PROJECT BRIEF

1. IDENTIFIERS

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

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.

3. COSTS AND FINANCING (MILLIONS US$)

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

4. OPERATIONAL FOCAL POINT ENDORSEMENT

Name: Antonio Gustavo Rodrigues
Organization: Ministerio Do Planejamento, Orcamento E Gescao Secretaria de Assuntos Internacionais

Title: Secretario Adjunto de Assuntos Internacionais
Date: 29 September 1999

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

1. BACKGROUND AND CONTEXT

1.1 The environmental benefits of hydrogen fuel cell urban buses

1. Diesel-engined 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.

2. Hydrogen fuel cell buses now offer a technological solution to these problems. 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.

3. Hydrogen fuel cell buses are already operational in experimental revenue-earning service (3 with the Chicago Transit Authority and 3 with B.C. Transit in Vancouver). These buses are adaptations of a standard North American diesel bus, with engine and drive train replaced by fuel cell stacks and an electric drive train. The Chicago buses are fuelled from a liquid hydrogen store and those in Vancouver by electrolysis of water in the bus garage. Thus the technological feasibility of building, operating and fuelling hydrogen fuel cell buses has been demonstrated. Analysis carried out during the PDF work leading to this proposal indicates that fuel cell buses have the potential, in the next decade, to become cost-competitive with diesel buses on a lifecycle basis. The challenge now is to achieve this cost target, particularly in developing countries, and the environmental benefits that will result from large-scale deployment of the technology.

1.2 Barriers to large-scale deployment

4. 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 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 buses 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 buses; and
- The lack of public awareness of and support for the new technology.

5. 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.

6. 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% (6.8 million daily person-trips)
Private car 33% (6.6 million daily person-trips)
Bus 25% (5 million daily person-trips)
Commuter rail and Metro 8% (1.6 million daily person-trips)

7. The large share of journeys made 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 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.

8. Despite major efforts over three decades to tackle atmospheric pollution, the SPMR continues to have major problems with air quality, which drops below acceptable standards during 140 days per year. The region consumes more energy in the form of automotive liquid fuels than as electric power. Moreover, considering the low efficiency of internal combustion engines, thermal losses alone, from the vehicle fleet, slightly exceed electric power consumption. Diesel engines in trucks and buses account for a significant contribution to toxic emissions:

Over 25% of carbon monoxide;
20% of unburnt hydrocarbons;
80% of nitrogen oxides;
75% of sulfur oxides; and

30% of particulates.

9. 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.

10. 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.

11. The SPMR is capable of absorbing 500 high-technology buses per year, as part of its normal fleet renewal programme 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. Existing electrolyser technology makes it possible to generate the hydrogen fuel economically and safely within the bus depot. In Brazil, 92% of electricity generation is from hydro-power. There is enough surplus overnight electric power capacity in the SPMR to fuel 12,000 buses. There is already substantial experience of re-fuelling with high-pressure gaseous fuel, through the fleet of over 300 CNG (compressed natural gas) buses operating on a daily basis in the SPMR.

12. 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.

13. Thus, the SPMR and the actions planned within it in the near future offer among the most favourable 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.

1.4 Further expansion potential

14. 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.

15. 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 Marco Polo and Busscar. Brazil exports significant numbers of buses to the rest of Latin America and even to Europe.

16. 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.

17. 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 major exports. 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.

18. 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) Revival of the PROÁLCOOL program (generation of fuel for cars from renewable resources), which has suffered since the early 1990's due to a push to encourage more use of gasoline in cars in order to better balance the refinery's diesel-gasoline production mix and from a lack of consumer confidence in ethanol availability that has led to a near cessation of demand for new ethanol vehicles.

d) Potential for extension of hydrogen fuel cell drive-lines into other urban-based vehicles, such as delivery and other fleet trucks;
e) Stimulus to the development of fuel cell powered cars and light trucks, using on-board ethanol reformers;
f) Stimulus to the development of sources of hydrogen other than from electrolysis, such as biomass;
g) General stimulus of demand for the development of renewable energy resources; and
h) Reinforcement of strategies for the development of public transport.

Furthermore, it will strengthen the core basis of experience with renewable energy technologies in Brazil, Latin America and the world. It will also provide an exemplary boost to the development of public sector/private sector initiatives.

19. 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_2 emissions.

20. 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_2 emissions per year (0.845 m tons C). (Eliminated tailpipe CO_2 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_2 emissions by 1.6 million tons per year (0.436 m tons C). (This assumes an efficiency for the fuel cell buses of 8 kg H_2 per 100 km, which has recently been demonstrated at the prototype level).

21. 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_2 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_2 per bus-year (35.7 t C), and emissions associated with hydrogen fuel cell buses would be 66 tCO_2 or 18 t C per bus-year).

22. Sustainability will be ensured through the building up of national/regional capabilities, which will continue well after the involvement of GEF. It is anticipated that GEF support through either IFC or the World Bank will be required beyond support for the project proposed in this document for achievement of the programmatic goals of this initiative. As this project proceeds through project document preparation and finalization, the World Bank, IABD, and IFC will be

involved with the goal of ensuring their participation in Phase III of the Brazilian program.

2. RATIONALE AND OBJECTIVES FOR THE PROJECT

2.1 Project Objectives

23. 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. It has been designed to be consistent with GEF Operational Program 11 "Promoting Sustainable Transport".

24. 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.

