GEF Project BRA/99/G32: Hydrogen Fuel Cell Buses for Urban Transport in Brazil

Mid-Term Evaluation Report

18 January 2014

Evaluator
Dr. Eric D. Larson
elarson@princeton.edu

Evaluation mission in Brazil conducted 18-23 August 2013.

Project Information	
Country	Brazil
ATLAS Award ID:	00011660
PIMS Number:	543
GEF Focal Area:	Climate Change
GEF Strategic Objective:	Operational Programme 11
GEF Budget (USD):	12,274,000
Co-Financing Budget (USD):	4,684,993
Project Document Signature date:	October 15th, 2001
Date of first disbursement:	February 1st, 2002
Original Planned Closing Date:	November 30th, 2006
Executing Agency:	UNDP
Date of Project Closure	December 31st, 2014

Project Stakeholders:

- Brazilian Ministry of Mines and Energy (MME), executing agency
- Brazilian Projects and Studies Financing Agency (FINEP), co-financing
- São Paulo Urban Transportation Metropolitan Enterprise (EMTU), implementing agency and co-financing
- private sector consortium contracted for the project (EPRI International, Petrobras Distribuidora S.A., Tutto Indústria de Veículos e Implementos Rodoviários Ltda, Macropolo S.A., Ballard Power Systems Inc., Hydrogenics Corp.)

The author thanks individuals representing the project stakeholders listed above for the input that provided the basis for this report. (FINEP was not contacted for this evaluation). Additionally, the author thanks UNDP/GEF personnel Rose Diegues, Oliver Page, and Marcel Alers for their input. See Annex 1 for a full list of individuals that provided input. UNDP/GEF, EMTU, and MME provided comments on a draft of this report (dated 29 October 2013), and their comments are reflected in this final report.

Contents

Executive Summary

This report is a mid-term evaluation of GEF Project BRA/99/G32, "Hydrogen Fuel Cell Buses for Urban Transport in Brazil," hereinafter referred to as the "Brazil FCB" project. The project was one of several envisioned as part of the fuel cell bus commercialization support program established by the UNDP and GEF beginning in the late 1990s, and it is in this context that the Brazilian FCB project is evaluated here. UNDP/GEF created the FCB commercialization support program to help ensure that FCBs, which showed promise for significant reductions in GHG emissions and ancillary benefits vis-à-vis local air pollution and other factors, would become available for developing country markets in a timely and sustainable way.

At the time the larger UNDP/GEF program was being formulated most fuel-cell engine companies were targeting primarily automobile markets and had interest in FCBs only to the extent that they could provide a stepping stone to the automotive market. The UNDP/GEF sought to focus private sector resources on understanding and meeting the unique demands of bus markets in developing countries while helping to prepare these markets for the large-scale introduction of FCBs. Projects supported by the UNDP/GEF, such as the Brazilian project, were intended to enable countries to gain experience in operating and maintaining FCBs; to build institutional capacity for managing fuel-cell vehicles and infrastructure; to build public confidence in the technology; and to facilitate international joint ventures for technology transfer.

The long-term development objective of the Brazil FCB project is to reduce GHG emissions from the transportation sector in Brazil and other developing countries by catalyzing the commercial introduction of urban transit fuel cell buses running on hydrogen. The immediate objective of the project is to begin the adaptation and commercialization of fuel cell buses for Brazilian markets by demonstrating the operational viability of hydrogen FCBs in the Sao Paulo metropolitan area, together with the requisite re-fueling infrastructure. The intended project outputs were 1) a significant demonstration of the operational viability of fuel cell drives in urban buses and their refueling infrastructure under Brazilian conditions, 2) a cadre of bus operators and staff trained in the operation, maintenance, and management of fuel cell buses, 3) an accumulated substantial body of knowledge about reliability, failure modes and opportunities for improving the design of fuel cell buses for Brazil, 4) an assessment of the performance of the electrolysis unit for hydrogen production, 5) a proposal for a follow-on "Stage III" project that would be designed to expand the market for and the manufacturing of fuel cell buses in Brazil, and 6) increased awareness and support among the public for fuel cell buses in urban Brazil.

This mid-term evaluation was conducted by reviewing a large number of documents collected from stakeholders and other sources. Interviews were also undertaken with representatives of each of the key project stakeholders. Annex 1 lists all those interviewed and Annex 2 lists project-related documents that were reviewed. The evaluation had goals of identifying any problems with the design of the project, assessing progress towards the achievement of project objectives and broader GEF objectives, and making recommendations for project-related actions. One key question for the evaluation was why the project has been delayed so significantly and what impact the delays are likely to have on the overall success of the project.

The outputs and activities in the logframe matrix are well defined, and quantitative indicators are identified for measuring success. An unusually strong and committed set of Brazilian public-sector stakeholders came together to participate in the project and provide 30% of the US$21 million project budget, including about a 10% contribution from international private-sector companies. In hindsight, the major shortcoming of the logframe matrix was that it underestimated the impact of external factors that impacted the time required to achieve milestones and the costs of doing so. The project document called for a five-year project that would be launched in mid-2001. The project was launched as expected, but its closing date has been extended to 2014.

Nearly 4.5 years passed from the UNDP's initial publishing of a request for expressions of interest from potential private-sector project participants to a fully-signed contract for project implementation by a strong international consortium. Time was consumed in bringing on board the right technical and strategic partners, and project decision-making was drawn out by the need for all consortium members to agree each step of the way. In retrospect, given the non-commercial nature of FCBs and the corresponding lack of any EPC (engineering, procurement and construction) firm prepared to deliver a turnkey project, the long time period involved in the organic formation of the consortium might have been better anticipated. Nevertheless, in the end, a highly competent and dedicated team that has worked well with the project implementing agency, EMTU (the São Paulo Urban Transportation Metropolitan Enterprise), was formed and it has sustained its commitment to the project despite significant delays.

Other delays that have had detrimental impacts on progress include a long (and ongoing as of late 2013) delay in the disbursement of co-financing funds from FINEP, the government co-financing source. As a result, key operating and maintenance activities connected with the first prototype bus had to be scaled back, resulting in less operating experience than planned. Importing replacement parts and bringing engineers from outside of Brazil to commission or fix imported equipment added additional delays.

In addition to project delays, the number of buses planned for the project was reduced from eight specified in the project document to four: a single prototype bus was operated in "Phase II.2" of the project and three buses will be operated in "Phase II.3". There were several reasons the number of buses was reduced. One reason was that the original project was designed (in 1998/1999) assuming that both GEF funds and co-financing funds would be available to use toward purchase of hardware such as buses and spare parts. When the co-financing was finalized (in 2002), it came to light that institutionally, the co-financing agency, FINEP, could not fund hardware purchases. A second contributing factor was that reductions in the price of hydrogen production equipment anticipated in the original project design did not materialize and so additional funds were needed there. An important additional reason for the reduced number of buses was that the private-sector consortium suggested the project pursue a strategy that would enhance the likelihood of achieving UNDP/GEF's broader objective for its fuel cell bus program, the sustainable commercial deployment of fuel cell buses in developing country megacities. The suggested strategy, which was adopted for the projectc, entailed engineering a new generation of fuel cell bus design incorporating domestically produced chassis, body and major power train components rather than importing "lock-stock-and-barrel" a fuel cell bus produced in Europe or North America. Implementing this strategy would require extensive engineering, testing and know how transfer activities (all at added costs), but successful implementation would mean achievement of better technology performance, a stronger commitment and involvement of Brazilian industries, and higher public acceptance. To reduce project risks, UNDP/GEF negotiated a two-stage approach for implementing this strategy, Phase II.2 and II.3.

The prototype (Phase II.2) bus successfully operated and provided important lessons for the design of the Phase II.3 buses, which will be starting operation in March 2014. Hydrogen consumption per kilometer driven was considered a key metric for judging the technical success of the prototype design. Measured hydrogen consumption was well below the design target of 15 kg/100 km and almost 50% below that achieved in the previous generation of fuel cell buses that utilized fuel cell engine technology from the same supplier (Ballard Power Systems).

The Phase II.3 bus designs have incorporated many lessons from the prototype experience. The most important of the modifications was the effort made to adopt much more Brazilian-made equipment into the design. "Brazilian-ization" was pursued to help reduce cost, but also having in mind that with larger domestic content the technology will be more sustainable in Brazil in the longer term. The Phase II.3 buses are costing US$1.01million each, which compares with a bus cost of about US$3 million (in today's dollars, or $2.3 million in year-2000 dollars) when the project was first conceptualized. This cost reduction exceeds expectations and sets a new global benchmark. It should be noted, however, that the Phase II.3 buses have yet to be operated, and successful operation will be essential before definitive conclusions can be reached regarding the cost reduction achievement.

The Brazilian-ization and cost reduction efforts, coupled with EMTU-led efforts to increase awareness and public support for fuel cell buses in Brazil represent critical achievements toward the objective of the larger UNDP/GEF fuel cell bus program of helping ensure that FCBs become a sustainable option for developing countries in a timely way.

As an overall evaluation of the project results to date, the quantitative targets set out in the logframe matrix have, strictly speaking, been achieved in only a marginally satisfactory way, but the qualitative results achieved, involving Brazilian-ization of the technology and engaging/informing the public, are highly satisfactory and suggest there are good possibilities for long-term sustainability of fuel cell buses in Brazil, assuming the Phase II.3 buses are successfully operated.

Thus, despite the delays, the project has maintained momentum and appears to be on a sound trajectory toward achieving most of its larger goals. This continued progress can be attributed largely to the strength and commitment of the private-sector consortium contracted by UNDP to implement the project and the unflagging support provided by the UNDP Brazil office.

The following are some of the key lessons from the project thus far:

1. The project has brought a substantial level of maturity to hydrogen fuel cell bus technology in Brazil, such that there is a real possibility to deploy this technology in the future in revenue-generating bus transit operations.
2. The four buses that have been or will be operated in the project won't make a discernible difference to the environment, considering that more than 15,000 transit buses ply the streets of the Sao Paulo metropolitan area on a daily basis. However, the wide press coverage and other outreach efforts by EMTU and others seem likely to stimulate additional deployment activities that will make a difference.
3. Technology know-how has been transferred to Brazilian industry (not left overseas or transferred only to Brazilian government or academia). This enhances the prospects for expanded and sustainable deployment of fuel cell buses in the future in Brazil.
4. Simpler institutional arrangements would be desirable for the next project. In particular, having initially eight, and subsequently six, companies each needing to sign each agreement involved in the project was cumbersome and time consuming. The consortium has recognized this issue, and for future negotiations and agreements it has assigned signing authority to the representatives from EPRI who have been leading the consortium.
5. When inevitable technical problems arose with the prototype bus, they were quickly diagnosed and solutions identified. However, time and costs involved with importing equipment created serious delays in implementing solutions. Recognizing that higher local content for the buses would be important for reducing these problems (and coincidentally for enhancing the prospects for long-term sustainability of the technology in Brazil), the project consortium pursued this direction in the design of the Phase II.3 buses.
6. The strictly engineering aspects of the project to date have been very good. The prototype bus has performed as well as, if not better than, expected, although the number of kilometers logged has fallen far short of original goals. The Phase II.3 buses remain to be demonstrated in operation.

Three recommendations are offered with the aim of helping ensure the success of the project and the larger UNDP/GEF fuel cell bus commercialization program:

FINEP Funds

The release of the final two installments of FINEP co-financing funds (totaling about R$3.8 million) has been delayed substantially due to an inadvertent, but still unresolved inconsistency in original project agreements signed by the project executing agency, the Ministry of Mines and Energy (MME). As of late August 2013, it appeared that a resolution of this issue was imminent.[*] My recommendation is that the remaining FINEP funds be made available as soon as possible so as be able to properly support the final stages of the Phase II.3 project, especially the operation of the Phase II.3 buses.

Phase II.3 bus operations

It will be important to operate the Phase II.3 buses for as many kilometers as needed for EMTU decisions makers and other local stakeholders to gain full confidence in the FCB technology and thereby maximize the chances that follow-on deployment of an expanded fleet of FCBs will be given serious consideration. This may require operating the Phase II.3 buses beyond the end of 2014, the scheduled closing date for the GEF project. At least one additional year of operation is recommended, and 18 to 24 months might be more optimal. Closing the GEF project as scheduled at the end the of 2014 is not necessarily in conflict with continuing to operate the buses beyond this date, but additional resources would be needed to support post-2014 operation. If the Phase II.3 buses are operating well during 2014, as seems likely, the GEF may be reluctant to provide even a “no-cost” extension to keep the project open for any additional time, since it has already been extended (with good justification) far beyond its original closing date. On the other hand, if the Phase II.3 buses do not run well during 2014, then there may be an argument for extending the project in order to solve the problems and end the project with the buses running well. Some ideas for funding the extended operation of the Phase II.3 buses are offered in the body of this report.

Stage III project proposal development

The Brazil FCB project and a similar one concluded in 2011 in China, represent Stage II projects in the larger UNDP/GEF FCB commercialization program. Stage III of the UNDP/GEF FCB program was intended as the final stage of GEF involvement by supporting projects involving larger-scale market deployment of FCBs. The Brazil FCB project document calls for the drafting of a Stage III proposal for Brazil. Assuming the Phase II.3 buses operate successfully, and there are good reasons to expect that they will, a Phase III project would be a logical next step. Indications are that GEF may be receptive to such a proposal in the mid-2014 timeframe. Since many discussions among potential stakeholders will be required in developing a proposal, the process should begin immediately.

The project document ambitiously called for a Phase III project involving a fleet of some 200 fuel cell buses deployed in Sao Paulo. Because scale-up of fuel cell engine technology has not evolved as rapidly as originally envisioned when the project document was written, a more

[*] As of late November, the issue had yet to be fully resolved.

modest number of buses is appropriate. EMTU personnel with whom I discussed follow-on projects felt that 20 would be a good number, given the size of the current cadre of trained operators and maintenance personnel.

