer shall indicate the 80 km/h speed with a 2% accuracy and be graduated with 10 km/h sections, with 5 km/h subsections just with a broken line marking.

The kilometrical accumulator shall be provided with six digits, reaching its maximum capacity at 999.999 km.

### **Tachograph/computer aided graphic recorder**

#### **Manometer**

The manometer shall measure the pressures in the air chambers of the front and back brakes independently, by means of two pointers and its scale graded from 0 to 10 bar, partitioned every 2 bar.

#### **Lighted indicators**

The dashboard shall have the following lighted indicators:

- traction;
- air brake;
- insulation of the 220 V circuit;
- motor ventilation/temperature;
- stop requested;

- reverse gear selection;
- on speed;
- high beam;
- blinker;
- parking brake applied.

### **Ventilation and air-conditioning**

The vehicle shall be provided with 2 (two) forced ventilation systems:

- ventilation/windshield defogger;
- ventilation or air-conditioning of the passengers compartment.

The supplier shall specify and quote an air-conditioning system as an option.

### **Interior communication system**

The communication between passengers and the driver shall be performed by means of the stop sign operated by means of buttons installed respectively on the posts and along the whole paid area in the vehicle.

When the stop sign is pressed for the first time, a short sound sign shall ring near the driver and lighted signs shall switch on, and that sound shall not ring another time, even if the stop sign is pressed again.

The system shall be reset when the doors are closed, after leaving the bus-stop, or by means of the reset button on the dashboard.

The lighted stop signs shall remain lighted until the doors are opened.

The lighted signs shall be amber, so that they are seen at daylight, and located on the following places:

- near the driver's seat;
- on the dashboard;
- near the mechanisms protecting boxes of the disembarking doors.

### **Interior lighting system**

The interior lighting system shall comply with the CONMETRO Resolution 01/93, utilizing fluorescent lights, preferably protected by translucent material.

### **Exterior lighting system and signaling**

The vehicle shall have:

Headlights, body demarcating lamps, brake lights, blinkers, backing lights, license plate light, equipment boxes lights.

The intensities of the whole lighting shall follow the specific ABNT guidelines and the traffic legislation.

### **Painting**

The exterior painting, interior visual communication and exterior visual communication of the vehicle shall be those determined by the EIP, whose definition will take place up to three months before the date previous to the delivery of the vehicles.

### **Accessories**

The vehicle shall be supplied with all the accessories allowing for the adequate safety conditions required by the legislation in effect.

The vehicle shall have a fire extinguisher loaded with 6 kg chemical powder, according to ABNT NB 161 guideline, and shall be installed within the driver's reach.

- Safety triangle.
- Package compartment to be used by the driver.

### **Towing devices**

The vehicle shall be provided with towing devices in both ends, so as they do not interfere in the operation and in the bumpers action.

The device shall be such that the tow bar will work with no interference with the bumper.

The vehicle shall have on its front end a connector to receive signs of the towing vehicle to switch on the backlights, brake lights and blinkers.

Near the bumpers there shall be a fast air connector for the brakes and another one for the wet chamber, when the vehicle is towed.

### **Ticket collection system**

The ticket collection system provides for the use of a ratchet wheel with electronic locks near the (front) embarking door of the vehicle.

### **Destination Electronic Panel (PED)**

The buses shall be provided with Destination Electronic Panels (DEP) in the front and side ends, being perfectly visible even under natural or artificial lights.

The messages on the panels shall be legible, with no interference impairing the free view of the route by users located at least 50 meters from the vehicle, at the extremity of 65 degrees to both sides of the perpendicular line of the center of the main plan of the messages area.

Panels with minimum 1,000 x 200 mm dimensions shall be utilized. The height of the alphanumeric characters shall not be less than 160 mm, except for extraordinary cases duly justified.

The Electronic Panel shall present the Flip Dot concept, configuring the messages by means of software-controlled lines and columns.

The DEP box shall be impervious to water, dust, dirt and insects during the usual operation or washing. In the front DEP, the glass shall be tilted 7 degrees frontward to prevent sunlight or public lights reflections, allowing for their reading under any exterior lighting condition.

The interior lighting of the panel shall be done so as to reduce reflection during the nightly use. The feeding of the panels shall be compatible with the capacity and electric offer of the vehicle.