2.2 The overall hydrogen fuel cell bus program

25. The proposed project is the next step- Phase II - in a complete program, the phases of which are summarized in the Figure 1 below:

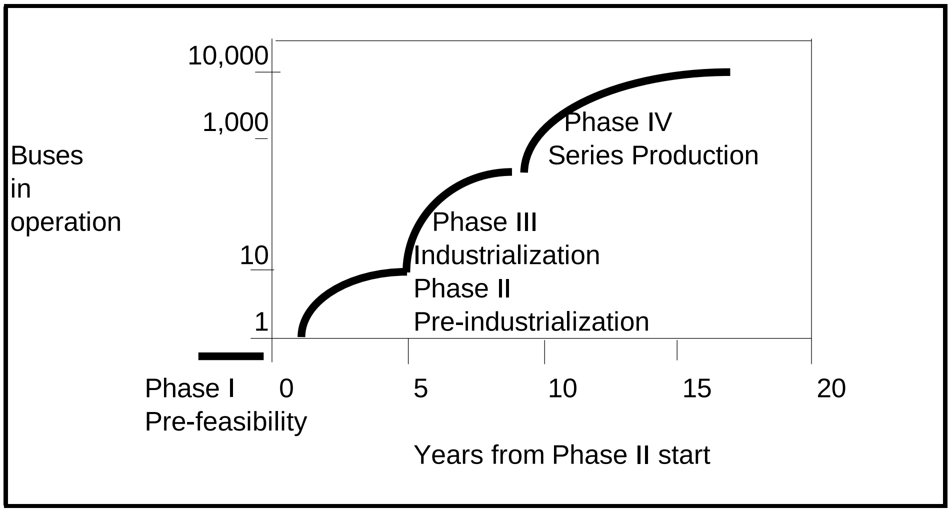
a) The Phase I pre-feasibility study has been completed. (*The arguments presented in Section 1 of this proposal are condensed from the Phase I final report);*

b) Phase II – the subject of this proposal - 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. This phase will require further GEF support to compensate for the remaining incremental costs of these buses; and

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

2.3 Size, duration and location of the Phase II project

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

1) 1 million vehicle-kilometres 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 kilometres, 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.

27. 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 (mean time between failures) and FMA (failure mode analysis), at the end of the 4rd 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.

3. PROJECT ACTIVITIES AND EXPECTED RESULTS

3.1 Phase II project outputs

28. The results of the Phase II 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: 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 5: Increased awareness and support of the public for an increased role for fuel cell buses in Brazil's urban transport system.

3.2 Phase II Project activities

29. In order to achieve the results listed above, fifteen activities are being proposed. The first activity, Activity 0, will involve the finalization of the work-plan, project document and monitoring and evaluation plan for the project. The proposed activities are listed below:

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: 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 1.4: 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.

Activity 1.5: 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 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.

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, analyse, 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.

Activity 4.1: 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 4.2: 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 4.3: 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 evaluation of the Phase II project, according to GEF procedures.

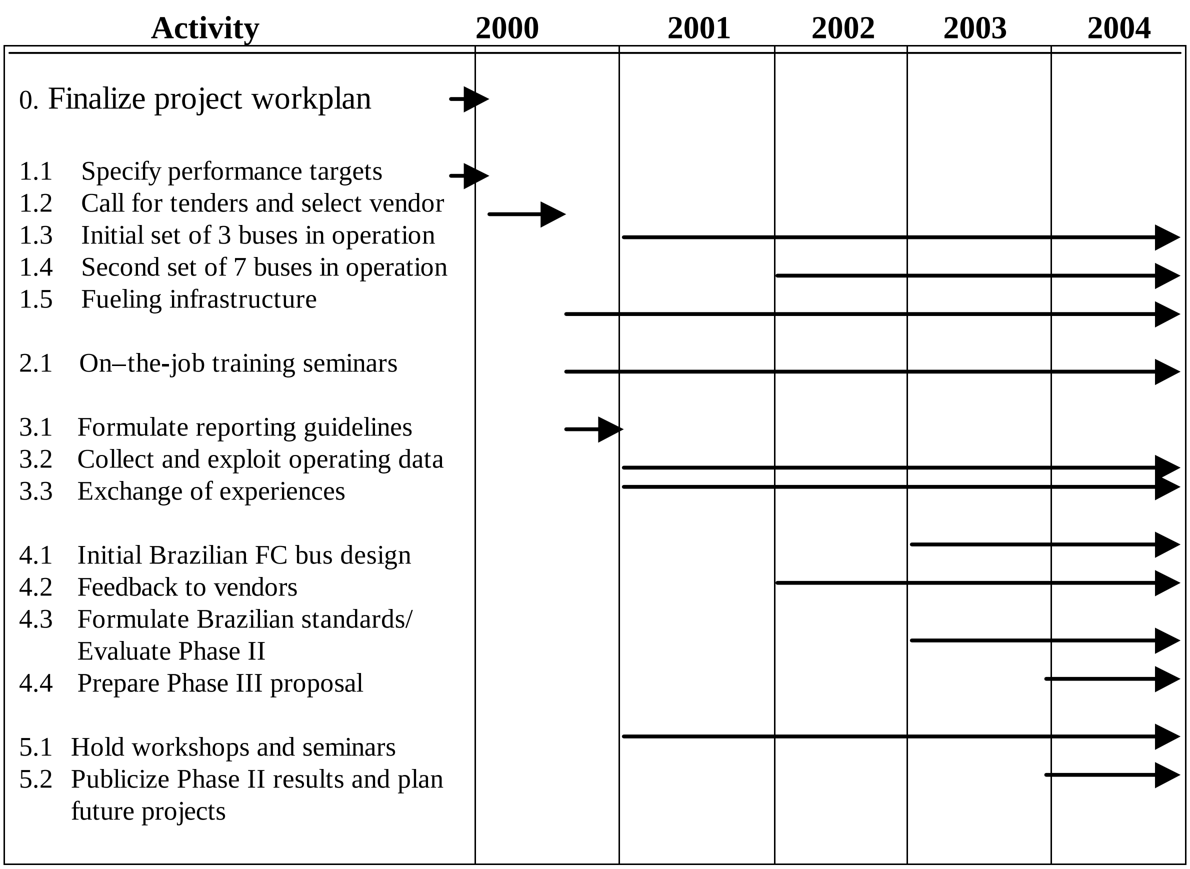
Activity 4.4: Prepare proposal for Phase III Project—Taking into account the Phase II experience and the independent evaluation, the project team will prepare a proposal for a Phase III project. (GEF resources will not be devoted to this activity). Phase III is expected to involve the procurement and 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).