One idea for a Stage III project relates to planned improvements for the Sao Paulo metropolitan region in bus transit efficiency via expansion of bus-rapid-transit (BRT) systems. A proposal idea under discussion at high levels in the state of Sao Paulo is for a R$500 million public-private partnership (PPP) that would build and operate a 17 km stretch of one of the new BRT corridors planned for the Sao Paulo area. The BRT could be designated as a clean-bus corridor and served by a fleet of 20 hydrogen fuel cell buses. A Stage III project might be designed such that GEF funds cover some or all of the incremental cost of deploying fuel cell buses in this corridor rather than conventional diesel buses with higher greenhouse gas emissions. A rough estimate of the incremental cost for the purchase of 20 FCBs in lieu of diesel buses is US$16 million. This model for a project is relatively familiar to GEF in the area of under-utilized renewable energy systems, where market deployment is the emphasis rather than technology development. Such a Stage III proposal might fit well in the GEF portfolio of projects on “Sustainable Transport” or “Sustainable Cities”.

A summary of this mid-term evaluation is given in the following ratings table:

1. Monitoring and Evaluation	***Rating****	***Comments***
M&E design at entry	HS	The PRODOC defines clearly the M&E requirements.
M&E plan implementation	HS	The evaluator received several excellent detailed reports documenting engineering design decisions, FCB and hydrogen fueling station performance, and other technical data that were generated in the project. Many other such reports were also prepared. The M&E plan also calls for annual reviews of “progress towards cost reduction, reliability improvement and increased durability”. The evaluator is not aware whether these reviews have been taking place. The project has moved more slowly than anticipated, so this is not surprising. However, a cost, reliability and durability review would be important to conduct once the end of Phase II.3 of the project is approached.
Overall M&E	***HS***	
2. IA& EA Execution	***Rating****	***Comments***
Quality of UNDP Implementation	MS	The project schedule stipulated in the PRODOC was highly optimistic. The original project schedule has not been followed. Nevertheless, UNDP staff have been active and conscientious about lending support as needed to keep the project going.
Project implementation - Implementing Agency	MS	Leaving aside the project schedule (which was overly optimistic from the start), EMTU has managed the project reasonably well.

Project execution – Executing Agency	MS	MME has facilitated the project well. Faster resolution of the problem encountered with FINEP co-financing would have been desirable.
Overall Implementation, Execution	***MS***	
3. Assessment of Outcomes	***Rating****	***Comments***
Relevance	HS	At the time of signing of the PRODOC, Brazil was formally pursuing hydrogen as part of its overall energy development strategy. Hydrogen has since been de-emphasized as a result of changing energy market conditions and slower than expected development of hydrogen technology. Nevertheless, because Brazil is among the biggest urban transit bus markets in the world, and conventional diesel buses are among the most significant contributors to local air pollution in cities, the pursuit of clean FCBs continues to be highly relevant for the Brazilian context.
Effectiveness	HS	Most of the objectives defined in the PRODOC are likely to be achieved, with the exception of the million bus-km operating target. In retrospect, due to other FCB projects worldwide, achieving the bus-km target was not critical to the overall success of the project. More critical have been the cost reductions for FCBs that were achieved and the related Brazilian supply of some key FCB components and Brazilian-ization of the capability for design and assembly of FCBs.
Efficiency	HS	It is difficult to assess cost effectiveness for a technology development / assimilation project. A crude measure is the total resources expended per FCB, which will be US$4.23 million per bus. This is comparable to the 20-FCB project in Whistler, Canada, with an announced cost of $4.30 million per bus. In most cases, larger projects will benefit from scale economies and have lower per-unit costs. The fact that the Brazilian project deployed only one-fifth as many buses as the Whistler project, yet has comparable unit costs indicates a more efficient use of resources than one would expect by simple extrapolation down from the Whistler project.
Overall Outcome	***HS***	

4. Sustainability	***Rating****	***Comments***
Financial resources	ML	The availability of financing for subsequent FCB fleets in Brazil is a critical issue. The first cost of FCBs will likely always be higher than first cost of conventional buses, but as manufacturing costs fall, FCBs should eventually compete on a full cost-accounting basis because of the much higher fuel efficiency they can achieve. Achieving this level of cost-competitiveness in Brazil will require at least one and perhaps more Brazilian-ized FCB fleets to be deployed after the current project. Financing these will be challenging, and will depend, *inter alia,* on how the FCB's very low emissions of local air pollutants and CO_2 are valued. Innovative approaches, such as the idea for a Stage III projected described in this report, will be required. The success of the current project in raising the confidence of bus planning and regulating agencies like EMTU will help gain acceptance for innovative solutions.
Socio-political	L	Mass transit is a critical element of the urban infrastructure in Brazil. The project reviewed here has demonstrated that the attractive environmental features of FCBs vs conventional buses are easily understood and readily accepted by bus system operators and the bus-riding public in Sao Paulo. The planned expansion of dedicated bus corridors and bus rapid transit systems presents an ideal context for deployment of FCB fleets.
Institutional framework and governance	ML	A number of legal and institutional challenges were encountered in this project and solutions were found in all cases. This is encouraging for the longer-term. Substantial technical know-how regarding FCBs has been transferred to a limited number of individuals and institutions in Brazil. The introduction of future FCB fleets will require an expanded cadre of trained individuals and organizations, but there is no intrinsic hurdle to achieving this.
Environmental	L	FCBs have been clearly demonstrated to be much lower in local and global (carbon) pollution. This is an intrinsic feature of the technology.
Overall sustainability	***ML***	
* HS = Highly satisfactory (no shortcomings), S = satisfactory (minor shortcomings), MS = moderately satisfactory, MU = moderately unsatisfactory, U = unsatisfactory, HU = highly unsatisfactory, R = Relevant, ** L = likely, ML = moderately likely (moderate risks), MU = moderately unlikely (significant risks), U = unlikely (severe risks), HU = highly unlikely.		

1 Introduction

This report provides an analysis and assessment of progress of the GEF Project BRA/99/G32 – Hydrogen Fuel Cell Buses for Urban Transport in Brazil (hereinafter called the "Brazil FCB" project). This mid-term evaluation was undertaken with the goals of identifying any problems with the design of the project, assessing progress towards the achievement of specific project objectives and broader UNDP/GEF objectives, and making recommendations of project-related actions that might be taken going forward. The evaluation also aims to identify lessons that might be applied to improve design and implementation of other UNDP/GEF projects.

The main stakeholders for this mid-term evaluation are the Brazilian Ministry of Mines and Energy (MME), the Brazilian Projects and Studies Financing Agency (FINEP), the São Paulo Urban Transportation Metropolitan Enterprise (EMTU), and the private sector consortium contracted within the project (EPRI International, Petrobras Distribuidora S.A., Tutto Indústria de Veículos e Implementos Rodoviários Ltda, Macropolo S.A., Ballard Power Systems Inc., Hydrogenics Corp.)

The author conducted the evaluation by reviewing a large number of documents collected from stakeholders and from other sources. Additionally, on a one-week visit to Brazil, the author met with representatives of each of the above-listed stakeholders (except for FINEP) for in depth and frank discussions about the project. Follow-up email exchanges also ensued. Annex 1 is a list of meetings held and names of individuals participating in each. Annex 2 lists the project-related documents that were reviewed in the course of this evaluation. In addition to representatives of the stakeholders noted above, those with whom meetings were held included the UNDP/Brazil program officer responsible for the project (Rose Diegues Peixoto), one outside consultant involved in the project (Gabriel Branco), the UNDP-GEF climate change portfolio manager for Latin America and the Caribbean (Oliver Page), and the UNDP-GEF Principal Technical Advisor for Energy Infrastructure, Transport and Technology (Marcel Alers).

A goal of the meetings was to solicit perspectives on problems encountered by the project, as well as lessons learned and progress made. Key questions going into the evaluation included why the project has been delayed so significantly and what impact the delays are likely to have on the overall success of the project.

By way of additional introduction to the evaluation, I should add a few words about my own background and connection with fuel cell buses. As part of my research activities at Princeton University, I had the opportunity starting 15 years ago to become familiar with fuel cell bus technology developments. Starting in the late 1990s, I advised UNDP/GEF on the development of a GEF-supported program designed to help catalyze the commercialization of hydrogen fuel cell transit buses for developing country megacities.[1] I did not directly participate in the design of the Brazil FCB project, and for about the past decade I have not tracked the development of the FCB industry in any detail. In preparation for this mid-term evaluation, I reviewed literature to bring myself up to speed on developments within this industry.

2 Context

The Brazilian FCB project was one of several projects envisioned for the fuel cell bus commercialization support program established by the UNDP and GEF beginning in the late 1990s. It is important to understand the overall goals and strategy for the UNDP/GEF program to appreciate the extent to which the Brazilian FCB project will or will not contribute to these.

The strategic vision for the UNDP/GEF program was to help reduce GHG emissions from the transport sector over the long-term in GEF program countries. The program was envisioned to involve partnerships between UNDP, GEF, private industry, and local/national governments and to be consistent with other public sector support for fuel cell bus technology development outside of GEF program countries, including several public sector programs in North America and Europe.

UNDP/GEF decided to create the FCB commercialization support program to help ensure that FCBs would become available for developing country markets in a timely and sustainable way. At the time the UNDP/GEF program was being formulated most fuel-cell engine companies were targeting primarily automobile markets and had interest in FCBs only to the extent that they could provide a stepping stone to the automotive market. By supporting commercial demonstration of FCBs in GEF program countries, UNDP/GEF sought to focus private sector resources on understanding and meeting the unique demands of these important potential markets for FCBs while helping to prepare the market in developing countries for the large-scale introduction of FCBs.

Commercial demonstration projects supported by the UNDP/GEF were intended to enable host countries to gain experience in operating and maintaining FCBs; to build institutional capacity for managing fuel-cell vehicles and infrastructure; to build public confidence in the technology; and to facilitate international joint ventures for technology transfer. There would additionally be benefits from reduced local air pollution, new export opportunities attributable to local manufacturing, and improved quality of public transit service. Finally, because FCBs are hydrogen fueled, the UNDP/GEF program would also assist countries in preparing for a future transition to lower-GHG fuel-supply systems.

The UNDP/GEF program was designed with three stages.

Stage I, which was completed around 2000, involved identifying candidate host countries and assessing the strength of their local bus markets, verifying local and national political and financial support for FCB technology, evaluating the local bus industry's capabilities for new technology development, studying the potential availability of hydrogen supplies, and developing strategic plans for the next two stages. Five countries were identified as strong candidates for Stage II projects: Brazil, China, Egypt, India, and Mexico. These constitute five of the world's largest bus markets, and UNDP/GEF project proposal development efforts were launched in each. The decision to launch this relatively large number of proposal development efforts was made in the recognition that some of the projects would ultimately probably not go forward to implementation for various reasons.

Stage II was the Demonstration Phase, the focus of which was to be on proving the operational viability of FCBs for urban transit in major cities of host countries. GEF funding for this stage was intended to pay for the incremental costs of FCBs relative to conventional transit buses as part of the effort to "buy down" the cost of FCB technology to more competitive levels. Stage II was also intended to provide significant operational experience with FCBs in host countries so as to allow for informed decisions about the viability of, and interest in, expanded deployment of FCBs.

A key goal of Stage II projects was that they would provide the learning needed to help reduce costs of FCBs to more competitive levels. Assessing the state of the FCB industry at the time, analysis conducted as part of Stage I concluded that a cost reduction trajectory like that shown in Figure 1 might be expected. (Prices projected there are in year-2000 US dollars and assume North American equipment and assembly of the buses.) The curve in Figure 1 can be translated into an expression for the price of a bus as a function of the cumulative number of buses manufactured:

$$Bus\ Price\ (in\ Year\ 2000\ US\$) = 2.978\ \times 10^6 \times (Cumulative\ number\ of\ buses\ produced)^{-0.257}$$

This corresponds to a 16% reduction in price for each doubling in the cumulative number of buses produced. This cost learning rate is in line with rates observed for a variety of technologies at the stage of being relatively new to commercial markets and amenable to mass-production techniques, e.g., gas turbines, wind turbines, solar PV cells, and many others.[2]

Considering inflation, the bus price trajectory expressed in today's US$ would be

$$Bus\ Price\ (in\ Year\ 2013\ US\$) = 3.9\ \times 10^6 \times (Cumulative\ number\ of\ buses\ produced)^{-0.257}$$

where the US GDP deflator[3] has been used to adjust from year-2000 to year-2013 dollars.

When the projection in Figure 1 was made (based on input from the Ballard Automotive Company), it was expected that cars would be the primary transportation application for fuel cell engines, and that bus engines would "piggy back" on cost reductions in automotive fuel cell engines by basically being built with two automotive fuel cell stacks in parallel rather than a single fuel cell stack redesigned for heavy-duty bus applicaitons. The fuel cell bus price trajectory was predicated on the assumed ramp up in sales of fuel cell engines for cars. However, the fuel cell car market has not materialized as anticipated in the past decade, and fuel cell producers like Ballard have instead turned their attention to developing fuel cell stacks customized for buses.

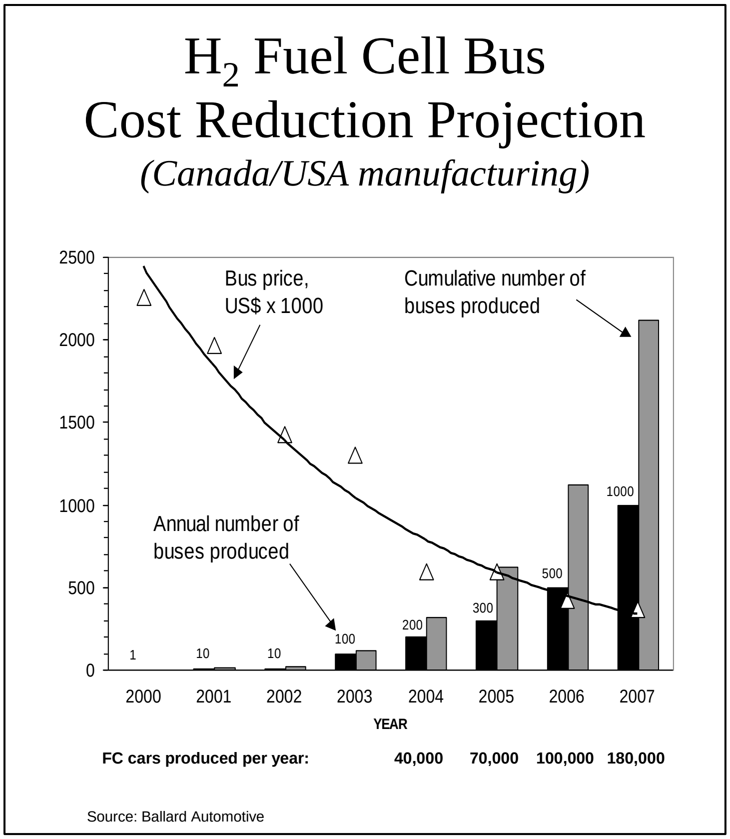

Figure 1. Price trajectory projected in year 2000 for fuel cell buses, assuming North American manufacturing.[4] Prices are in year-2000 US dollars.