In order to certify reliability, the equipment shall be tested for at least 12 continuous hours of operation in a 70° Celsius temperature. It shall also be qualified to operate between -5° and 70° C.

## 6 – BASIC TECHNICAL SPECIFICATIONS FOR THE HYDROGEN SUPPLY

### 6.1 – HYDROGEN QUALITY REQUIREMENTS

The hydrogen fuel cells system is still a recent technology, where the prototypes are extremely expensive, and the catalyzer applied on the cell membrane is sensitive to some elements and chemical compounds, especially to the carbon monoxide (CO) and sulphur compounds, which may cause poisoning or passivation of the catalyzers and a decrease in the efficiency of the cell, damages to the membrane and the resulting loss of the cell or of the hydrogen cells battery. Bearing in mind these considerations, the quality standards of the hydrogen fuel expounded in the following table must be strictly respected.

On the other hand, in order to increase the cell efficiency, some water must be introduced by means of the hydrogen humidification to keep the control on the conductivity of the membrane and of the electrode. A small oxygen concentration (<5000 ppm) in the fuel is also accepted to help the beginning of the oxidation.

That way, the minimum quality requirements required for the hydrogen supplied to the vehicle are:

total purity at the vehicle storage level	>99,95%
maximum CO concentration (in case it is free from sulphur)	<10 ppm
maximum S concentration (measured as H <sub>2</sub> S or SO <sub>2</sub> )	Free (<1ppm)
maximum S + CO concentration	<10 ppm
maximum N <sub>2</sub> concentration	<400 ppm
maximum HC concentration (measured as methane)	<10 ppm
maximum KOH concentration	Free (<1ppm)
oxygen addition (*)	<5.000 ppm
water addition (*)	Saturated gas in the maximum pressure

\* in the case of hydrogen produced by electrolysis, the addition of O<sub>2</sub> e and water may be considered as part of the production process, as long as it does not imply the introduction of other non-specified contaminators.

These specifications shall be necessarily followed in the case of the hydrogen placed in the vehicle containers, so the supplier shall specify in detail the procedures that it recommends in the case of transfer from intermediary containers, from the production of the gas up to the final supply of the vehicle.

### 6.2 – HYDROGEN SUPPLY BY THIRD PARTIES

In case of a supply by third parties, the hydrogen shall be supplied every two to five days, so as to ensure the continuous operation of the vehicles. That supply, estimated as a nominal hydrogen

volume of 200 kg/ day (2000Nm<sup>3</sup>/day), shall be requisitioned by EMTU-SP whenever it is necessary and at its exclusive discretion.

### **6.2.1 – SUPPLY MODE**

The bidder shall detail thoroughly the procedures, requisites and specifications of the equipments required to the hydrogen supply by third parties, to the vehicles fueling, as well as the International guidelines required in the operations. The storage conditions shall comply with what is provided for in the Chapter 8 of this Invitation to Bid.

If the hydrogen is to be periodically supplied, the storage requirement becomes obviously higher, and a subsystem must be specified, ensuring the fueling of the fleet without the risk of interruption in its operation.

### **6.3 – INSTALLATION**

If the supply of hydrogen by third parties is more convenient to the trial stage of the project (stage 2), allowing for the concentration of all efforts in the development of the bus, the garages shall be equipped with just the storage and fuel equipments for the vehicles, complying with the requirements of chapter 8 of this Invitation to Bid. EMTU-SP, with the assistance of the UNDP and GEF, will be in charge of taking that decision, in case the convenience exists.

## **7 – BASIC TECHNICAL SPECIFICATIONS OF THE HYDROGEN PRODUCTION SUBSYSTEM**

Economically speaking, one of the most promising options for the production of hydrogen is setting the subsystems in the area of the garage itself, preventing additional transportation and storage costs and gas contamination problems during the transfer from one container to another. In that case, the hydrogen production equipment shall be preferably modular, so as the investments may be progressive, according to the size of the fleet and the fuel demand.

If the production process involves a high consumption of electric power (as in the case of electrolysis), it shall be utilized out of peak times, at lower prices, and considering the largest daily operation period of time possible in order to decrease the installed power and the electric distribution network.