Activity 5.1: 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 5.2: 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.

The sequence of the Phase II project activities and their timing are summarized in Fig. 2:

Figure 2: Phase II project time chart



4. RISKS AND SUSTAINABILITY

30. 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.

31. 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.

32. 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.

33. 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.

34. 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 and 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.

5. STAKEHOLDER PARTICIPATION AND IMPLEMENTATION ARRANGEMENTS

5.1 Stakeholder participation in the PDF phase

35. The project has been conceived and designed (in the PDF phase) with the involvement of a wide range of Brazilian institutions, all of which are expected to participate in the implementation phase, as discussed in the next section. There have also been extensive consultations with potential equipment suppliers to evaluate their interests and capabilities in participating in Phase II and beyond.

5.2 Implementation arrangements

36. The following institutions, which will be involved in implementation of the project, were also involved or consulted during the PDF phase:

1) The coordinating and supervising 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);

2) 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;

3) 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;

4) USP (the University of São Paulo) will provide technical backstopping, as it did during the PDF phase;

5) FINEP (Financing Institute for Studies and Research), under the Federal Ministry of Science and Technology is expected to provide national financial participation. CESP, CEMIG and COPEL (the State Energy Companies of São Paulo, Minas Gerais and Paraná) or their successors will participate as electrical energy providers;

6) The participation of ANEEL (Agência Nacional de Energia Elétrica - National Agency for Electrical Energy) and ANP (Agência Nacional do Petróleo - National Petroleum Agency) is also expected – both of these agencies coming under the direction of the Federal Ministry of Mines and Energy.

7) In addition to the above agencies, EMTU/SP will ensure input of the bus-riding public through the use of focus groups or ridership surveys for those of its customers riding the routes to which the fuel-cell buses are assigned. These tools will be used to gauge the reaction of the public-at-large--and especially of bus riders--to this new technology.

5.3 Institutional Contributions

5.3.1 Brazilian contribution

37. Brazilian institutions will make major contributions to this project:

a) The efforts of the Brazilian project team in defining the project, setting the product specifications, negotiating the procurement of equipment and managing the project as a whole;
b) Experience in engineering and operating electric trolley-buses;
c) The loan of EMTU/SP personnel and facilities during the three years of operation and analysis;
d) Financial and political support to the project;
e) Promoting the new technology in the SPMR, elsewhere in Brazil and world-wide; and
f) Making the results of Phase II available to the world operator and vendor community.

In return, they will be strengthened in:

a) Their capability to assimilate and ultimately manufacture fuel cell buses and hydrogen supply systems in Brazil;
b) Their ability to organize and manage the later Phases of the program;
c) Their visibility and reputation within the state of São Paulo, nationally and internationally; and
d) Their ability to promote broader applications of this and other renewable energy technologies, in Brazil and elsewhere.

5.3.2 Vendor contribution

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

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

In return, they will gain:

1) Invaluable experience and a strong reference in the application of their technologies;
2) Unique feedback into their product and process development;
3) Accelerated product and process development, with reduced risk;
4) A possible head-start in bidding for Phase III involvement; and
5) A reinforced positioning against other opportunities in Brazil and elsewhere.

5.3.3 GEF contribution

39. The GEF's contribution will be to:

- **a)** Bridge the incremental cost gap between the baseline cost of EMTU/SP operating an equivalent number of diesel buses and that of mounting the 4-year test and development program with 8 (3+5) fuel cell buses and their fuelling infrastructure;
- **b)** Provide an important incentive for the committed involvement of the vendor(s), including their taking a financial stake in the project;
- **c)** Propose financing mechanisms through which such a stake might be achieved, e.g. having the vendors provide the vehicles to EMTU/SP on a lease basis, with or without option to acquire at the end of the lease period, with the lease terms including technical service support; and
- **d)** Enable the accelerated commercialization for São Paulo, Brazil and elsewhere of a low GHG emitting technology that promises to be a cost-competitive option for public bus service over the long term.

In return, it will gain:

- **a)** Unique experience in being the enabler of a major new technology;
- **b)** Reinforced visibility and credibility;
- **c)** Accelerated cost-reductions in a clean energy/transport technology increasing the ability of other GEF programme countries to access the technology at a lower cost; and
- **d)** Reduced GHG emissions in long term.

6. INCREMENTAL COSTS AND FINANCING ARRANGEMENTS

40. The incremental cost calculations are discussed in detail in Annex I of the proposal. 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 one million vehicle-km over the three-year demonstration period. As detailed in Annex I 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.

41. 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..

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

1) The Brazilian Government contribution will comprise US$ 5.0 million in cash (plus the already committed US$262,600 PDF-B contribution);
2) EMTU/SP will contribute US$1.3 m (in-kind) in the form of bus operation and maintenance;
3) EMTU/SP will contribute US$1m (in cash) in the form of future fares from the fuel cell buses;
4) The private sector , in this case, the technology providers, will provide US$1.6m as a contribution, through the residual value of the vehicles at the end of the 4 year test (perhaps via a lease); and
5) GEF will provide US$12.274m (plus the already committed PDF-B of US$324,124).