While the total number of fuel cell buses produced since 2000 has not chronologically tracked the projection shown in Figure 1, there have been a substantial number of fuel cell buses produced since 2000, and it is of interest to evaluate to what extent cost reductions have followed the projections. I will discuss this in Section 4.3 of this report.

Of the originally-envision five Stage II demonstration projects, the ones in Egypt, India, and Mexico did not go forward for various reasons. Brazil's Stage II project is the subject of this mid-term evaluation report.

China undertook a Stage II effort in two phases.[5,6] The project document for Phase 1 was signed in 2002, and the project was concluded in 2005. It involved the direct purchase of 3 "first-generation" FCBs from Daimler Chrysler (using Ballard fuel cell technology) and operation of these in Beijing, together with a hydrogen refueling station. The Phase 2 project document was signed in 2007, and that project concluded at the end of 2011. Phase 2 involved the domestic manufacture of six FCBs and demonstration operation of these in Shanghai, together with hydrogen refueling. A Stage III project for China was recommended in the Final-Term Review Report for the Phase 2 project,[5] but I am not aware whether that recommendation is being implemented. It is worth noting, however, that Silvano Pozzi, a director of business development at Ballard Fuel Cell Power Systems, states that there is "lots of movement in the (fuel cell bus) sector recently" in China, and Ballard has signed an agreement that may lead to large volume deployment in China in the next 2 to 3 years.[7]

Stage III of the UNDP/GEF FCB support program – the Commercialization Phase – was intended to be the final stage of GEF involvement. This stage will be designed to increase the demand for, and production of, FCBs in host countries to the point where their costs are nearing competitiveness with conventional diesel bus costs. Private industry's financial contributions at Stage III are expected to reach at least 50% of total project costs. The extent to which Stage III projects go forward and the magnitude of support needed from GEF will depend on the degree to which Stage II demonstrations and other (non-GEF) FCB development activities succeed. The original GEF plan called for Stage II projects to be completed by the 2005-2007 timeframe, but Stage II projects have taken longer than expected, and so decisions relating to Stage III have been correspondingly delayed.

3 Project Description

The long-term development objective of the Brazil FCB project is to reduce GHG emissions from the transportation sector of Brazil and other developing countries by catalyzing the commercial introduction of a new low-carbon fuel and a new propulsion technology for urban transit buses. The new fuel is hydrogen and the propulsion technology is the fuel cell. This project is specifically designed to initiate and accelerate the development and commercialization of hydrogen fuel cell buses in Brazil. In the long term, assuming that this project and the follow-on Stage III project are successful, the production and deployment of an increasing number of hydrogen FCBs will help drive down their costs to the point where they will approach commercial competitiveness with conventional diesel buses.

The immediate objective of the project is to begin the adaptation and commercialization of fuel cell buses for Brazilian markets by demonstrating the operational viability of hydrogen FCBs in the Sao Paulo metropolitan area, together with the requisite re-fueling infrastructure. The project was designed to achieve 1) a significant demonstration of the operational viability of fuel cell drives in urban buses and their refueling infrastructure under Brazilian conditions, 2) training for a cadre of bus operators and staff in the operation, maintenance, and management of fuel cell buses, 3) an accumulation of a substantial body of knowledge about reliability, failure modes and opportunities for improving the design of fuel cell buses for Brazil, 4) an assessment of the performance of the electrolysis unit for hydrogen production, 5) a proposal for a follow-on Stage III effort to lay the foundation for the expansion of the fuel cell bus market in Brazil and increase the involvement of local engineering and production of fuel cell buses, and 6) an increased awareness and support of the public for fuel cell buses in Brazil's urban transport systems.

The logical framework matrix for the project is reproduced here (Table 1) from the Project Document.[8]

Table 1. Logframe matrix for the Brazil FCB project.

	Program or project summary	**Indicators**	**Verification**	**External factors**
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 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*	Significant demonstration of the operational viability of fuel cell drives in urban buses and their refueling infrastructure under Brazilian conditions 1.1 Specify technical performance targets 1.2 Tender and select vendor for bus provision 1.3 Install, operate and maintain refueling infrastructure 1.4 Place initial set of 3 buses in operation 1.5 Place second set of 5 buses in operation	Buses operate according to pre-specified levels (hrs or km per year) – Refueling station operates satisfactorily to supply sufficient H_2 at reasonable cost Breakdowns are limited in frequency to acceptable levels (< 50,000 km between breakdown)	Annual and final project reports Vehicle log books and records	Assumption: Fuel-cell buses can be produced from commercial vendors at satisfactory cost Risk of vendor failure
Output 2 *Activities*	Cadre of bus operators and staff trained in the operation, mainten-ance, and management of fuel cell buses. 2.1 Hold on-the-job training seminars for 430 drivers, 126 mechanics and 12 specialized electronics technicians	Number of operators/maintenance staff trained Enrollment in training seminars	Quarterly and annual project reports	
Output 3 *Activities*	Accumulation of a substantial body of knowledge about reliability, failure modes and opportunities for improving the design of fuel cell buses for Brazil 3.1 Formulate guidelines for quarterly reporting on in-service performance of the buses 3.2 Collect, analyze and evaluate operating data on reliability, failure and potential improvements 3.3 Exchange experiences with Chicago, Vancouver, and other users of fuel cell buses	Development of quarterly reporting forms Persons consulted in formulating reporting guidelines Quarterly reports collected Publication of documents demonstrating accumulated experience and knowledge	Quarterly and annual project reports Project files and history	

Output 4 *Activities*	Assessment of the performance of the electrolysis unit 4.1 Systematic logging, analysis and interpretation of operating parameters. 4.2 Opportunities identified for potential improvements of performance and cost reductions. 4.3 Evaluation of safety aspects. 4.4 Establishment of operating standards for the electrolysis unit.	Development of quarterly reporting forms Persons consulted in formulating reporting guidelines Quarterly reports collected Publication of documents demonstrating accumulated experience and knowledge	Quarterly and annual project reports Project files and history	
Output 5 *Activities*	Proposal for Phase III of the Brazilian Fuel-cell Bus program 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 5.4 Prepare proposal for Phase III Project	Satisfactory preparation of Phase II proposal based upon Phase II experience, reconfigured bus designs, Brazilian standards and continued dialogue with vendors	Quarterly, annual and final project reports	
Output 6 *Activities*	Increased awareness and support of the public for an increased role for fuel cell buses in Brazil's urban transport system 6.1 Hold workshops & seminars to publicize results 6.2. 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	4-year, 8-bus test. Based in a single bus garage in São Paulo Electrolytically-generated hydrogen fuel, based on renewable hydraulic energy resource Cost: Approximately US$21m			

4 Findings

4.1 Project Formulation

The conceptual design of the project was sound. The outputs and activities in the logframe matrix (Table 1) are well defined, and quantitative indicators are identified for measuring success. An unusually strong and committed set of Brazilian public-sector stakeholders, as well as Brazilian and international private sector entities were expected to participate in the project.

The budget sources for the project (Table 2), including a 30% contribution from Brazilian sources, reflect the strong Brazilian commitment to the effort at the outset. The commitment has been sustained throughout the project. The estimated private sector contribution of US$2.6 million has been realized in the form of in-kind contributions by the companies constituting the private sector consortium contracted to supply the buses and hydrogen fueling system.[9]

Table 2. Source of project funds (million US$), as envisioned in the project document.[8]

	Brazilian Public Sources			Private	
Total	EMTU	Bus fares	MME/FINEP	Sector	GEF
21.180	1.306	392	4.597	2.611	12.274
100%	6%	2%	22%	11%	58%

EMTU = Sao Paulo Metropolitan Public Transit Authority
Bus fares = those collected during FCB revenue service operation.
MME = Ministry of Mines and Energy
FINEP = Projects and Studies Financing Agency
Private = private companies expected to bid for project contracts.

In hindsight, the major shortcoming in the logframe matrix was the underestimate of how external factors might impact the project. In particular, the project design underestimated both the time that would be required to achieve the project milestones, as well as the costs. The project document called for a five-year project that would be launched in mid-2001. The project was launched as expected, but its closing date has now been extended to the end of 2014. Additionally, in the course of the project the number of buses to be included in the demonstration was reduced by half, from eight to four. Key reasons for project delays and cost escalations are discussed in the next section.

While the schedule and costs for the project have not evolved as expected, the project has compensated to an important degree by emphasizing "Brazilian-izing" of the FCB systems and increasing the domestically-produced content of the demonstration buses. This will likely accelerate the trajectory of FCB cost reductions and market adoption in Brazil in ways that were not anticipated in the original formulation of the project. Together with the strong and committed set of Brazilian stakeholders (described further in Section 4.2), this increases the prospects for success when wider deployment of FCBs is contemplated in a Stage III project.

4.2 Project Implementation

In evaluating the implementation of the project, it is important to begin with a sketch of the institutional structure established for administering and financing the project, as well as a description of the international consortium selected to implement the work and the process which led to the contracting of this consortium.

4.2.1 Administrative and financial framework

The administrative and financial arrangements for the project are summarized in Figure 2.

GEF funds are disbursed to the project through the UNDP/Brazil office. Additionally, UNDP/Brazil has contributed some contingency funds to the project. Most of the GEF/UNDP funds are directed for equipment purchases by the international consortium contracted to supply and support operation of equipment in the project.

The Sao Paulo Urban Transportation Metropolitan Enterprise (EMTU), which is the Sao Paulo state agency responsible for public transit planning and regulation in the Sao Paulo metropolitan region outside of the city proper, is the implementing agency for the project and is providing a substantial amount of co-financing (Table 2). The EMTU bus garage facility in Sao Bernardo do Campo is the site of the hydrogen refueling station and FCB maintenance facility. The EMTU bus route system includes dedicated bus lanes and bus corridors designed to increase the efficiency of bus transit operations.† Demonstration operation of the fuel cell buses in the project takes place in a dedicated bus corridor.

The Ministry of Mines and Energy (MME) is the Brazilian agency with overall responsibility for project execution. Their responsibilities include reviewing expenditures requested by EMTU to be covered by co-financing from the Brazilian Projects and Studies Financing Agency (FINEP). The Brazilian Cooperation Agency (ABC) decides which international projects the Government of Brazil will support and so is a key agency in the determination of which projects are included in the Brazil's UNDP project portfolio.

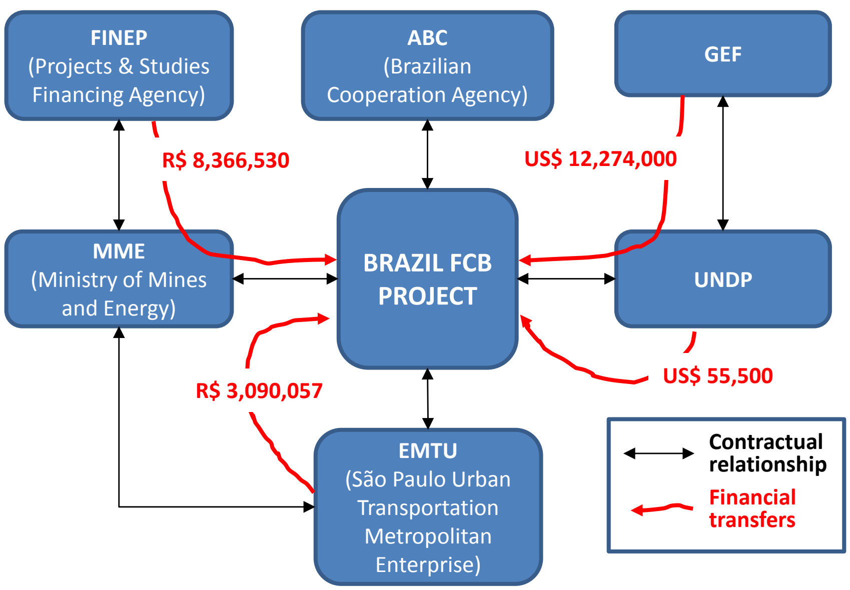

Figure 2. Administrative and financial arrangements for the Brazil FCB project. As of the time of this writing, the exchange rate was R$2.4 per US$. This is as high as it has been in at least the last five years. In mid-2011, it was as low as it has been in the past five years (about R$1.6 per US$).

† Bus lanes are marked lanes on the same roadways as automobile lanes. Bus corridors are lanes that are physically separated from the lanes used by private vehicles. Passenger cars and other private vehicles are prohibited from driving in bus lanes or bus corridors.

In the early years of the project, the administrative and financing framework seems to have worked adequately, but a difficulty arose beginning in 2008 that has had a substantial negative impact on the project. Key events in the chronology, as communicated to me in interviews, are the following:

- 2001: MME, EMTU, ABC, and UNDP sign the Project Document (PRODOC) to implement the project. The PRODOC includes the stipulation that 3% of total project funds (from GEF and co-financing sources) are paid to UNDP as its General Management Services (GMS) administrative fee.
- 2002: MME and FINEP sign an agreement that formalizes FINEP co-financing for the project. (MME and EMTU sign a separate agreement for EMTU to be the implementer of FINEP funds.) Undetected by MME in its agreement with FINEP is the FINEP rule that does not allow FINEP funds to be used for administrative fees, thereby setting up a conflict for MME with the contract it signed in 2001.
- 2011: In May 2011 EMTU provided its 2010 annual project expense accounting report to MME, which uses the accounting reports as a basis for requesting disbursement of FINEP funds to the project. The 2010 report, like prior EMTU annual project expense reports up to that time, did not report any UNDP GMS fees as expenses. In July 2011, MME became aware of the inconsistencies relating to payment of GMS fees in the 2001 and 2002 agreements it had signed and began to investigate the issue. On November 29, EMTU provided a letter to MME to formally raise the GMS issue and request a resolution so that GMS fees (which began accruing in 2008 but had not been included in expense reporting) could be paid from FINEP co-financing funds.
- 2012 (21 December): EMTU submits to MME its 2011 annual expense accounting report[10] that shows, for the first time in an annual accounting report, the 3% UNDP administrative fee back-reported to 2008, when UNDP first started charging it. Sometime after receiving this report from EMTU, MME sends the report informally to FINEP and enters into discussions to try to resolve the problem created by the inconsistency in the two main contracts.
- 2013 (23 August): As of the end of my evaluation visit to Brazil, the conflict between the 2001 and 2002 agreements signed by MME had yet to be resolved, but there were strong indications given by Symone Christine de Santana Araujo, who leads MME involvement in the project, that a resolution was being discussed between MME and FINEP, and the expectation was that the matter would be satisfactorily resolved by the end of 2013 so that FINEP co-financing resources could become available to the project.