The production, storage and fueling facilities in the garages shall be provided with a sensor to detect hydrogen leakages, associated to alarm devices, fans and exhausters. The areas intended to such facilities shall be isolated from the other facilities and buildings.

The suppliers of all infrastructure equipment shall be responsible for their assembly, installation and maintenance during the whole development stage period (4 years).

### **7.1 – OPTIONS FOR THE PRODUCTION TECHNOLOGY**

The hydrogen to be supplied shall be obtained from renewable energy sources, and the production by means of water electrolysis is the preferred one, for it does not generate the contaminating elements mentioned above, preventing the poisoning of the cell catalyzers, remarking that the optimization of the use of electric power is part of this project' s concept. That way, the hydrogen produced by this process may be 99.95% pure, as long as the impurities contained are basically water and oxygen and free from electrolyte compounds.

## **7.2 – BASIC TECHNICAL SPECIFICATIONS FOR THE HYDROGEN PRODUCTION AND COMPRESSION SUBSYSTEM**

The equipment required to the production and compression of hydrogen shall be described as detailedly and as thoroughly as possible, indicating the following items:

- the area required to settle the hydrogen production and compression equipment;
- basic layout of the facilities, with approximate measures;
- energy consumption per kg of hydrogen produced and installed power of the equipment;
- procedures for the equipment operation, the reliability degree of the system, safeguards against occasional failures, mainly concerning the issue of gas leakage, possible risks of accidents and protection against environmental damages;
- description of the leakage monitoring system and safety alarms;
- estimate of the cost of the hydrogen placed in the containers of the garage and of the vehicle.

The equipment used in the hydrogen production subsystem by water electrolysis and their compressors shall be designed to meet the following technical requirements:

### **7.2.1 - Efficiency**

The overall efficiency of the conversion of electric power into hydrogen inner energy shall be superior to 60%, and the bidder must provide the specifications of the electrodes and their main performance features (potential difference, electrode performance curves, etc.).

### **7.2.2 – Durability and Reliability**

As a project target of the trial or development stages, in the design of each subassembly, the quantity of failures that may occur implying repairs out of the maintenance intervals shall be provided. The equipment shall not present failures interrupting their operation longer than 5 consecutive days and in intervals lower than 30 days.

The durability previewed for the equipment shall be 15 (fifteen) years or 5,000 accumulated hours of use. The supplier shall provide a 4 (four)-year warranty on the operation and be responsible for a preventive maintenance plan, including the replacement of vital parts, ensuring the supply of the subsystem with the reliability desired, and specify the terms for the replacement of components before the occurrence of failures.

### **7.2.3 – Noise emission**

The hydrogen production facilities shall comply with the legal requirements issued by the Government of São Bernardo do Campo and CETESB for industrial facilities. They shall not emit noise exceeding the 55 dB (A) level in the boundaries of the grounds where they are fitted.

### **7.2.4 – Electromagnetic noise emission**

The supplier shall ensure the protection required to prevent interferences on the equipment in the surroundings, such as pacemakers, airbags, ABS brakes, etc., besides describing and specifying the protection devices utilized with that purpose.

In the electro-electronic equipment, sensitive to the generation of electromagnetic noise impairing radio-reception, the proper filters to suppress that noise shall be provided.

The radio-interference (electromagnetic noise) levels generated by the vehicle will be subjected to the buyer' s approval.

#### **7.2.5 – Pressure of the hydrogen supplied to the vehicles**

The nominal pressure of the hydrogen supplied to the vehicles is 350 to 380 bar. The hydrogen production equipment shall meet the specifications ensuring the resistance, the imperviousness and its perfect operation under those pressures, and supply the gas in such a way that the pressure will be maintained during the whole fueling period of the vehicles, without creating conditions likely to impair the operation.

#### **7.2.6 – The area occupied by the facilities**

The area occupied by the facilities shall not exceed 70 m<sup>2</sup>.

#### **7.2.7 – Safety Guidelines**

The supplier shall specify the Safety Guidelines utilized and manifest the compliance of his product with those guidelines, indicating the types of sensors utilized and their location, as well as the conception of the monitoring and safety system concerning leakages.

It is advisable that the subsystem control devices have diagnostic indicators of defects, hydrogen leakages and other safety items, and that there are integrated control and supervision devices.