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	Government of Brazil	EMTU/SP in-kind	EMTU/SP cash	Private Sector	TOTALS
Subcontract [a]	11.685	2.881	0.0	0.0	1.600	16.166
Equipment	0.0	0.0	0.0	0.0	0.0	0.0
Training[b]	0.0	0.0	0.323	0.075	0.0	0.398
Travel[c]	0.0	0.168	0.0	0.0	0.0	0.168
Other[d]	0.589	1.951	0.983	0.925	0.0	4.448
TOTALS	12.274	5.000	1.306	1.000	1.600	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.

7. MONITORING AND EVALUATION PLAN

43. The monitoring and evaluation plan for the project will be based on pre-agreed benchmarks, to be developed by the project team, consistent with the project objectives and procurement specifications. A proposed set of benchmarks is listed below:

1. Preparation of a detailed work-plan, showing the milestones and benchmarks;
2. Timely execution of specification-setting, solicitation and procurement activities in the first year;
3. Delivery and commissioning of buses, fuelling system, spares inventories, software, etc in the second and third years;
4. Quarterly reports on achievement of hours and kilometres of operation by individual vehicles and the fleet;
5. Quarterly reports on the availability of vehicles and on fuel consumption;
6. Quarterly reports on MTBF (mean time between failures) and FMA (failure mode analysis), for both vehicles and the fueling system;
7. Quarterly reports on proposed engineering modifications and the communication of these to vendors, plus confirmation of actions taken;
8. Quarterly reports on operator and maintenance personnel training and achievement;
9. Annual review of progress towards cost reduction, reliability improvement and increased durability; and
10. Annual records of communication activities: participation in international meetings, information dissemination within Brazil.

44. The indicators listed in Annex 2 (log-frame matrix) will be further defined and specified during the formulation of the project document.

7.1 Lesson Learned From Previous Experiences

45. The design of this project has benefited in the first instance from the EMTU's experience of developing trolley buses for use in the Sao Paolo 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 focuses 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 for between 1 and 1.5 million km to obtain a sufficient sample size of experiences to verify the potential utility of the technology. For this reason, the goal that has been set is to obtain one million vehicle kilometers of experience.

46. The design of this project has also 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. However, the Vancouver demonstration is at a relatively earlier stage than that of Chicago, so that the operational experience is more limited.

47. 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.

48. In recent months, the state of California has announced its intention to work with an ambitious demonstration of fuel-cell buses and vehicles. However, as the details of this agreement have yet to be fully negotiated, it is still too early to draw any lessons from this experience.

LIST OF ANNEXES

Annex A. **Incremental Cost**

Annex B. **Logical Framework**

Annex C. **STAP Roster Technical Review**

Annex C1. **Response to STAP/Council/IA comments**

OPTIONAL ANNEX:

Annex D **Notes on Projects**

Additional Material Available Upon Request

R. Hosier and E. Larson, October, 1999. "GEF Participation in Fuel Cell Bus Commercialization," Discussion Paper available from UNDP GEF, New York.

Ministry of Mines and Energy, May 1999. "Environmental Strategy for Energy: Hydrogen Fuel Cell Buses for Brazil (ESE/HB): Final Report on Phase I-- Pre-Feasibility Study". BRA/97/G41, UNDP GEF; EMTU Sao Paolo and University of Sao Paolo. UNDP GEF, New York and Brasilia.

World Bank User

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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 Paolo 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 Paolo is estimated to emit 18 g of CO; 13 g of NO_x; 1.2 g of SO_x; 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_x emissions; 1.1 tonnes of SO_x emissions; 2.7 tonnes of HC emissions; and 1560 tonnes of CO_2 emissions. In addition to these local pollutants, diesel buses emit approximately 1.1 kg of CO_2 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 Paolo 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 Paolo alone, this amounts to nearly 1.5 million tons of CO2 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_2 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_2 per bus-year (35.7 t C), and emissions associated with hydrogen fuel cell buses would be 66 tCO_2 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 NO_x, 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 Hydrogen Fuel Cell Bus Project Phase II:
Estimation of Costs, Incremental Costs and Financing
(See Annex D for Project Cost notes.)

Fuel Cell Bus Budget **(1000 US$ -- Nov. 1998)**	**Baseline Costs**	**Project Costs** (TOTAL)	**Sources of Finance**				
			Brazilian Sources			*Private*	*GEF*
			EMTU in-kind	Fares	Other		
Investment							
Vehicles(amortization) (a)	275	13285				1600	11685
Electrolyzers (b)		1300			1300		
H_2 storage (c)		300			300		
Garage modifications (d)		40			40		
Additional power equip. (e)		30			30		
Monitoring, etc. (f)		1800			1211		589
SUBTOTAL	275	16755	0	0	2881	1600	12274
Operating costs							
Diesel fuel	141						
Electric power (g)		233		233			
Electrolyzer maint. (h)		40		40			
Vehicle maint. (parts) (i)	67	119		119			
Operating personal (j)	776	776	776				
Administration (k)	66	66	66				
Staff training (salaries) (l)		323	323				
Facilities amortization (m)	44	44	44				
SUBTOTAL	1093	1601	1209	392	0	0	0
Info. Dissem. & exchange							
National seminars (n)							
Salaries		55	55				
Registration fees		23		23			
International seminars (o)							
Salaries		23	23				
Travel & expenses		108			108		
Other int'l travel (p)							
Salaries		19	19				
Travel & expenses		60			60		
Workshops Sao Paulo (q)		75		75			
Advertisement (r)		300		300			
SUBTOTAL	0	663	97	398	168	0	0
SUBTOTAL	1368	19,019	1306	790	3049	1600	12274
Contingency (s)		2161		210	1951		
TOTAL	**1368**	**21,180**	1306	1000	5000	1600	12274
		100%	6%	5%	24%	7%	58%
	Incremental	→19,812					