FINEP co-financing was to be released to the project in five installments and held in a UNDP account until disbursed to pay project costs. Three installments were released, the most recent one in 2010. After MME learned of the conflict between the two agreements it had signed, MME chose not to request release of remaining FINEP funds (totaling about R$3.8 million) until the conflict was resolved. [It may be noted that independent audits of the project finances have been completed (as required by UNDP procedures), the most recent in 2011, and all found expense accounting to be in order.]

The magnitude of the total UNDP administrative fee in question is between US$100,000 and US$160,000 (depending on the exchange rate) out of a total project cost of more than US$21,000,000. But the delay in the release of the 4th installment of FINEP funds has had an impact on the project far in excess of the impact suggested by this quantitative comparison. The delay has meant that some operating and maintenance activities connected with the first prototype bus (described more fully below) have been scaled-back or indefinitely delayed. As a result less experience has been able to be accumulated with the prototype bus than would otherwise have been the case. Reprogramming of funds was evidently not possible, because GEF funds were stipulated for use primarily for capital equipment purchases, whereas FINEP co-financing was stipulated for use only to pay Brazilian labor, operating, and maintenance expenses in the project. UNDP/Brazil has contributed some discretionary contingency funds (see Figure 2) to help support the project in the absence of the FINEP funds, and EMTU has shouldered some project expenses that would have been paid by FINEP funds had these been available. Additionally, members of the international consortium implementing the project made some unanticipated cash and in-kind contributions to help sustain the project while awaiting release of FINEP funds. Despite the voluntary contributions from UNDP, EMTU, and the project consortium, insufficient funds have been available to support the continued steady operation of the prototype bus, which would have resulted in important additional learning.

Additionally, delays in the project (not due to difficulties with FINEP co-financing) have contributed to loss in value of FINEP funds due to currency exchange fluctuations. The FINEP funds are denominated in R$, but undergo an exchange to US$ when deposited into the account managed by UNDP. The funds are converted back to R$ at the time of disbursement from the UNDP account to pay for project expenses in Brazil. EMTU analysts have estimated that there has been a net loss of some R$500,000 of FINEP funds to foreign exchange fluctuations due to long time delays between the release of funds by FINEP to the UNDP account and the disbursement of these funds from the account.[10] About 70% of the net loss resulted from delays between 2002/2003, when the first two FINEP installments were deposited into the UNDP account (and the exchange rate was around R$ 3.50 per US$), and 2007/2008 when most expenses were paid from the account (and the exchange rate was around R$ 1.70 per US$).

4.2.2 International Consortium

The participation of the international consortium contracted to supply and support the buses and hydrogen fueling station for the project has been highly satisfactory. In fact, the strength and cohesiveness of the consortium has been among the most important reasons that the project is likely to be judged an overall success in the end. The consortium has been so effective in part because of the time and care that was taken to identify strong and committed private sector members.

In January 2002 UNDP/Brazil published a request for expressions of interest in implementing the Brazil FCB project. Only a single response was received (in February 2002). This was from a private-sector partnership that included Ballard (a Canadian fuel cell stack supplier), Stuart Energy (a Canadian supplier of electrolysis-based hydrogen refueling systems), and Marcopolo (a Brazilian builder of bus bodies). Discussions ensued with UNDP, as a result of which in November 2004 the UNDP published a tender with detailed technical specifications for the Brazil FCB project. A proposed consortium of 8 companies (that included the original 3) responded with a technical and commercial proposal for implementing the first phase of the project. As UNDP considered the proposal, the consortium was formally constituted, with all eight members signing a consortium agreement by June 2005. A contract between the UNDP and the consortium was then signed by the UNDP in January 2006, and another five months were required to secure signatures on the contract from all eight consortium members. Nearly 4.5 years had passed from the UNDP's initial publishing of a request for expressions of interest to a fully-signed contract with a private-sector consortium that would supply and support equipment for the project.

The consortium included Ballard Power Systems, Hydrogenics (which acquired Stuart Energy in November 2004), Marcopolo, Tuttotrasporti (a Brazil bus-chassis builder and systems integrator), Nucellsys (a German maker of fuel cell engines using Ballard fuel cells), Petrobras Distriubidora (the distribution arm of the Brazilian national oil company), AES Eletropaulo (the electricity supplier to the EMTU facility), and EPRI (the Electric Power Research Institute, a research and development organization in the U.S.). Nucellsys and Eletropaulo subsequently left the consortium. Nucellsys was acquired by Daimler Chrysler in 2005, and Daimler took a decision to close Nucellsys to outside projects. Nucellsys withdrew from the consortium, but has continued to provide limited support for the development and operation of the prototype bus despite officially being outside of the consortium. Eletropaulo was involved with the consortium primarily to ensure proper specification of the substation needed for the additional electric power supply for the hydrogen refueling station. Once this work was completed, Eletropaulo elected to withdraw from the consortium.

Creating the consortium took over two years, during which considerable thinking and searching for the right technical and strategic partners took place, led by the EPRI representatives. The six current members of the consortium constitute a highly competent and dedicated team that has also been working well with the EMTU.

The strongest champion of the project and the leader of the consortium is EPRI, as represented by Ferdinand and Monica Panik. Dr. Ferdinand Panik comes from years of industrial experience with Mercedes Benz in heavy-duty vehicle (bus/truck) R&D and subsequently in launching of a commercial business for heavy duty vehicles in the Latin American market. From 1989 to 1996, he was a member of the Board of Management of Mercedes-Benz do Brasil, Sao Paulo, responsible for product development. He subsequently led the creation of Daimler-Chrysler's fuel cell vehicle development program in Germany. He retired from Daimler in 2002 and is currently Professor for Alternative Vehicle Concepts at the University of Applied Science in Esslingen, Germany. Monica Panik (his wife) is Brazilian and has expertise in project management and technical communications relating to fuel cell vehicles.

Ballard Power Systems is a leading company in the design, development and manufacturing of proton exchange membrane (PEM) fuel cells for vehicle applications. Nucellsys fuel cell engines use their technology for automotive applications, and Ballard is one of the few fuel cell engine developers pursing heavy-duty bus applications.[‡]

Another notable consortium participant is Tuttotrasporti, a company with deep expertise in building bus chassis and integrating electrical and mechanical systems into buses. The company has worked closely with Marcopolo over several decades, producing more than 95,000 integrated buses.

Marcopolo is the biggest builder of bus bodies in the Americas. For the project, they are providing the bodies for the four FCBs.

Petrobras Distribuidora (brand/logo "BR") is the distribution arm of Brazil's national oil company, Petrobras. BR maintains over 7,000 service stations in the country and also brings to the project relevant experience from the Petrobras Research and Development Center (CENPES). The role of BR in the FCB project is as integrator and operator of the hydrogen production and fueling station.

Hydrogenics is a well-established leading Canadian company in development and manufacture of hydrogen production and fueling stations. Hydrogenics has worked with Petrobras Distribuidora and Eletropaulo in the preparation and installation of the production and fueling station and in training of station operators to ensure safe and reliable operation.

4.2.3 Comments on project implementation

The project implementation has been guided by the logframe matrix (Table 1), but several of the activities associated with the outputs have been pursued at a slower than anticipated pace and with reduced quantitative targets, as discussed below. Despite these setbacks, the project has maintained momentum and appears to be on a sound trajectory toward achieving most of its larger goals. This continued progress can be attributed largely to the strength of the private-sector consortium contracted by UNDP to implement the project and the unflagging support provided by the UNDP Brazil office. The commentary here is organized around the outputs and activities defined in the logframe matrix.

[‡] Toyota, Hyundai, and Daimler are evidently also pursuing development of fuel cell buses. The status of their technologies is unknown to the author, but in any case they do not appear to be targeting Brazilian or other developing country markets, and so their technologies may not be suitable or affordable for these markets.

4.2.3.1 Output 1

Output 1 is a “significant demonstration of the operational viability of fuel cell drives in urban buses and their refueling infrastructure under Brazilian conditions” (Table 1). Activities were to include i) specifying bus technical performance targets, ii) tendering and selecting a vendor for provision of buses, iii) installing and operating/maintaining a hydrogen refueling infrastructure, iv) placing an initial three fuel cell buses into operation, and v) placing a second set of five buses into operation. The first two of the activities have been completed successfully. Issues with the 3rd activity, the hydrogen station, are discussed in Section 4.2.3.4. The last two activities are discussed here.

The total number of buses that were to be put into operation was reduced by half from the 8 buses stipulated in the Project Document. A single prototype bus was put into operation in “Phase II.2” of the project, and three buses will be put into operation in “Phase II.3”. The original number of buses was selected with the goal of achieving a target collective number of bus-km of operation (one million) during the project. The quantitative bus-km target was set “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.” Due to the reduced number of buses and other factors, the bus-km target will not be met, but in hindsight, reaching the million bus-km target is not critical to the success of the project. (See additional discussion below in Section 4.3.) Nevertheless, it is important to understand the reasons for the reduced number of buses in the project. There are two main reasons.

First, there was an early misunderstanding about how co-financing resources, especially FINEP funds, could be used in the project. When the project document was released in 1999, it indicated a full project budget of US$21.7, which had been arrived at based on an estimate of the costs for eight buses plus the costs for supporting their operation and the costs of undertaking the other project activities described in the logframe matrix. The assumption behind the project document was that both GEF and co-financing funds would be available for purchase of hardware in the project. Only when the co-financing commitment from FINEP was formalized (in March 2002) did it become clear that co-financing funds would not be available for hardware purchasing due to FINEP regulations, nor for international costs for engineering and services. Thus the funds available for hardware purchases were limited to the GEF’s US$12.274 million contribution (at a maximum).

The second main reason was that the contracted private-sector consortium suggested that the project pursue a strategy that would enhance the likelihood of achieving UNDP/GEF’s broader objective for its fuel cell bus program, the sustainable commercial deployment of fuel cell buses in developing country megacities. The consortium’s strategy entailed engineering a new generation of fuel cell bus design incorporating domestically produced chassis, body and major power train components rather than importing “lock-stock-and-barrel” a fuel cell bus produced in Europe or North America. Implementing this strategy would require extensive engineering, testing and know how transfer activities (all at added costs), but successful implementation would mean achievement of better technology performance, a stronger commitment and involvement of Brazilian industries, and higher public acceptance. To reduce project risks, UNDP/GEF negotiated a two-stage approach for implementing this strategy, Phase II.2 and II.3.

The Phase II.2 bus (prototype) involved a fundamental re-engineering of the bus design used in the previous generation of fuel cell buses that were demonstrated in the CUTE project.[11] The CUTE buses operated well, but suffered from high fuel consumption (20 to 24 kg H_2 per 100 km). A key modification that was expected to reduce the fuel consumption by as much as 50% was to integrate a battery and regenerative braking into the bus design.[12] Regenerative braking recovers energy that in conventional buses is dissipated as heat when brakes are applied. The energy is recovered as electricity, and the battery provides a means for storing this energy. When high power levels are required by the bus (e.g., for uphill acceleration), electricity delivered by the battery supplements the electrical output of the fuel cells, rather than having the fuel cell consume more hydrogen to provide the full power need. The Phase II.2 prototype bus was one of the first two on-the-road implementations of the so-called hybrid fuel cell/battery bus designs that incorporate key lessons learned from the CUTE program. (If not for delays in the project, the Phase II.2 bus may have been the world's first on-road implementation.) The prototype bus consisted of an advanced hybrid fuel cell propulsion system (all imported equipment) integrated in Brazil into a chassis and body produced in Brazil.

The Phase II.2 bus successfully completed functional testing during 2009, followed by a first stage of verification testing (ended August 2010) that involved operating in one of the EMTU bus corridors without passengers, and a second stage of verification testing with passengers that ended February 4, 2011. An estimated 1200 passengers were carried in the second stage verification tests, and a total of 7,900 km were driven during the two stages of verification testing.

Hydrogen consumption while driving on the EMTU corridor was considered a key metric for judging the success of the prototype design. Average hydrogen consumption varied depending on the passenger loading of the bus and on which of the four trained drivers was operating the bus. On 22 different days of testing, the average hydrogen consumption each day ranged from 7.4 kg per 100 km to 13.8 kg/100 km.[13] Conservatively, EMTU quotes an overall average consumption for a bus carrying passengers of 13 kg/100 km. The design target was 15 kg/100 km. This indicates a successful demonstration of one key aspect of the prototype bus design, which was to reduce fuel consumption by as much as 50% compared to fuel consumption for the previous generation of buses that used Ballard fuel cell engines but did not use regenerative braking or a storage battery.

For the Phase II.3 buses, additional design modifications were made to incorporate lessons from the Phase II.2 experience. These changes and the rationale for them are described in detail in the "Design Freeze" report for the Phase II.3 bus.[14] The most important of the modifications was the effort made to adopt much more Brazilian-made equipment into the design. "Brazilian-ization" was pursued to help reduce cost, but also having in mind that the larger the domestic content of the bus the more sustainable its production in Brazil would likely to be in the longer term.