#### **7.2.8 - Painting**

The exterior painting of the facilities will be determined by the EIP, whose definition will be made up to 3 months before de date previous to the subsystem delivery.

### **7.3 – REQUIREMENTS OF THE HYDROGEN PRODUCTION AND COMPRESSION SUBSYSTEM**

The supplier shall specify all the requirements of its product that will demand changes in the garage fittings, such as electric and hydraulic fittings, the need of heat exchangers, etc.

Those specifications shall be previously approved by EMTU-SP and all changes shall be conducted by the transportation operator, with project allowances provided with that purpose, supervised by EMTU-SP.

### **7.4 – OPTIONS FOR THE HYDROGEN PRODUCTION TECHNOLOGY**

In case the suitable hydrogen production subsystems aren' t offered, EMTU-SP shall opt, at its own discretion, for the production of hydrogen from renewable energy sources and produced by means of any other commercially proved process, as long as the basic purity specifications described above are maintained.

Equipment based on other commercially proved processes (ex.: biomass or ethanol gasification) may be proposed for evaluation and shall necessarily respect the specifications mentioned previously, concerning the quality of the hydrogen produced and the minimum standards of contaminating elements and compounds. In addition, they shall comply with the requirements concerning electrolyzers, when applicable, or with similar requirements concerning their performance, durability, etc.

Additionally, in processes that cause pollutant emissions, the facilities shall comply with the environmental and occupational requirements that may be applied to the garage environment, besides being unable to create adverse conditions to its operation.

## **8 – BASIC TECHNICAL SPECIFICATIONS OF THE HYDROGEN STORAGE AND SUPPLY SUBSYSTEM**

The hydrogen storage shall be performed as a gas, under a 350bar pressure. One must take into account that the vehicles fueling will be made during the night period and the hydrogen production will take place 20 hours per day. The fuel shall be stored in a quantity ensuring the vehicles fueling for 10 (ten) consecutive days and, when it is supplied by third parties, in the proper frequency so as to prevent interruption in the vehicles operation.

The suppliers shall present the procedures required to the hydrogen storage subsystem operation and vehicles fueling, including the supply frequency and the minimum stock of the fuel.

The suppliers of all infrastructure equipment shall be responsible for their assemblies, fittings and maintenance for the whole period comprised by the second stage (4 years).

Those fittings shall be provided with sensors to detect hydrogen leakages, connected to alarm devices, fans and exhausters. The areas previewed for such fittings shall be isolated from the other facilities and buildings.

### **8.1 – THE REQUIRED EQUIPMENT**

The equipment required to the hydrogen storage and its transfer to the vehicles shall be described as detailedly and thoroughly as possible, indicating the following items:

- the area required to install the equipment for hydrogen storage and transfer to the vehicles containers;
- basic layout of the facilities, with approximate measures;
- energy consumption per hydrogen kg transferred to the vehicles (in case there is an additional pumping) and the installed power of the equipment, if it is applicable;
- the procedures for the equipment operations, the degree of reliability of the system, safety in case of occasional failures, mainly concerning the gas leakage issue, possible accident risks and protection against environmental damages;
- description of the leakage monitoring and safety alarms systems;
- estimate of the cost of the hydrogen placed in the vehicle container.

The consumption capacity forecasted is 70 to 200 kg/day, in the pilot trial stage with 3 to 8 buses, respectively.

The equipment shall be designed to meet the following requirements:

#### **8.1.1 – Durability and reliability**

As a project target of the trial or development stages, in the design of each subassembly, the occurrence of failures causing an interruption in the fueling operation implying repairs out of the maintenance intervals shall be prevented.

The durability previewed for the equipment shall be 15 (fifteen) years or 5,000 accumulated hours of use. The supplier shall provide a 4 (four)-year warranty on the operation and be responsible for a preventive maintenance plan, including the replacement of vital parts, ensuring the supply of the subsystem with the reliability desired, and specify the terms for components replacement before the occurrence of failures.

### **8.1.2 – Noise emission**

The hydrogen fueling operation shall not produce noise exceeding the 55 dB(A) level in the boundaries of the grounds where it is fitted.

### **8.1.3 – Resistance to pressure and imperviousness**

The hydrogen storage and vehicles fueling system shall meet the specifications ensuring the resistance and imperviousness for a 350bar nominal pressure.