Table I-2 Incremental Cost Matrix

	Baseline	GEF Project	Increment
National impact	• Public transit in Sao Paolo continues its heavy reliance on diesel buses. • Diesel fuel consumption continues. • Emissions from Diesel Buses: CO emissions .= 18 g/km NO_x emissions .= 13 g/km SO_x emissions. = 1.2 g/km HC emissions. = 2.9 g/km Particulates =. 0.8 g/km	• Commercial development of FCB's accelerated through GEF support. • Brazilian assimilation of FCB technology accelerated. • Zero CO, HC, NO_X, SO_2 and particulate emissions per vehicle-km. • Reduced wasted heat emission	• Commercial development of FCB's accelerated through GEF support. • Brazilian assimilation of FCB technology accelerated. • Diesel fuel use reduced. • Avoidance of CO, HC, NOx, SOx, and Particulate emissions from diesel bus traffic.
Global impact	• Diesel Bus Emission: CO_2 emissions = 1,100 g/km or 300 g C/km. .	• Zero CO_2 or Carbon emissions. • Fuel cell bus cost reduction and commercialization accelerated. • "Southernization" of fuel cell bus technology accelerated.	• Significant quantities of CO_2 or Carbon emissions avoided. • Fuel cell bus cost reduction and commercialization accelerated. • "Southernization" of fuel cell bus technology accelerated.
Cost	• EMTU/SP in-kind = $1.305 million • EMTU/SP cash = $0.063 million **Total = $1.368 million**	• EMTU/SP in-kind = $1.306 million • EMTU/SP cash = $1.000 million • Brazilian local = $5.000 million • Private sector = $1.600 million • GEF = $12.274 million **Total = $21.180 million**	• EMTU/SP in-kind = 0 • EMTU/SP cash = $0.937 million • Brazilian local = $5.000 million • Private sector = $1.600 million • GEF = $14.474 million **Total = $19.812 million**

Annex B

Table 2.1 The logical framework (logframe) matrix

	(1) Programme or project summary	(2) Indicators	(3) Means of verification	
Development objective	To reduce GHG emissions via the introduction of a new energy source and propulsion technology for urban buses	CO_2 emissions from São Paulo buses decreased by 1560 tonnes over the project's life-time		
Immediate objective	To demonstrate the operational viability of fuel cell drives in urban buses and their refuelling infrastructure under Brazilian conditions	Ten buses are operated for one million vehicle-km so that operational statistics can be gathered	Final project report	
Output 1 Activities	A significant fleet of fuel cell buses operated over a meaningful test period 5.1 Specify technical performance targets 5.2 Tender and select vendor for bus provision 5.3 Place initial set of 3 buses in operation 5.4 Place second set of 7 buses in operation Install, operate and maintain refueling infrastructure	Buses operate according to pre-specified levels (hrs or km per year)— Breakdowns are limited in frequency to acceptable levels (<50,000km between breakdown) Refueling station operates satisfactorily to supply sufficient H2 at reasonable cost	Annual and final project reports Vehicle log books and records	As car cor sat Ris
Output 2 Activities	Operators trained to operate and maintain fuel cell buses 5.1 Hold on-the-job training seminars for drivers and maintenance staff	Number of operators/maintenance staff trained Enrollment in training seminars	Quarterly and annual project reports	
Output 3 Activities	Substantial body of experience-based knowledge on the operation of fuel cell buses on hydrogen is acquired	Development of quarterly reporting forms Persons consulted in formulating reporting	Quarterly and annual project reports	

	5.1 Formulate guidelines for quarterly reporting on in-service performance of buses 5.2 Collect, analyze and evaluate operating data on reliability, failure and potential improvements 5.3 Exchange experiences with Chicago, Vancouver, and other users of fuel cell buses	guidelines Quarterly reports collected Publication of documents demonstrating accumulated experience and knowledge	Project files and history	
Output 4 <u>Activities</u>	Proposal for Phase III Project 5.1 Develop initial Brazilian bus design for hydrogen-powered fuel cell buses in Brazil 5.2 Provide feedback to vendors to improve future bus designs 5.3 Formulate Brazilian standards for hydrogen fuel cell buses for urban transport Prepare proposal for Phase III project	Satisfactory preparation of Phase III proposal based upon Phase II experience, reconfigured bus designs, Brazilian standards and continued dialogue with vendors	Quarterly, annual and final project reports	
Output 5 <u>Activities</u>	Enhanced public awareness and understanding of the potential role of fuel cell buses 5.1 Hold workshops & seminars to publicize results 5.2 Use media to publicize results of project and future plans	Number of local, national and international workshops/seminars held and attended Number of professional publications produced Number of reports in media	Project reports Project files Publications produced	
Inputs	3-year, 10-bus test . Based in a single bus garage in São Paulo. Electrolytically-generated hydrogen fuel, based on renewable hydraulic energy resource Cost: Approximately US$24m			

Annex C
STAP Roster Technical Review

Dr. Mark Delucchi
Institute of Transport Studies
University of California, Davis

OVERALL ASSESSMENT OF PROJECT BRIEF

A well thought-out, generally worthy proposal. As the proposers note, much depends on the assumption that the returns to scale and technological"learning" provided by large-scale production eventually will make the lifecycle cost of fuel-cell buses (FCBs) close to that of diesel buses.