The key components in the bus design that were "Brazilian-ized" are the traction motor, related electronics, and the fuel cell engine cooling system. The project consortium worked with a Brazilian electronics firm, WEG, which will supply the traction motor and electronics. (Siemens was the supplier for the Phase II.2 bus.) This required WEG to develop a water-cooled motor for heavy-duty vehicle applications, which was not one of its previous offerings. WEG successfully completed the development and now more than 30 of WEG's water-cooled motors with steel casings are installed on electric trolley buses operating in Brazil. The WEG motor for the Phase II.3 bus will utilize an aluminum casing to reduce weight, which will make it WEG's first aluminum water-cooled heavy duty traction motor to be installed. The fuel cell engine cooling system design for the Phase II.3 buses was dramatically streamlined from the imported system used on the prototype bus, largely to reduce weight. The new system will be supplied by a Brazilian vendor.

In addition to the redesign of the electronics and cooling system, the equipment layout within the bus was modified to enable use of a standard low-entry diesel bus chassis manufactured at a MAN facility in Rio de Janeiro and a bus body built by Marcopolo in Caxias do Sul that includes two passenger doors on each side of the bus. Additionally a new battery pack design and chemistry (relying on lithium rather than sodium) was adopted and a single heavy-duty fuel cell stack replaces the two smaller stacks (designed for automotive applications).

As a result of the extensive redesign from the Phase II.2 prototype to the Phase II.3 buses, the cost of each bus has been driven down to US$1.01 million each (Table 3). Cost reduction was one of the primary justifications for financing of the project by GEF. And while the expectation was that by demonstrating a larger number of buses, there would be greater cost reductions achieved, the cost reductions reached for the Phase II.3 buses exceed the reductions that were projected when the project was first conceptualized. An important reason for this better-than-expected achievement is that the limited funding available for the project forced a more careful examination of costs and a more concerted effort to find lower-cost solutions than in most FCB demonstration efforts that have taken place elsewhere, because most previous efforts took place in regions of the world (e.g., Europe and N. America) where public funds are more readily available. The Brazil Phase II.3 buses have set a new benchmark in cost reduction.

Table 3. Brazil Phase II.3 FCB cost (materials and production) in US$.[15]

	Supplier	Cost/Price
Chassis and cooling system	Tutto/MAN	166,228
Electric propulsion system	WEG	121,181
Batteries	Valence	66,400
Fuel cell system	Ballard	459,359
Air compressor	Rotrex (via Ballard)	15,828
Bus body & AC	Marcopolo	112,000
On-bus H_2 storage cylinders	Dynetek	69,950
	Total	**US$ 1,010,946**

Cumulatively, there are an estimated 79 fuel cell buses with Ballard fuel cells that have been operated (with different levels of intensity), and an additional 31 will be entering operation within the next year (Table 4). This represents a cumulative number of buses produced to date of 110. Recalling from Section 2 the cost projection made at the inception of the GEF FCB program:

$$Bus\ Price\ (in\ Year\ 2013\ US\$) = 3.9\ \times 10^6 \times (Cumulative\ number\ of\ buses\ produced)^{-0.257}$$

and applying it to buses with fuel cell engines using Ballard technology, the projected cost per bus at this stage of technology deployment experience would be $1.17 million. This projection is remarkably close to a completely independent FCB cost estimate made for 2012 in a major comparison study of alternative bus technologies for Europe:[16] US$1.125 million (Figure 3, left side, converted from Euro).

The Brazil Phase II.3 buses have a cost about 10% below this level, suggesting that some cost reduction "leap-frogging" (beyond industry expectations) has occurred. At a minimum, the cost developments in Brazil suggest that cost learning is proceeding (as a function of increasing number of buses produced) more-or-less as originally projected. With further scaling up of the number of buses produced, it can be expected that the trend in cost reduction will continue.

The first 37 buses listed in Table 4 used first-generation fuel cell engines consisting of a parallel arrangement of two fuel cell stacks designed for automotive applications. Ballard's expectation was that the automotive fuel cell engine market would grow more rapidly than bus engine markets and that bus designs could take advantage of the cost reductions that would occur as production of automotive fuel cells was scaled up. The automotive fuel cell market did not develop as anticipated, and so Ballard made a decision to focus their vehicle fuel cell efforts on heavy-duty applications.

The next 73 buses listed in Table 4 were built with a single fuel cell stack designed for heavy-duty applications (Ballard model HD6) and with onboard batteries and regenerative braking. The latter two features were pioneered in the Phase II.2 prototype bus and have subsequently become standard design features in state-of-the-art FCBs.

Ballard plans to introduce its next generation of heavy-duty fuel cell stack (the HD7) by mid-2014, incorporating technological improvements and cost reductions resulting from its HD6 experience. The expectation is that this will continue to move the fuel cell bus technology further down the cost reduction curve. The two Brazilian projects listed as under discussion in Table 4 would include some buses with HD7 engines and some with HD6 engines.

Table 4. Fuel cell buses that have operated, are currently operating, or will soon be operating with Ballard fuel cell stacks.[17]

Location/Program/Host	Number of Buses	Warranty (hours) on fuel cell	Start Date
Amsterdam, Barcelona, Beijing, Hamburg, London, Luxembourg, Madrid, Perth, Porto, Reykjavik, Stockholm, Stuttgart, (CUTE, ECTOS, STEP projects)	36		2003
Sao Paulo, Brazil (EMTU, Phase II.2)	1		07/2009
USA (GERC)	1	12,000	11/2009
Whistler, Canada (BC Transit)	20	12,000	02/2010
California, USA (SunLine AT)	1	8,000	04/2010
California, USA (Sunline AA)	1	12,000	11/2010
Amsterdam, Holland	2	15,000	2010
Cologne, Germany	2	15,000	2010
Flanders, Belgium	1	15,000	2011
London (TFL)	8	12,000	2011
Oslo, Norway	5	15,000	2012
Ohio, USA (DesignLine)	1	6,000	07/2013
Expected to enter service within the next 12 months			
California, USA (Sunline AA)	2	12,000	10/2013
San Remo, Italy	5	15,000	2013
Sao Paulo, Brazil (EMTU, Phase II.3)	3	6,000	03/2014
Massachusetts, USA (Nuvera)	1	12,000	03/2014
Connecticut, USA (CT Transit)	1	12,000	05/2014
Irvine, California, USA	1	12,000	08/2014
Chicago Transit Authority, Illinois, USA	1	3,000	09/2014
Di-Lijn, Belgium	5	15,000	2014
Aberdeen, Scotland	10	15,000	2014
Cologne, Germany	2	15,000	2014
TOTAL BUSES	**110**		
Proposed			
Sao Paulo, Brazil (EMTU)	20	3,000	01/2015
Under Discussion			
Sao Paulo, Brazil	75	3,000	2015
Espirito Santo, Brazil	100	3,000	2014/2015

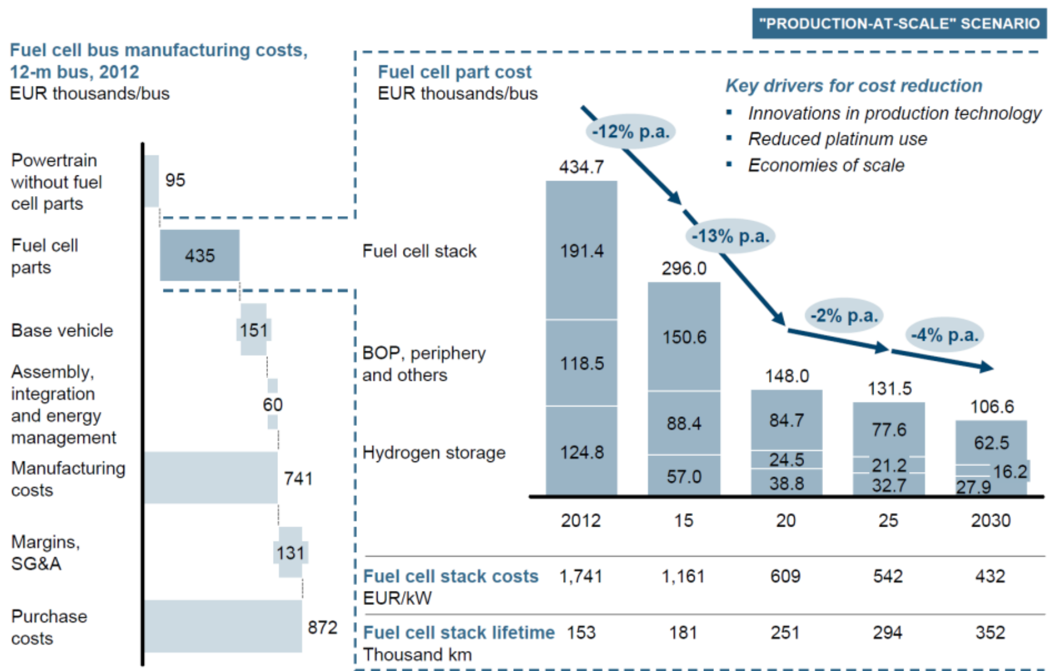

Figure 3. Fuel cell bus costs in a major European study published in 2012.[16] The bus cost shown for 2012 (0.872 million Euro), if converted to US$ at the average 2012 exchange rate (1.29 US$/Euro) is US$ 1.125 million. The projected costs for 2015 and beyond are for the "Production-at-Scale" scenario described in the study, for which a key assumption is that FCBs capture significant market share, resulting in production of 1,500 buses per year per manufacturer between 2020 and 2030.

4.2.3.2 Output 2

Output 2 is "a cadre of bus operators and staff trained in the operation, maintenance, and management of fuel cell buses." Given the reduced size of the FCB fleet installed at EMTU, the size of the trained cadre has been similarly downscaled. To date, a total of 21 people have been trained as drivers or in maintenance at EMTU and METRA (the company that operates buses for EMTU), including four drivers. Additionally, there has been a transfer of know-how from Ballard to Tuttotrasporti relating to the design, construction, and maintenance of fuel cell buses and assessment of their performance. Additional personnel will be trained as Phase II.3 proceeds, but it seems unlikely that the quantitative targets stipulated in the logframe matrix (Table 1) for the number of drivers and mechanics to be trained will be achieved.

4.2.3.3 Output 3

Output 3 is "the accumulation of a substantial body of knowledge about reliability, failure modes and opportunities for improving the design of fuel cell buses for Brazil." Considerable knowledge was gained in the design, construction, and operation of the Phase II.2 prototype bus and incorporated into the design of the Phase II.3 buses, as attested to by cost reductions achieved for the Phase II.3 buses. However, the operating hours logged by the prototype bus were far fewer than envisioned in the original design of the project. This is regrettable, and resulted in far less learning from the prototype bus than desirable considering the investment made. There appear to be two major reasons for the fewer-than-targeted number of operating hours.

One reason was unanticipated delays in bus repairs when replacement parts were required. Since the majority of the equipment on the bus was imported, when part replacements were needed, they had to be ordered from abroad, and considerable time was spent waiting for delivery to, and customs clearance after arrival in, Brazil. This was one important motivation for incorporating more Brazilian equipment into the design of the Phase II.3 buses. The most troublesome equipment in the prototype bus appears to have been the batteries, which were sodium-based. This battery chemistry has, in principle, attractive features for FCB applications, especially high storage capacity per unit weight,[18] but maintaining good performance in practice in the prototype bus proved very challenging in part because effective operation of the battery requires keeping it at an elevated temperature at all times. For this reason, the project adopted lithium-based batteries for the Phase II.3 buses. Subsequent to the building of the prototype bus, lithium batteries have proven to have acceptable performance in FCB applications, e.g., the 20-bus fleet of FCBs in Whistler, British Columbia all utilize lithium batteries. (The 20 FCBs constitute the entire Whistler Transit bus fleet.) No replacement of the fuel cell stacks on the prototype was ever required, although spare fuel cell stacks had been purchased to have onsite as a contingency. (If the prototype is operated for a longer time, it is anticipated that these spares will be used, not necessarily because of operation-induced failures, but rather because of failures arising from infrequent use.)

A second reason for the shortened operating hours for the prototype bus was the lack of a contract with Tuttotrasporti to provide maintenance support during operation. The project budget calls for the use of FINEP co-financing funds to pay for the maintenance contract. Because of the stoppage in the flow of FINEP funds to the project (discussed in Section 4.2.1), a contract for maintenance of the prototype bus was not entered into with Tuttotrasporti. Tuttotrasporti has on special occasions (such as my visit to see the bus) used some of its own resources to provide maintenance support, but this is not a sustainable option for steady, longer-time operation. Ironically, more consistent operation would probably reduce the need for maintenance, since industrial equipment is generally designed to be operated continuously rather than off and on.

4.2.3.4 Output 4

Output 4 is "an assessment of the performance of the electrolysis unit." (Presumably this output refers to the performance of the hydrogen production and fueling station as a whole, rather than only the electrolysis unit.) As of this writing, the electrolysis unit had been successfully commissioned, but the full hydrogen station had not. Thus, no overall assessment of the performance of the hydrogen production and fueling station has yet been possible. (Hydrogen fuel for the prototype was purchased on the open market.)

The construction and commissioning of the hydrogen production and refueling station have taken years longer than should be the case with a well-established commercial technology like water electrolysis. Interestingly, the concern that licensing of the hydrogen facility might delay construction and commissioning due to licensing authorities being unfamiliar with hydrogen turned out not to be a problem, because the project team familiarized the licensing authorities with hydrogen stations by holding a technical workshop (November 2006) and also leading a visit to operating European hydrogen facilities (May 2007).