### **8.1.4 – The area occupied by the facilities**

The area occupied by the hydrogen storage facilities and transfer to the vehicles shall not exceed 30 m<sup>2</sup>, and must be suitably designed so as to ease the access and moving of the vehicles to be fueled.

### **8.1.5 – Safety Guidelines**

The supplier shall specify the Safety Guidelines utilized and manifest the compliance of his product with those guidelines, indicating the types of sensors utilized and their location, as well as the conception of the monitoring and safety system concerning leakages.

It is advisable that the subsystem control devices have diagnostic indicators of defects, hydrogen leakages and other safety items, and that there are integrated control and supervision devices.

### **8.1.6 – Painting**

The exterior painting of the facilities will be determined by the EIP, whose definition will be made up to 3 months before de date previous to the subsystem delivery.

### **8.1.7 – Emergency supply**

In order to ensure the ongoing buses operation during a period of occasional failure in the hydrogen production, the garage storage subsystem shall allow for the gas supply by third parties. That is the sole emergency instance in which the supply of hydrogen that has not been produced by a renewable source shall be accepted.

## **8.2 – OPERATIONS PROCEDURE FOR THE VEHICLES FUELING**

Handbooks shall be provided containing the operations procedure for the vehicles fueling, the measures required to prevent gas contamination, accident prevention and procedures in case of accidents, as well as training courses for the fueling subsystem operation and explanations concerning the risks of the hydrogen and/or equipment handling.

The supplier shall indicate in detail the rates and parameters characterizing the performance in the vehicles fueling, mainly concerning the storage volume, number of vehicles that may be sequentially fueled, fueling time for each vehicle, considering the first and the last vehicle fueled in the sequence.

The bidder shall also provide an estimate of the number of employees and the qualification required from those who will operate the fueling subsystem. All cost and personnel estimates shall take into account the assumption of work for 3, 10 and 200 vehicles.

## **9. COMPLEMENTARY CONDITIONS**

### **9.1 – TRAINING**

Technical and operations handbooks for all the equipment fitted shall be provided, besides a specific training concerning the systems operation. In addition, the specific safety guidelines shall be described for the equipment installed and procedures in case of accidents.

Training courses for the personnel belonging to the Operator Company, indicated by the EIP, shall be scheduled, on the technologic concepts of the systems acquired and on the operation and maintenance procedures of the equipment and vehicles, with an annual updating and with a frequency to be established in agreement with the EIP, during the whole trial period.

### **9.2 - MAINTENANCE**

The suppliers or supplier consortium of the main systems and subassemblies shall offer to the EIP the maintenance procedures, the training programs and permanent technical support with a residing engineer, placed at the EIP disposal.

The fittings in the garages for the maintenance of the vehicles shall be provided with sensors to detect hydrogen leakages inside the garage, connected to alarm devices, fans and exhausters. The area previewed for the maintenance of the hydrogen buses shall be isolated from the areas where the other buses circulate.

For each subsystem a detailed Preventive Maintenance Plan of the equipment and components installed shall be presented, in which the terms for the replacement of parts and equipment **before** the occurrence of failures shall be specified.

As to the fixed fueling systems, those shall not present severe failures resulting in hydrogen leakage, with the risk of severe accidents. Other failures whatsoever that may occur out of the maintenance interval shall be forecasted, specified, duly quantified and the corrective procedures shall be clearly established. The occurrence of such failures shall not, under any circumstance, compromise the bus transportation operation system.

The average effective life of the production, storage and fueling subsystems shall be at least 15 years. Taking into account that the small pieces of equipment and components may be replaced more frequently, the main equipment subassemblies shall last longer than that.

The manufacturer shall indicate the reliability predicted in its project, which will be an object of scoring.

### **9.3 – SPARE PARTS**

The suppliers shall propose plans for the replacement of parts, both for preventive maintenance and in the case of failures, so as to ensure the full operation of all pieces of the equipment and, in the case of failures, brevity in the repairs that may be required, preventing occasional detriments to the bus transportation system.

### **9.4 – SAFETY PROCEDURES**

The suppliers of all subsystems, mainly those associated with the hydrogen, shall provide the safety procedures and recommendations required to their operation, as well as the overall safety of the full garage facilities. The recommendations shall include those related to the recommended distances from other pieces of equipment.