However, this assumption, and several related to it, are open to more question than the proposers acknowledge. (I discuss this more later.) Although I do not think that this is any reason at all to scrap or substantially modify the project, I do think that the GEF needs to continually re-evaluate the long-term potential of this transportation pathway.

RELEVANCE AND PRIORITY

There is no question that FCBs powered by non-fossil hydrogen have the potential to greatly reduce lifecycle emissions of greenhouse gases, along with emissions of urban air pollutants. Thus, hydrogen FCBs, unlike some other bus fuel/technologies (e.g., diesel-cycle engines using liquid fuels derived from natural gas), do not involve environmental tradeoffs (e.g., climate vs. urban air quality). However, these benefits of FCBS will be realized only if the lifecycle cost of hydrogen FCBs is competitive. Assuming that it is not unreasonable to anticipate that long-term cost reductions will make FCBs competitive, one then reasonably can believe that hydrogen FCBs have great long-term environmental potential, and hence that is important for the GEF to support their development.

BACKGROUND AND JUSTIFICATION

Considering that these proposals are supposed to be pithy, the background and justification seems of appropriate length. Naturally, one can challenge the assumptions, arguments, and analyses at any point (I do a bit of this later), and in effect demand something tantamount to a full-fledged analysis of alternatives (that is, beyond just diesel, electric trolley, and FCB), but this does not seem to be what is required here.

SCIENTIFIC AND TECHNICAL SOUNDNESS

The project involves three major analytical areas with which I am reasonably familiar, and several technical/managerial areas with which I am not familiar. The analytical areas are: lifecycle environmental impact analysis (urban air pollution, global warming), lifecycle private-cost analysis, and social (or environmental) cost analysis. In general (i.e., not in this particular proposal), all of these analytical areas involve a good deal of uncertainty, and are the subject of much academic debate. In this particular case, the environmental claims, as delimited, and ignoring second-order impacts, are straightforward: "hydrogen FCBs have no major environmental impacts". The private lifecycle cost analyses are competent but subject to some criticisms, and the social-cost analyses or claims are merely illustrative.

Environmental impacts: it is unarguable that hydrogen FCBs will improve urban air quality. However, the matter of GHG emissions is a bit more complicated. I discuss this in a separate section below.

Private lifecycle costs (estimated in Pre-Feasibility Study, and Hosier/Larson paper): Really, this is the crux of the project. If there is no basis at all for believing that hydrogen FCBs will be cost competitive under high volume, then arguably there is little reason for GEF to be involved. Conversely, if the analyses and claims of the papers are reasonable -- if it really seems likely that hydrogen FCBs can be cost competitive -- then this indeed is an excellent technology for GEF to support.

Their private lifecycle cost analysis (in Hosier and Larson) turns on several key estimates and assumptions: i) that the manufacturing cost of fuel cells will decline, with volume and learning, to under $100/kW; ii) that the FCB will have a longer life than does a diesel bus (this lowers the annualized capital cost); iii) that FCBs will have lower maintenance and repair costs; iv) that low-cost power is available to electrolyze water; and v) (implicitly) that there are no other lifecycle cost differences.

i) The Hosier/Larson paper shows an estimate of $85/kW for the price of afuel-cell stack. Assuming that this is a retail-level price (which of course it ought to be), it corresponds to something on the order of $40/kW manufacturing cost, which is consistent with a recent, detailed costanalysis for PEM stacks. The estimate thus is reasonable, albeit perhaps optimistic. However, at $85/kW and 265 kW, the stack accounts for a minority of the $100,000 initial cost increment for the FCB. Presumably hydrogen storage and the electric drive account for the rest. But this seems way too high to me. Perhaps the cost estimates do not assume cost reductions for the electric drive or H2 storage (?). I would estimate that the total incremental cost of the drive train and hydrogen storage should be well under $50,000 under high volumes.

ii) Hosier/Larson assume that the FCB lasts as long as does an electric trolley bus, which is 50% longer than a diesel bus lasts. This does not seem reasonable. In the first place, I don't think that the FCB should be compared with an electric trolley bus, but rather should be presumed to be a diesel bus with the engine changed out. The new engine -- i.e., the electric drive -- arguably might tend to last longer than the diesel engine itself. Maybe, just maybe, 50% longer. But even if it does, a 50% increase in the life of a minor cost component will not translate into a 50% increase in the life of the vehicle. I would recommend a 10-15% increase in the life.

This, as you know, is an EXTREMELY important parameter, and cannot be taken lightly. If you use for the FCB the same capital amortization factor as for the diesel bus, the annualized cost per mile goes up by $0.21/km, equivalent to a $69,000 initial cost difference using the original amortization factor!

I believe that when you combine a lower initial cost increment with the lower lifetime, you will end up with a slightly higher annualized cost per mile.

iii) The Hosier/Larson paper assumes that FCBs will have 33% lower maintenance costs than diesel buses. Although this is within the range of assumptions that most analysts have made (25-50% reductions, for battery EVs compared to gasoline ICEVs), my own recent analysis of the maintenance and repair costs for battery EVs vs. gasoline ICEVs indicates that a 25% reduction is more reasonable.

iv). I have no comment on the fuel-cost analysis.

v). A portion of a vehicle's insurance premium, no matter how paid or calculated, is related to the capital replacement cost of the vehicle. Hence, if the FCB has a higher capital cost, it will have a higher insurance cost. In the case of battery EVs, this extra insurance cost is not trivial: it is larger than the difference between the gasoline and the EV maintenance and repair cost.

The upshot of these comments is that I believe that the private lifecycle cost of the FCB will be higher than the proposers and paper authors have assumed or estimated. However, I do not believe that the costs will be so much higher as to render support for the development of FCBs unwise. Rather, I believe that all supporters of the technology should keep a close eye analytically on where costs are headed.