Delays in the construction and commissioning are difficult to have anticipated:

1) The basic equipment for the station (electrolyzers, hydrogen storage tanks, etc.) were delivered to the site in December 2007 and January 2008. The equipment proceeded to sit uninstalled until January 2010, when installation was started and continued through June 2010. The reason for the long delay between equipment delivery and installation was that no responses were received to the initial tenders issued by UNDP for a company to assemble the hydrogen station equipment that had been delivered to the site by Hydrogenics. Evidently, no local companies were comfortable with doing the work to interconnect equipment for an electrolysis-based hydrogen production, storage, and dispensing station for the price being offered. Ultimately, Hydrogenics supplemented the available funds from internal resources to ensure completion of the interconnection work.
2) The hydrogen station is located on the grounds of the EMTU bus garaging facility in Sao Bernardo do Campo. The station needs to maintain an inventory on site of potassium hydroxide (KOH), the electrolyte used in the electrolyzers. This is a tightly regulated chemical due to its potential as a bomb ingredient. Hydrogenics was responsible for obtaining the KOH needed before commissioning of the station could take place. However, Hydrogenics did not have the legal authority required for it to be able to get a permit from the Federal Police to purchase the KOH. Eligibility for a permit is available only to entities with a CNPJ number (Cadastro Nacional de Pessoa Jurídica). Recognizing the difficulty that Hydrogenics might encounter in getting a CNPJ, Petrobras Distribuidora (BR), the intended operator of the hydrogen station, assumed the task of securing the KOH in July 2010. BR also did not have a CNPJ for the land on which the hydrogen station was to be built, because it did not hold the land (which is a requirement for obtaining a CNPJ). EMTU began the process of ceding the land area to BR, a process that was expected to take several months, and which would thereby further delay the commissioning of the station. EMTU, which already had the requisite CNPJ number went ahead and applied for a KOH purchase permit from the Federal Police, and this was finally issued on May 30, 2011. The KOH was purchased by EMTU in August 2011. [The process of ceding the land to BR (for the duration of the project) was finally concluded in September 2012, but as of this writing BR is still awaiting a CNPJ number.]
3) With the KOH issue resolved, Hydrogenics proceeded in August 2011 to apply for work visas for their engineers to travel from Canada to commission the hydrogen station. A full-year passed before the visas were issued. The commissioning of the electrolyzers at the hydrogen station finally began in August 2012 when a Hydrogenics engineer was able to be

onsite. As a result of several years of non-use of the hydrogen station equipment, Hydrogenics engineers ended up making four trips from Canada to Sao Paulo between August 2012 and May 2013 to perform repairs and maintenance and replace some non-functioning parts so that the commissioning could progress. The commissioning of the electrolyzers was completed, but problems were then identified with the hydrogen compressor in December 2012. The commissioning was halted at that point while waiting for a technician from the compressor manufacturer (PPI) to travel to Sao Paulo to repair it. The repair was completed in May 2013, when a Hydrogenics engineer returned to continue with the commissioning. With the compressor working, some leaks in the hydrogen storage tanks (which were provided by another company, Dynetek) were found. Pending decisions about repair of the tanks, the Hydrogenics engineer flew back to Canada. Once the repair strategy for the tanks was defined, he returned to Brazil again in early August 2013 to repair the leaks and complete the commissioning. However, upon arrival at the Sao Paulo airport, he was prevented from entering the country because he had not registered his visa with the Federal Police on his first entry in Brazil (a requirement of which he had not been aware). He was sent directly back to Canada from Sao Paulo airport and as of the end of August 2013 was awaiting another visa. The expectation is that he will be able to return to Sao Paulo to fix the leaks and complete the commissioning in September or October 2013.

4.2.3.5 Output 5

Output 5 is "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." The project has not yet begun formulating a Phase III proposal. My recommendation (as elaborated in Section 5.3) is that a Phase III project should be pursued, and co-funding for such a project should be requested from GEF. The development of GEF proposals is time-consuming, and considering that the Phase II project is scheduled to conclude at the end of 2014, the proposal development process should begin immediately.

4.2.3.6 Output 6

Output 6 is "increased awareness and support of the public for an increased role for fuel cell buses in Brazil's urban transport system." The results in this case have been highly satisfactory. Led by EMTU, the project has focused its outreach efforts on educating the public about the existence and the potential benefits of hydrogen fuel cell buses for Brazil. The activities have included *i)* operating the prototype bus in revenue service with a total of about 1200 riders and distributing information leaflets to riders; very good feedback has been received from riders, *ii)* distributing public service videos produced by EMTU, *iii)* receiving news coverage of the project on television, magazine, and newspapers, including interviews with EMTU participants, *iv)* appearing in a featured segment of a special Discovery channel show aired on Brazilian television, *v)* publishing a book recounting the story of the development of the prototype bus, *vi)* holding a highly-publicized FCB launch event upon the roll-out of the prototype bus, *vii)* participating at national and international meetings, and *viii)* having the prototype bus voted in 2010, by both the public and by a technical jury, as one of the Top 3 winners of Brazil's prestigious "GreenBest" award for sustainability in the transportation category.

4.3 Project Results

The Brazil FCB project has moved much more slowly than originally anticipated, it will involve only half as many buses as originally designed, and the total cumulative operating mileage for the buses will fall far short of the one million kilometer mark stipulated in the logframe matrix (Table 1). Despite the shortfall in achieving this quantitative target, the project seems likely to produce most of the other stipulated outputs and provide an important step toward reaching the larger goal envisioned by the UNDP/GEF when it launched its program in support of fuel cell bus demonstrations.

Regarding the quantitative metric of bus-kilometers operated, the project document[8] specified the one million km milestone "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." In hindsight, the large number of FCB demonstration programs around the world (see Annex 3) have, in effect, substituted for some of the mileage intended to be logged in the Brazilian project and have thereby helped improve the reliability and durability of FCBs even as the Brazilian project was being scaled back and encountering delays. The technical progress elsewhere in the world made the strictly technical aspects of fuel cell bus demonstration in Brazil a less urgent need.

Over a period of less than 12 months ending in August 2013, thirty-six FCBs operating with Ballard engines in six cities around the world recently logged nearly 4 million bus-km of operation (Table 5), and operation of these buses has been continuing. Most of these bus-km have been logged by the BC Transit fleet of 20 FCBs in Whistler, Canada. This is particularly relevant here because the Whistler fleet utilizes Ballard fuel cell technology and bus designs that are similar in many technical ways to the Phase II.3 buses. The similarities are not accidental, because the design of the Whistler buses was informed in part by lessons learned from the Phase II.2 prototype bus, and the design of the Phase II.3 buses incorporate lessons from the Whistler fleet. The fuel cell stacks used in the Whistler buses (Ballard HD6) were manufactured alongside the HD6 stacks that are slated for use in the Phase II.3 buses. Ironically, the Phase II.3 buses were intended to be the first in the world to operate with HD6 technology, but because of the delays in the project, they will now be among the last before Ballard introduces its new HD7 generation of technology in mid-2014.

The Whistler fleet entered service in 2010 and is currently logging revenue-service mileage at a collective rate of about 4 million bus-km per year. In the past year the buses demonstrated an availability above 56%, and problems specific to the fuel cells took buses out of service less than 2% of the time (Figure 4). The overall cost of the Whistler fuel cell bus project, spanning 2006-2014 and including buying, fueling, operating, and maintaining the Whistler fleet, is an estimated US$86 million.[19] It would be fair to say that the GEF expenditures in the Brazilian project have leveraged and directly benefitted from these far larger expenditures, as well as expenditures on FCB programs in other countries around the world.

Table 5. Summary operating data for the period Oct. 15, 2012 – August 15, 2013 for fuel cell buses with Ballard fuel cell engines.

	# of buses	Bus-hrs	Bus-km
Whistler (BC, Canada)	20	163,154	3,467,720
TFL, London	5	26,071	166,264
Sunline (California, USA)	2	9,272	124,373
van Hool	5	4,106	96,390
APTS, Amsterdam	2	3,332	59,025
APTS, Cologne	2	2,979	57,836
TOTALS	36	208,915	3,971,608
* These figures were provided by Ballard.[20] They likely underestimate the actual amount of operation because Ballard is only an equipment supplier to these projects. As such, Ballard relies on the bus operators to collect and report data. In most cases, the operators have no specific obligation to report data to Ballard, and so data reporting is inconsistent by some of them.			

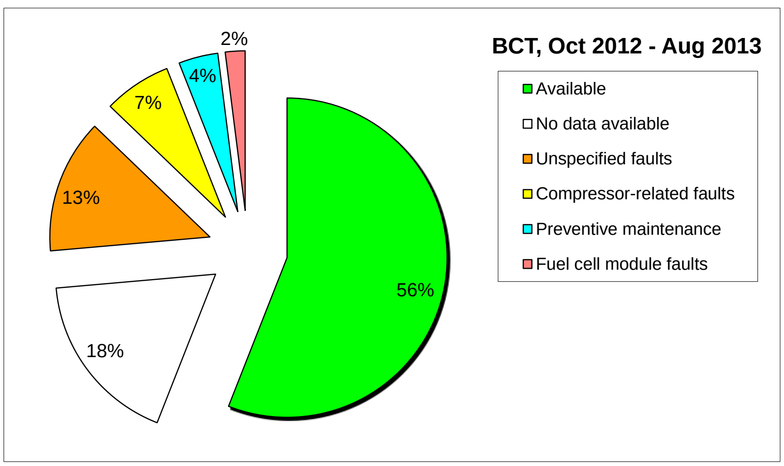

Figure 4. Availability and fault data for the 20 fuel-cell buses operated by BC Transit in Whistler, Canada.[20] During the indicated time period, the bus fleet ran for 163,154 bus-hours and logged 3,467,720 km (Table 5).

With foresight, the project document also notes that "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." (Phase III is further discussed in Section 5.3.) It is fair to say that the project has been very successful in showing a fuel cell bus operating on the streets of Sao Paulo and in familiarizing key institutions and individuals in Brazil (one of the world's biggest bus markets) with fuel cell buses. Moreover, the project has also begun "Brazilian-izing" the technology by domestically sourcing key equipment components for the Phase II.3 buses. This has had the added benefit of helping to reduce the cost of the buses as a whole. These are all critical achievements toward the larger objective of the original multi-country GEF fuel cell bus demonstration program, which was to help ensure that FCBs would become available for developing country markets in a timely and economically sustainable way. An indicator of the success achieved toward this end is the active discussions ongoing within EMTU regarding a next phase of fuel cell bus deployments in Brazil. (See related discussion in Section 5.3.)

As an overall evaluation of the project results to date, the quantitative objectives set out in the logframe matrix, strictly speaking, have been achieved in only a marginally satisfactory way, but the qualitative results achieved, involving Brazilian-ization of the technology and experience with fuel cell buses, are highly satisfactory. The latter rating suggests good possibilities for long-term sustainability of fuel cell buses in Brazil, assuming the Phase II.3 buses are successfully operated.

5 Conclusions, Lessons, Recommendations, and Ratings Summary

5.1 Conclusions

The Brazilian FCB project was one of several projects envisioned as part of the fuel cell bus commercialization support program established by the UNDP and GEF beginning in the late 1990s, and it is in this context that the Brazilian FCB project was evaluated here. UNDP/GEF created the FCB commercialization support program to help ensure that FCBs, which showed promise for significant reductions in GHG emissions and ancillary benefits vis-à-vis local air pollution and other factors, would become available for developing country markets in a timely and sustainable way. At the time the UNDP/GEF program was being formulated most fuel-cell engine companies were targeting primarily automobile markets and had interest in FCBs only to the extent that they could provide a stepping stone to the automotive market. By supporting commercial demonstration of FCBs in GEF program countries, UNDP/GEF sought to focus private sector resources on understanding and meeting the unique demands of these important potential markets for FCBs while helping to prepare the market in developing countries for the large-scale introduction of FCBs. Demonstration projects supported by the UNDP/GEF, such as the Brazilian project, were intended to enable countries to gain experience in operating and maintaining FCBs; to build institutional capacity for managing fuel-cell vehicles and infrastructure; to build public confidence in the technology; and to facilitate international joint ventures for technology transfer.

In this context, the original design of the Brazil FCB project was sound. The outputs and activities in the logframe matrix are well defined, and quantitative indicators are identified for measuring success. An unusually strong and committed set of Brazilian public-sector stakeholders came together to participate in the project and provide 30% of the US$21 million project budget.

In hindsight, the major shortcoming in the logframe matrix was its underestimate of how external factors might impact the project, including the time required to achieve milestones and costs. The project document called for a five-year project that would be launched in mid-2001. The project was launched as expected in 2001, but its closing date has been extended from 2006 to 2014. Nearly 4.5 years had passed from the UNDP's initial publishing of a request for expressions of interest in 2002 to a fully-signed contract with a private-sector consortium to supply and support equipment for the project. Time was consumed in bringing on board the right technical and strategic partners and decision-making was complicated by the need for all consortium members to sign the contract with the UNDP. In retrospect, because the FCB and hydrogen fueling technologies are not "off-the-shelf" systems, the time-consuming consortium building process should probably have been anticipated. Nevertheless, in the end, the members of the consortium constitute a highly competent and dedicated team that has also been working well with EMTU, the project implementing agency.

Other delays have occurred. One that had an especially negative effect on the project was the delayed disbursement of FINEP co-financing (an issue that was still unresolved as of late 2013). As a result, key operating and maintenance activities connected with the first prototype bus had to be cut back, resulting in less operating experience than expected. Importing replacement parts and bringing engineers from outside of Brazil to commission or fix imported equipment added additional delays.

In addition to project delays, the number of buses to be built and operated in the project was reduced from eight specified in the project document to four: a single prototype bus was operated in "Phase II.2" of the project and three buses will be operated in "Phase II.3". One reason for the reduced number of buses was that in the original formulation of the project document (in 1999), it was assumed that both GEF funds and co-financing funds would be available to purchase hardware. The co-financing arrangements were finalized only several years later, and the co-financing funds that actually supported the project (from FINEP) were, by FINEP's institutional rules, not eligible for use toward hardware purchases. The second main reason for the reduced number of buses was that the private-sector consortium suggested the project pursue a strategy that would enhance the likelihood of achieving UNDP/GEF's broader objective for its fuel cell bus program, the sustainable commercial deployment of fuel cell buses in developing country megacities. The suggestion was adopted, and the strategy entailed engineering a new generation of fuel cell bus design incorporating domestically produced chassis, body and major power train components rather than importing "lock-stock-and-barrel" a fuel cell bus produced in Europe or North America. Implementing this strategy would require extensive engineering, testing and know how transfer activities (all at added costs), but successful implementation would mean achievement of better technology performance, a stronger commitment and involvement of Brazilian industries, and higher public acceptance. To reduce project risks, UNDP/GEF negotiated a two-stage approach for implementing this strategy, Phase II.2 and II.3.

The prototype (Phase II.2) bus successfully operated and provided important lessons for the design of the Phase II.3 buses. Hydrogen consumption per kilometer driven, a key metric for judging the success of the prototype design, averaged about 13 kg/100 km for the prototype when carrying passengers. This is well below the design target of 15 kg/100 km and almost a 50% reduction compared to the previous generation of Ballard fuel cell buses tested in the Europe-based CUTE project.

The Phase II.3 bus designs incorporate many lessons from the prototype experience. The most important of the modifications was the effort made to adopt much more Brazilian-made equipment into the design. “Brazilian-ization” was pursued to help reduce cost, but also having in mind that the larger domestic content in the bus will make them more sustainable in Brazil in the longer term.

The Phase II.3 buses are costing US$1.01 million each, which compares with a bus cost of about US$3 million (in today’s dollars) when the project was first conceptualized. This cost reduction exceeds expectations and sets a new global benchmark. It should be noted, however, that the Phase II.3 buses have yet to be operated, and successful operation will be essential to demonstrate before definitive conclusions can be reached regarding the cost reduction achievement.

The Brazilian-ization and cost reduction efforts, coupled with EMTU-led efforts to increase awareness and public support for fuel cell buses in Brazil represent critical achievements toward the larger objective of the original UNDP/GEF fuel cell bus program of helping ensure that FCBs would become a sustainable option for developing countries in a timely way.

As an overall evaluation of the project results to date, the quantitative objectives set out in the logframe matrix, strictly speaking, have been achieved in only a marginally satisfactory way, but progress in other FCB projects worldwide have compensated for this shortfall. Moreover, the qualitative results achieved in the project, including Brazilian-ization of the technology and engaging/informing the public, are highly satisfactory and suggest there are good possibilities for long-term sustainability of fuel cell buses in Brazil, assuming the Phase II.3 buses are successfully operated.

Thus, despite the setbacks, the project has maintained momentum and appears to be on a sound trajectory toward achieving most of its larger goals. This continued progress can be attributed largely to the strength of the private-sector consortium contracted by UNDP to implement the project and the unflagging support provided by the UNDP Brazil office.

One output that has not yet been pursued in the project is the formulation of a proposal to UNDP/GEF for a Phase III project. The development of GEF proposals is time-consuming, and considering that the Phase II project is scheduled to conclude at the end of 2014, the proposal development process should begin immediately. (See related discussion in Section 5.3.)

5.2 Lessons

The following are some key lessons from the project:

1. The project has brought a substantial level of maturity to hydrogen fuel cell bus technology for Brazil, such that there is the real possibility to deploy this technology in the future in revenue-generating bus transit operations.
2. The four buses that have been or will be operated in the project won't make a discernible difference to the environment today, considering that more than 15,000 transit buses ply the streets of the Sao Paulo metropolitan area on a daily basis. However, the wide press coverage and other outreach efforts by EMTU and others seem likely to stimulate additional deployment activities that will make a difference.
3. Technology know-how has been transferred to Brazilian industry (not left abroad or transferred only to government or academia). This enhances the prospects for expanded and sustainable deployment of fuel cell buses in the future in Brazil.
4. Simpler institutional arrangements would be desirable for the next project. In particular, having initially eight, and subsequently six, companies each needing to sign each agreement involved in the project was cumbersome and time consuming. The consortium has recognized this issue, and for future negotiations and agreements it has assigned signing authority to the representatives from EPRI who have been leading the consortium.
5. When inevitable technical problems arose with the prototype bus, they were quickly diagnosed and solutions identified. However, time and costs involved with importing equipment created serious delays in implementing solutions. Higher local content for the buses would be important for reducing these problems and coincidentally enhancing the prospects for long-term sustainability of the technology in Brazil.
6. The strictly engineering aspects of the project to date have been very good. The prototype bus has performed as well as, if not better than, expected, although the number of kilometers logged has fallen far short of original goals. The Phase II.3 buses remain to be demonstrated in operation.

5.3 Recommendations

FINEP Funds

Make FINEP funds available as soon as possible to support the final stages of the Phase II.3 project, especially the operation of the buses to ensure that as many kilometers can be logged as possible.

Phase II.3 bus operations

Operate the Phase II.3 buses for as many kilometers as needed to engender in EMTU and other local stakeholders full confidence in the FCB technology such that follow-on deployment of an expanded fleet of FCBs in Brazil will be given serious consideration.

To implement this recommendation may require operating the Phase II.3 buses beyond the scheduled 31 Dec 2014 end date of the GEF project, since the buses are not expected to be put into operation until March 2014. At least one additional year of operation is recommended, and 18 to 24 months would be more optimal.

Additional funds may be needed to support this extended operation. Given that FINEP funds have been on hold since 2010, the possibility that within the remaining FINEP funds (some R$3.8 million) there would be enough to support extended operation of the Phase II.3 buses beyond 2014 should be assessed carefully by the project.

If the FINEP funds prove sufficient for longer operation of the Phase II.3 buses, it would likely require extending the closing date for the project to enable the funds to be spent out. However, if the Phase II.3 buses are operating well during 2014, the GEF is likely to be reluctant to provide a "no-cost extension" to keep the project open for any additional time, since it has already been extended (albeit with good justification) far beyond its original end date. On the other hand, if the Phase II.3 buses do not run well during 2014, then there may be an argument for extending the project in order to solve the problems and end the project with the buses running well.

Closing the GEF project as scheduled at the end of 2014 is not necessarily in conflict with continuing to operate the buses beyond this date, but in that case, additional resources would be needed to support post-2014 operation. Since EMTU will have ownership of the Phase II.3 buses and stands to benefit from greater learning with longer bus operation, EMTU might consider supporting the required maintenance contracts for the buses beyond the close of the GEF project. Also since Petrobras will have responsibility for operating the hydrogen production/fueling station and stands to acquire additional knowledge from continued operation, Petrobras might consider supporting the ongoing operation of the hydrogen station. Alternatively, or in addition, the idea of a project involving side-by-side comparison of electrolytic hydrogen and hydrogen via ethanol reforming might be evaluated, and if it looks interesting the ethanol industry might be approached to cultivate interest in supporting such an effort.

Stage III project proposal development

The project document calls for the formulation of a proposal to GEF for a Phase III effort in Brazil. Assuming the Phase II.3 buses operate successfully, and there are good reasons to expect that they will, I believe that a Phase III project should be pursued. The timing for having a Phase III project considered by the GEF may be fortuitous because a replenishing of the GEF funds ("GEF 6") is slated for mid-2014. Thus, it would be timely to have a draft Phase III proposal available by the beginning of the third quarter of 2014. Since many discussions among potential stakeholders, including the Brazilian Cooperation Agency (ABC), will be required in developing a proposal, the process should begin immediately.

It is important to note that if a Phase III proposal is to be submitted in 2014, and if that proposal involves EMTU, then the Phase II project will, in all likelihood, need to be closed as currently scheduled (by the end of 2014). Since it will take months to finalize/approve a Phase III project, data collection on Phase II.3 buses can continue beyond 2014 and any Phase III project can be modified if needed (based on new data) before it is finalized.

The project document ambitiously called for a Phase III project involving a fleet of some 200 fuel cell buses deployed in Sao Paulo. Because scale-up of fuel cell engine technology has not evolved as envisioned when the project document was written, a more modest number of buses would be appropriate. EMTU personnel with whom I discussed follow-on projects felt that 20 would be a good number of buses, given that the ability to effectively utilize fuel cell buses is currently limited by the number people trained in operating and maintaining them.

I recommend that preliminary analysis of Phase III project concepts begin immediately. One idea that came from my discussions in Brazil relates to planned improvements for the Sao Paulo metropolitan region in bus transit efficiency via greater use of bus-rapid-transit (BRT) systems involving dedicated bus corridors. EMTU currently operates a single corridor, is involved in the construction of 2 additional ones, and has four BRT systems in the project development phase. A proposal idea has been submitted to the state of Sao Paulo by a consortium of private companies, led by Ballard, for a R$500 million public-private partnership (PPP) to build and operate a 17 km stretch of one of the planned EMTU BRTs for the northwestern region of the Sao Paulo metropolitan area and to designate it as a “clean” BRT. The BRT is proposed to be served by a fleet of 20 hydrogen fuel cell buses.

The government of Sao Paulo state now entertains unsolicited proposal ideas for PPPs for major infrastructure-related projects. If the state judges such a proposal idea as interesting and fiscally prudent, the state may choose to issue a call for tenders that includes some or all elements of the original proposal idea. The call would be open to any competitive PPP proposal. The clean BRT proposal idea has already received a favorable review by state authorities, and an open call for tenders is anticipated in the second quarter of 2014. It remains to be seen how closely the project described in the call for tenders will resemble the proposal idea offered by the Ballard-led consortium for a clean BRT.

Should such a PPP effort materialize, a Phase III GEF project might be designed such that GEF funds cover some or all of the incremental cost of deploying in the clean BRT fuel cell buses rather than conventional buses that have higher greenhouse gas emissions. A rough estimate of the incremental capital cost for the purchase of 20 FCBs in lieu of diesel buses is US$16 million.[§] This model for a project, whereby incremental costs for lower GHG emissions are paid by GEF, is a familiar one for GEF in renewable energy projects where market

[§] This assumes each FCB costs US$0.9 million, or 10% less than each of the Phase II.3 buses, and that a diesel bus in Brazil costs about US$0.1 million, an estimate based on discussion with Leandro Sodre of Marcopolo in Caxias do Sul on August 22, 2013.

deployment is the emphasis, rather than technology development. Such a Stage III proposal might fit well in the GEF portfolio of projects on “Sustainable Transport” or “Sustainable Cities”.

5.4 Summary ratings

A summary of this mid-term evaluation is given in in the form of ratings and comments in Table 6.

Table 6. Ratings summarizing this mid-term evaluation.

1. Monitoring and Evaluation	***Rating****	***Comments***
M&E design at entry	HS	The PRODOC defines clearly the M&E requirements.
M&E plan implementation	HS	The evaluator received several excellent detailed reports documenting engineering design decisions, FCB and hydrogen fueling station performance, and other technical data that were generated in the project. Many other such reports were also prepared. The M&E plan also calls for annual reviews of “progress towards cost reduction, reliability improvement and increased durability”. The evaluator is not aware whether these reviews have been taking place. The project has moved more slowly than anticipated, so this is not surprising. However, a cost, reliability and durability review would be important to conduct once the end of Phase II.3 of the project is approached.
Overall M&E	***HS***	
2. IA& EA Execution	***Rating****	***Comments***
Quality of UNDP Implementation	MS	The project schedule stipulated in the PRODOC was highly optimistic. The original project schedule has not been followed. Nevertheless, UNDP staff have been active and conscientious about lending support as needed to keep the project going.
Project implementation – Implementing Agency	MS	Leaving aside the project schedule (which was overly optimistic from the start), EMTU has managed the project reasonably well.
Project execution – Executing Agency	MS	MME has facilitated the project well. Faster resolution of the problem encountered with FINEP co-financing would have been desirable.
Overall Implementation, Execution	***MS***	

3. Assessment of Outcomes	*Rating**	*Comments*
Relevance	HS	At the time of signing of the PRODOC, Brazil was formally pursuing hydrogen as part of its overall energy development strategy. Hydrogen has since been de-emphasized as a result of changing energy market conditions and slower than expected development of hydrogen technology. Nevertheless, because Brazil is among the biggest urban transit bus markets in the world, and conventional diesel buses are among the most significant contributors to local air pollution in cities, the pursuit of clean FCBs continues to be highly relevant for the Brazilian context.
Effectiveness	HS	Most of the objectives defined in the PRODOC are likely to be achieved, with the exception of the million bus-km operating target. In retrospect, due to other FCB projects worldwide, achieving the bus-km target was not critical to the overall success of the project. More critical have been the cost reductions for FCBs that were achieved and the related Brazilian supply of some key FCB components and Brazilian-ization of the capability for design and assembly of FCBs.
Efficiency	HS	It is difficult to assess cost effectiveness for a technology development / assimilation project. A crude measure is the total resources expended per FCB, which will be US$4.23 million per bus. This is comparable to the 20-FCB project in Whistler, Canada, with an announced cost of $4.30 million per bus. In most cases, larger projects will benefit from scale economies and have lower per-unit costs. The fact that the Brazilian project deployed only one-fifth as many buses as the Whistler project, yet has comparable unit costs indicates a more efficient use of resources than one would expect by simple extrapolation down from the Whistler project.
Overall Outcome	***HS***	

4. Sustainability	***Rating*****	***Comments***
Financial resources	ML	The availability of financing for subsequent FCB fleets in Brazil is a critical issue. The first cost of FCBs will likely always be higher than first cost of conventional buses, but as manufacturing costs fall, FCBs should eventually compete on a full cost-accounting basis because of the much higher fuel efficiency they can achieve. Achieving this level of cost-competitiveness in Brazil will require at least one and perhaps more Brazilian-ized FCB fleets to be deployed after the current project. Financing these will be challenging, and will depend, *inter alia*, on how the FCB's very low emissions of local air pollutants and CO_2 are valued. Innovative approaches, such as the idea for a Stage III projected described in this report, will be required. The success of the current project in raising the confidence of bus planning and regulating agencies like EMTU will help gain acceptance for innovative solutions.
Socio-political	L	Mass transit is a critical element of the urban infrastructure in Brazil. This project demonstrated that the attractive environmental features of FCBs vs conventional buses are easily understood and readily accepted by bus system operators and the bus-riding public in Sao Paulo. The planned expansion of dedicated bus corridors and bus rapid transit systems presents an ideal context for deployment of FCB fleets.
Institutional framework and governance	ML	A number of legal and institutional challenges were encountered in this project and solutions were found in all cases. This is encouraging for the longer-term. Substantial technical know-how regarding FCBs has been transferred to a limited number of individuals and institutions in Brazil. The introduction of future FCB fleets will require an expanded cadre of trained individuals and organizations, but there is no intrinsic hurdle to achieving this.
Environmental	L	FCBs have been clearly demonstrated to be much lower in local and global (carbon) pollution. This is an intrinsic feature of the technology.
Overall Sustainability	***ML***	
* HS = Highly satisfactory (no shortcomings), S = satisfactory (minor shortcomings), MS = moderately satisfactory, MU = moderately unsatisfactory, U = unsatisfactory, HU = highly unsatisfactory, R = Relevant, ** L = likely, ML = moderately likely (moderate risks), MU = moderately unlikely (significant risks), U = unlikely (severe risks), HU = highly unlikely.		