Social-cost estimates (mentioned in the Project Brief, discussed more in the other two documents): It is true that, on account of their relatively small external costs, hydrogen FCBs will fare better on a social-cost basis than on a private-cost basis. The question is whether the difference (in external costs, or social costs) is enough to cancel any possible LARGE differences in private costs, or rather is relatively small and not worth relying on in a quantitative cost analysis. I have examined this question in the case of battery-powered light-duty automobiles, and have found that whether or not one counts externalities does not really matter to the basic cost conclusion, which is that the lifecycle cost of batteries probably will be far too high for EVs to be cost competitive. (In other words, the external cost benefit of light-duty battery EVs is likely to be small compared to the private-cost deficit.) However, we can expect the situation to be different for hydrogen FCBs, on account of the much higher external costs of diesel buses, and the potential for great cost reductions in the manufacture of fuel cells.

My own illustrative calculations suggest that the externality-reduction benefits of hydrogen FCBs might not be trivial. I start with my estimates of the cost of the health impacts of air pollution from heavy-duty diesel vehicles in Los Angeles: \$0.20 to \$3.20/mi, in 1991\$ (Report #11 in my social-cost series). Personally, I don't believe the upper end, and expect that improvements in the analysis will narrow the range to something like \$0.10 to \$1.00, for Los Angeles. I will choose \$0.60/mile here. On the basis of my other work, this reasonably can be multiplied by 1.5 to account for crop damages, visibility, materials damages, and other costs of air pollution. This gives \$0.90/mi. Updating to 1997 \$ gives something like \$1.00/mi.

Now, the per-capita income in Sao Paulo is lower, probably by several fold, but the exposure (population density) in Sao Paulo probably is several- fold higher, so that overall, I speculate that the updated LA values should be reduced by half, to \$0.50/mi. However, the biggest adjustment is in the g/ mi emission factor: the baseline emissions in our analysis actually are quite high, and should be reduced by at least a factor of 5 to represent new, relatively clean bus emissions. Allowing for emissions deterioration, and other factors, I would assume \$0.10/mi, with a range of \$0.05 to \$0.50.

The noise-reduction benefit probably is smallish, probably not more than \$0.02/mi. Valuing CO2 at \$10/metric ton (global value), the fuelcycle GHG reduction benefit is on the order of \$0.02/mi. Energy security benefits are especially difficult to quantify, especially for other countries.

All told, I would estimate that the external-cost reduction benefit of FCBs might be on the order of \$0.15/mi, with range of \$0.10 to \$0.55/mi. This is significant compared to the \$100,000 extra capital cost of the hydrogen FCB, which according to the Hosier/Larson calculation equates to \$0.50/mi. Obviously, my calculations here are merely illustrative, too. But they do suggest that it is not unreasonable to expect that a real analysis might show that the external-cost benefits of hydrogen FCBs will cancel a substantial portion of the extra capital cost, and perhaps even tilt the social-cost analysis in favor of hydrogen FCBs. This is important.

I am not competent to comment on the proposals regarding developing and operating the actual bus fleet.

OBJECTIVES

I believe that the overall objectives can be achieved if the technology is available as expected and develops as expected, and if someone is constantly keeping an eye on the long-term cost potential.

ACTIVITIES

Because I am an analyst and modeler, and not an actual experimenter or manager of people and things, I cannot comment with much insight on the actual implementation plan. I can offer only my general impression, which is favorable: this seems like a serious plan, backed by relevant experience and know-how.

PARTICIPATORY ASPECTS

The project involves appropriate private and public institutions. It does not involve community participation, apart from bus-riding, presumably on the assumption that the bus service in the community will not change.

However, bus riders and those on the street presumably will notice that the buses sound different, ride different, and don't pollute. It would be interesting to learn what the public thinks about these changes.

Maybe the public has concerns that the service providers haven't anticipated, or values changes differently than do the analysts. This is worth knowing.

GLOBAL BENEFITS

The project brief and other materials do not present any actual analysis of lifecycle GHG emissions. As regards emissions of CO_2, the essential claim of the report is that the activities of generating electricity from existing hydro-power facilities, electrolyzing water, and using hydrogen in a fuel cell, do not, in themselves, produce CO_2. That, of course, is true. The proposal then suggests that if a large number of fuel cell vehicles used renewable hydrogen, the global climate would benefit. That probably is true also, although not necessarily trivially true.

I have no problem with the proposition that if the entire transportation world ran on solar hydrogen, the environment would benefit. I also have no problem with the proposition that THAT, ultimately, is the aim of this project. If one stops here, then there is no need for detailed analysis. However, there are a variety of other possible outcomes that might be of interest to analysts, Brazil, or the GEF, and whose environmental impacts are not as straightforward as might appear at first glance. For example, suppose that this sort of development path leads not to the entire transportation world using solar hydrogen, but rather to some modest fraction of it using hydrogen from a variety of sources, including fossil fuels. To analyze the impact of this on global climate, we must do more than a few calculations of carbon emissions. First, we must expand the system boundaries to include not only the lifecycle of fuels, but also the lifecycle of materials inputs. We must determine when and how production capacity might be expanded. (Generally these effects are smallish, and hence acceptably ignored when they are believed to be the ONLY effects [as in the case of solar H_2], but they cannot be ignored when everything starts to add up.) We must include all the gases that affect climate, not just CO_2, and must include all of the sources of those gases. (In some renewable energy systems, emissions of non-CO_2 GHGs make a very large contribution to lifecycle CO_2-equivalent emissions.) And, perhaps most importantly of all, we must analyze the technical system as a part of an economic system, which, via price changes, can generate large "equilibrium" impacts. (For example, a modest displacement of oil will reduce the price of oil in the remaining sectors, and thereby stimulate consumption of, and hence GHG emissions from, petroleum in the remaining sectors worldwide. USDOE research indicates that this can be a large effect.)