6 References

[1] Larson, E.D., Hosier, R., and Page, C., 2002. "Hydrogen Fuel-Cell Buses for Megacities of Developing Countries," *Sustainable Development International*, Spring issue, pp. 99-104.

[2] A. McDonald and L. Schrattenholzer, 2001. "Learning rates for energy technologies," *Energy Policy*, 29: 255-261.

[3] *Economic Indicators*, US Government Printing Office (accessed online, 8-31-13). http://www.gpo.gov/fdsys/browse/collection.action?collectionCode=ECONI&browsePath=2010%2F01%2F1&isCollapsed=false&leafLevelBrowse=false&isDocumentResults=true&ycord=263.

[4] Larson, E.D., 2000. "Commercialization Prospects for Fuel Cell Buses," presented at the Workshop on Commercialization of Fuel Cell Buses: Potential Roles for the GEF, UN Headquarters, New York, 27-28 April.

[5] M.T. Ocampo and T. Guangyu, "Demonstration for Fuel-Cell Bus Commercialization in China (Phase II): Final-Term Review Report," 25 December 2011 (rev3).

[6] Anonymous, "Summary Report on FCB Demonstration Operation Programs in China and Abroad," downloaded 8-31-13 from China UNDP/GEF FVC project website: http://www.chinafcb.org/chinafcb_en/index.htm.

[7] Pozzi, S., "Ballard: Smarter Solutions for a Clean Future," powerpoint slides, August 2013. (Presented at Ballard offices in Sao Paulo, August 19, 2013).

[8] GEF Project BRA/99/G32: Hydrogen Fuel Cell Buses for Urban Transport in Brazil (Project Document).

[9] "Co-financing from the Consortium Members from May 2006 to September 2013," (via email from Monica Panik), 10 September 2013.

[10] Letter (Dec. 21, 2012) from EMTU to MME detailing issues with the UNDP administrative fee and estimating exchange rate losses from delayed disbursement of FINEP co-financing.

[11] Binder, M., Faltenbacher, M., Kentzler, M., and Shuckert, M., 2006. "Clean Urban Transport for Europe Project No. NNE5-2000-00113," deliverable number 8, Final Report, 30 May.

[12] HyFLEET:CUTE partners, 2009. "Bus Technology & Fuel for TODAY and for a Sustainable Future: a Report on the Achievements and Learnings from The HyFLEET:CUTE Project 2006 – 2009," 2009.

[13] NETZ Automotiva, "Onibus Brasileiro a Hidrogenio, Relatorio Tecnico NZA 051/11-01-EF: Testes de Verificacao Parte II, 15 March 2011.

[14] Goncalves, S. and Panik, F., "Phase II-3 Design and Technical Specifications," 29 Sept 2012. (Electronic version provided to author by S. Goncalves on 22 August 2013 in Caxias do Sul.)

[15] Provided by M. Panik (EPRI, personal communication, 13 Sept 2013) based on UNDP BRA /99/G32FCB Consortium, "Hydrogen Fuel Cell Buses for Urban Transport in Brazil: Updated Commercial Proposal for Phase II.3" and second amendment to same.

[16] *Urban buses: alternative powertrains for Europe, A fact-based analysis of the role of diesel hybrid, hydrogen fuel cell, trolley and battery electric powertrains*, 2012. Published Oct. 29 by Fuel Cells and Hydrogen Joint Undertaking. [Study participants: <u>Bus Manufacturers</u> – EvoBus, Hess, Iveco, MAN, Solaris, Van Hool, VDL/APTS; <u>Bus Operators</u> – BVG (Berlin), Bogestra (Bochum), GVB (Amsterdam), HOCHBAHN (Hamburg), RET (Rotterdam), Ruter (Oslo), RVK (Cologne), MIVB/STIB (Brussels), SWS (Solingen), Transport for London, TMB (Barcelona), VRR (Gelsenkirchen); <u>Infrastructure Providers</u> – Air Liquide, Air Products, Ballast Nedam, Hydrogenics, H2 Logic, Linde, Shell; <u>Technology Providers</u> – ABB, BAE Systems, Ballard, Bombadier, Enerdel, Hydrogenics, NuCellSys, Proton Motor, Siemens, SKODA ELECTRIC, UTC Power, Voith, Vossloh, Kiepe, ZF; Organizations and Associations – European Fuel Cells and Hydrogen Joint Undertaking, NOW GmbH, Element Energy, Fuel Cell and Hydrogen Newtork NRW, HyuER (Hydrogen, fuel cells and electro-mobility in European Regions), HyCologne (Wasserstoff Region Rheinland); <u>Analytical Support</u> – McKinsey & Company.]

[17] Information provided by S. Pozzi (Marketing Director for Latin America, Ballard Power Systems), 19 Aug. 2013.

[18] M. Duvall and M. Alexander, "UNDP/GEF Fuel Cell Bus Project – Brazil: Preliminary Analysis of Energy Storage Options," Electric Power Research Institute (confidential), 27 April 2005.

[19] http://www.bctransit.com/fuelcell/fleet.cfm

[20] Information provided by S. Pozzi (Marketing Director for Latin America, Ballard Power Systems), 26 Aug. 2013.

Annex 1: Schedule of meetings with Eric Larson in Brazil

August 18th, 2013 - Sunday:
07:30 pm – At Hotel Marabá lobby, with Rose Diegues (UNDP), mission briefing.

August 19th, 2013 – Monday:
08:30 am – At Ballard (Av. Magalhães de Castro, 4800 - Edificio Capital Building, cj. 31-32, Jardim Panorama, SP)
Participants: UNDP: Rose Diegues
EMTU: Marcos Correia Lopes and Alysson Talaisys Bernabel
Project Consortium members:
EPRI: Monica Panik and Ferdinand Panik
Ballard: Silvano Possi and Elizabeth Connolly
Petrobras Distribuidora: Andre Luiz Duarte de Queiroz
Hydrogenics: Salim Pirani

02:00 pm – At hydrogen fueling station at EMTU facilities (R. Joaquim Casemiro, 290 – Bairro Planalto, São Bernardo do Campo, SP):
Participants: UNDP: Rose Diegues
EMTU: Marcos Correia Lopes and Alysson Talaisys Bernabel
Project Consortium members:
Tuttotrasporti: Sidney Goncalves
EPRI: Monica Panik and Ferdinand Panik
Ballard: Silvano Possi
Petrobras Distribuidora: Andre Luiz Duarte de Queiroz
Hydrogenics: Salim Pirani

August 20th, 2013 – Tuesday:
09:00 am – At EMTU office (R. Quinze de Novembro, 244 - 3º andar, Centro, SP)
Participants: Ivan Carlos Regina, Marcos Correia Lopes, and Alysson Talaisys Bernabel

03:00 pm – At Environmentality (R. Michigan 177, Brooklin, SP)
Participant: Gabriel Branco (consultant)

August 21st, 2013 – Wednesday:
11:00 am – Meeting at EMTU office (R. Quinze de Novembro, 244 - 3º andar, Centro, SP)
Participants: Ivan Carlos Regina, Marcos Correia Lopes, Alysson Talaisys Bernabel

August 22nd, 2013 – Thursday:
09:00 am – At Marcopolo, S.A. (Av. Rio Brqaco, 4889, Caxias do Sul, Ana Rech, RS)
Participants: Marcopolo: Leandro Sodre and Alan Marin
Tuttotrasporti: Sidney Goncalves
EPRI: Ferdinand Panik

02:00 pm – At Tuttotrasporti (Rua Antonia Aver, 132, Ana Rech, Caxias do Sul, RS)
Participants: Tuttotrasporti: Sidney Goncalves, Emílio Vacari Batista, Edio de Medeiros, Elencar Pereira, and Maurício Pasquali
EPRI: Ferdinand Panik

August 23rd, 2013 – Friday:
10:00 am – At Ministry of Mines and Energy (Gás Natural Department, Esplanadas dos Ministérios, Bloco U, 9. Floor, Brasília)
Participants: Symone Christine de Santana Araujo, Aldo, and Fernando.

02:30 pm – At UNDP (Setor de Embaixadas N. - Quadra 802, Conjunto C, Lote 17, Brasília)
Participants: UNDP: Rose Diegues
MME: Symone Christine de Santana Araujo, Aldo, and Fernando.
EMTU (on phone): Marcos Correia Lopes and Alysson Talaisys Bernabel

04:30 pm – Telephone meeting
Participant: UNDP/GEF: Oliver Page (UNDP-GEF climate change portfolio manager for Latin America and the Caribbean)

After return to U.S. (3 Sept 2013), telephone meeting with Marcel Alers (UNDP-GEF Principal Technical Advisor for Energy Infrastructure, Transport and Technology)

Annex 2: Project-related documents reviewed for this evaluation

Received from UNDP/GEF

- Project Document: Hydrogen Fuel Cell Buses for Urban Transport (UNDP BRA/99/G32)
- Contract with project consortium, plus 1st and 2nd amendments to the contract.
- UNDP-GEF Fuel-Cell Bus Programme: Update, May 2005.
- UNDP-GEF Fuel-Cell Bus Programee: Update, June 2006. (final year for this annual update)
- APR (Annual Project Review) for 2012, 2011, 2010, 2009, 2008, 2007, 2006, 2005, 2004, 2003.
- POA for 2013, 2012, 2011, 2010
- Relatoria de Auditoria, Exercicio de 2011: Programa das Nações Unidas para o Desenvolvimento – PNUD BRA/99/G32, Projeto Ônibus a Célula a Combustível Hidrogênio para Transporte Urbano no Brasil, Brasília DF, 2012. (Also 2006 and 2006 audits)

Received from EMTU

- *Onibus Brasileiro a Hidrogenio* (FCB project book published upon completion of prototype bus).
- Table summarizing prototype bus mileage and CO2 avoided and also projections of same for phase II.3 buses.
- 2011 Annual Report to MME/FINEP.
- December 21, 2012 letter from EMTU to MME detailing problems with payment of UNDP admin fees and exchange rate losses.
- Detailed annual (2005-2011) tables of project expenditures, broken down by FINEP and GEF.
- Monthly electricity bill for H2 station, Jan 2011-August 2013.
- World Cup 2014 schedule (EMTU is responsible for moving people around Sao Paulo).
- H2 Project Video (in Portuguese with English subtitles). DVD
- Institutional videos on technologies, BRTs, LRT, Environment, etc. DVD

Received from Project Consortium

- From EPRI
    - "Project BRA/99/G32 – Hydrogen Fuel Cell Buses for Urban Transport in Brazil: Story and Timeline"
    - PPT (shown 8/19/13 by Monica): "BRA/99/G32 – HYDROGEN FUEL CELL BUSES in BRAZIL, MID-TERM EVALUATION by ERIC LARSON," 19Aug2013.
    - PPT (shown 8/19/13 by F. Panik), "Fuel Cell Busses in Europe: Status, Analyses, Strategies"
    - WORD DOC (from F. Panik), M. Duvall and M. Alexander (Electric Transportation, EPRI), "UNDP/GEF Fuel Cell Bus Project – Brazil: Preliminary Analysis of Energy Storage Options," EPRI, 27 April 2005.
    - "Co-financing from the Consortium Members from May 2006 to September 2013," (via email from Monica Panik), 10 September 2013.
    - UNDP BRA /99/G32FCB Consortium, "Hydrogen Fuel Cell Buses for Urban Transport in Brazil: Updated Commercial Proposal for Phase II.3" and second amendment to same.
    - UNDP BRA /99/G32FCB Consortium, "Cost-Reductions/Project Contributions of each Company for the Phase II.3. (via email from Monica Panik), 10 September 2013.
- From Ballard
    - PPT (shown 8/19/13 by Silvano): "Ballard: Smarter Solutions for a Clean Future," Aug. 2013.
    - Spreadsheet (from Silvano after mission), "HD6 Product Performance Dashboard 08192013B.xls"
    - Promotional videos on Whistler, Brazil, and other projects. DVD
- From Hydrogenics
    - PPT (shown 8/19/13 by Salim): "UNDP Fueling Station Update"

    - PPT (shown 8/19/13 by Salim): "Hydrogenics Selected References Fueling Stations," 2013.
    - PPT (shown 8/19/13 by Salim): "Hydrogenics Selected References Grid Balancing, Power to Gas (PtG)," 2013.
- From Tutto (8/22/13)
    - PPT (shown 8/22/13 by Sidney): "Tuttotrasporti"
    - Goncalves, S. and Panik, F., "Phase II-3 Design and Technical Specifications," 29 Sept 2012. (*Design Freeze Document_noSign 29 09 12.pdf)*
    - Prototype bus test results
        - Project UNDP BRA/99/G32, Hydrogen Fuel Cell Buses for Urban Transport in Brazil: Verification Tests Part I Protocol - Executive Summary Report.
        - PPT: Verification Test 1, 13 - 22.August 2010, Brazilian Fuel Cell Bus, 25 Aug. 2010 (*10-08-24-BRA99G32_Testresult.ppt*)
        - "Ônibus Brasileiro a Hidrogênio: Relatório Técnico NZA 051/11-01-EF Testes de Verificação Parte II (15/03/2011) [Relatório *Relatório Técnico Verification Tests Part II - NZA 051-11-01-EF.pdf]*
        - NETZ: *Test Report - NZA10309 - Vehicle Technology and contract Terms (Attachments).pdf*
        - *Relatório Técnico Verification Tests Part II - NZA 051-11-01-EF Anexo 01.pdf*
        - *Relatório Técnico Verification Tests Part II - NZA 051-11-01-EF Anexo 02.pdf*

Received from Environmentality
- G.M. Branco and F.C. Branco, "Analise da eficiencia de conversao energetica do onibus movido a hidrogenio, 2a parte," November 2012.

Annex 3: Summary of worldwide fuel cell bus activities

Source: http://www.fuelcells.org/uploads/fcbuses-world1.pdf (accessed August 2013)

This summary of fuel cell bus projects, as posted online by the Fuels Cells 2000 organization, is included here to illustrate the widespread number and variety of FCB development efforts. The listing here is not necessarily comprehensive nor fully accurate in detail.

THE FULL VERSION OF APPENDIX 3 IS AVAILABLE AS A SEPARATE DOCUMENT.