My point, again, is this. If the claim is [merely] that the system the proposers intend to operate does not itself produce CO_2, or that a solar-hydrogen world would most likely benefit global climate, I have no serious quarrel. However, the impacts of most other long-term scenarios would have to be analyzed carefully if one wishes to know, within 10-20%,what the impacts on global climate would be.

GEF STRATEGIES AND PLANS

If one believes that hydrogen FCBs have some chance of becoming cost competitive (and I believe that they do have SOME chance..), and allows that hydrogen FCBs have environmental benefits, then this proposal clearly fits into GEF operational programs 7 and 11 as delineated in the material sent to me.

REPLICABILITY

Sao Paulo has several important albeit not necessarily unique characteristics that make it particularly well suited for this project: plenty of night-time hydropower capacity, an existing large bus fleet, a large and modern automotive industry, experience with electric buses, good relations with Ballard and other suppliers, and a genuine interest in sustainable transport. Certainly, any place else with similar characteristics also would be well suited to demonstrate and develop hydrogen FCBs. But there might not be many such places, and if there are not, then it will be important to do projects in places not so well suited, so that one will gain the experience needed to really be able to spread the technology.

CAPACITY BUILDING

No comment.

PROJECT FUNDING

Since I have not bought or operated buses, let alone hydrogen FCBs, I cannot comment in any detail the cost figures . However, on the basis of a few other reports and estimates I have seen, the funding seems to me to be at least generally appropriate.

TIME FRAME

Not having had any "hands on" experience with buses or fuel cells, I cannot really predict whether the project will go as planned. It is unhelpfully trite of me to observe that much depends on whether the technology develops and works as anticipated. Ballard I think has a good reputation, but everyone involved is exploring new territory, and has only a few previous and ongoing trials as guides. For what is worth, my sense is that they can stick to the long-run schedule give or take a year or two. However, as I noted earlier, I am somewhat skeptical regarding the claims about when the buses are likely to become cost-competitive with diesels.

SECONDARY ISSUES

The project itself will not have any appreciable direct affect on biodiversity or international waters. In the long run, where almost anything is conceivable, a hydrogen economy might develop in such a way as to raise concerns regarding biodiversity. From a strict technical point of view, the project is not especiallyinnovative, but then I presume that it is not meant to be.

ADDITIONAL COMMENTS

Some general analytical context for you:

In the U. S. and Europe, some analysts, policy makers, and persons in industry believe that fuel cell vehicles, especially those using on-board hydrogen, never will be cost competitive, and that "clean diesels" are the best transportation option. They argue that the most efficient diesel technologies have lifecycle CO2 emissions similar to those of fossil-methanol fuel-cell vehicles (they compare with fossil methanol because they believe that that is the only feasible option), and that their emissions of criteria pollutants, while not zero, can be made "acceptably" low. They argue that our goal should be modest reductions in GHG emissions from the transportation sector, and that this can be accomplished best by substituting efficient clean diesels for gasoline vehicles. They believe that we should aggressively develop clean diesel for at least the near and medium-terms, and perhaps even for the long term.

A lot of folks (me not among them) like this line of reasoning. They sneer at battery-powered EVs, and shrug their shoulders at fuel-cell vehicles. Although I do not agree with them, on analytical or ethical grounds, they are gaining power politically, and the GEF should be aware of them.

Annex C1

Response to STAP Technical Review

The STAP reviewer has thoroughly evaluated both the background material used to explain the context of the proposed intervention and the proposal itself. Although some of his comments apply more to the background material than the proposal itself, it is a very thoughtful review. Three points in particular require some response.

First, the reviewer feels that some of the cost estimates used in the background paper to estimate the future potential cost of fuel-cell buses may be wrong, thereby exaggerating the potential competitiveness of the fuel-cell buses. In conclusion, he writes "The upshot of these comments is that I believe that the private lifecycle cost of the FCB will be higher than the proposers and paper authors have assumed or estimated. However, I do not believe that the costs will be so much higher as to render support for the development of FCBs unwise. Rather, I believe that all supporters of the technology should keep a close eye analytically on where costs are headed." UNDP GEF used the best available materials in deriving the cost estimates to which the reviewer refers, and is already keeping a watching brief on developments and costs of this important technology. All costs will be carefully studied as this project and any subsequent projects proceed through implementation.

Second, the reviewer expressed a concern that "It would be interesting to learn what the public thinks about these changes. Maybe the public has concerns that the service providers haven't anticipated, or values changes differently than do the analysis. This is worth knowing." The omission of ridership surveys and focus groups is an oversight in the draft proposal. As the intention has always been to also canvas the public about the new technology, this has been explained in subsection 7) within paragraph 33. Focus groups and/or riderships surveys will be used to gauge public reaction to the new technology, increasing wider participation in the evaluation.

Thirdly, the reviewer raises a concern that by not including an larger, general equilibrium analysis of petroleum markets and their response to these new technologies, we may be missing some perverse effects and not be able to fully gauge the global benefits of the project on a global level. This is a serious concern for a massive roll-out of the technology being discussed and is something that UNDP GEF will have to keep in mind as it moves further in its support for the further development of fuel-cell buses. However, at this stage, the proposed project clearly demonstrates global benefits and subsequent efforts in Brazil may be devoted to ensuring that future hydrogen-powered vehicles draw their hydrogen supplies from renewable, particularly biomass, sources.

ANNEX D

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, warrantees 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_2 supply for 10 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_2).

(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: 3x3x2x5000/4 = $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.