I. Opening page

UNDP-supported GEF-financed Project BRA/99/G32
Hydrogen Fuel Cell Buses for Urban Transport in Brazil

Terminal Evaluation Report

December 22nd, 2016

Evaluator
Dr. Newton Pimenta Neves Junior

Country	Brazil
Region	LAC
ATLAS Award ID	00011660
PIMS Number	0543
GEF ID Number	6
GEF Focal Area	Climate Change
GEF Strategic Objective	Operational Programme 11
GEF Budget (USD)	12,274,000
Co-Financing Budget (USD)	Government: 2,233,269 UNDP: 55,347
Implementing partner	São Paulo Urban Transportation Metropolitan Enterprise (EMTU-SP)
Project Document Signature date	October 15th, 2001
Date of first disbursement	February 01st, 2002
Original Planned Closing Date	November 30th, 2006
GEF Implementing Agency	UNDP
Actual Date of Project Closure	December 31st, 2015 – operational completion date
Evaluation timeframe	December 30th, 2015 to December 31st, 2016

Acknowledgements
The author acknowledges the individuals representing the project stakeholders and companies of the consortium for the valuable information provided for this report. In addition, the author thanks the staff of UNDP/GEF for their input and continuous support.

II. Executive Summary

PROJECT SUMMARY TABLE				
Project Title	Hydrogen Fuel Cell Buses for Urban Transport in Brazil			
GEF Project ID	PIMS 0543		*at endorsement (Million US$)*	*at completion (Million US$)*
UNDP Project ID	PIMS 0543 ATLAS Award ID: 00011660			
Country	Brazil	*GEF financing*	12.274	11.597
Region	LAC	*Implementing Partner (EMTU)*	1.698	1.698
Focal Area	Climate Change	*Government (MME/FINEP)*	4.597	2.233
Operational Program	11	*Consortium* *UNDP*	2.611 0	2.601 0.055
Executing Agency	MME	*Total co-financing*	8.906	6.587
Other Partners involved	(informed in the next table)	*Total Project Cost*	21.180	18.184
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---	---	*Operational Closing Date*	Proposed: 30/Jun/2006	Actual: 31/Dec/2015

Project Description (brief)

The Brazil FCB project was developed under the fuel cell bus (FCB) commercialization support program established by the UNDP and GEF beginning in the late 1990s. This program was created to help ensure that FCBs would become available for developing country markets in a timely, economically viable, and sustainable way.

The development objective of the project was to reduce GHG emissions through the introduction of a new energy source and propulsion technology for urban buses based upon fuel-cells operating on hydrogen. This project was designed to initiate and accelerate the process of the development and commercialization of fuel cell buses in Brazil. Together with similar future initiatives in other countries, it was intended to provide a major push to the accelerated development of relatively clean technology in the mega-cities of developing countries. Over the longer term, assuming that this project and its successors performed as designed, this project would lead to an increased production in fuel cell propelled buses, and eventually, the reduction in their costs to the point where they would become commercially competitive with conventional, diesel buses. It had been designed to be consistent with GEF Operational Program 11 “Promoting Sustainable Transport”. The immediate objective of the project was to demonstrate the operational viability of fuel cell drives in urban buses, together with the requisite re-fueling infrastructure, under Brazilian conditions. It would begin the process of commercialization and adaptation of the fuel-cell buses in Brazilian markets.

The expected results of the project were:

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

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

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

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

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

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

Evaluation Rating Table *

Evaluation Ratings:			
1. Monitoring and Evaluation	***rating***	**2. IA& EA Execution**	***rating***
M&E design at entry	4	Quality of UNDP Implementation	5
M&E Plan Implementation	4	Quality of Execution - Executing Agency	4
Overall quality of M&E	4	Overall quality of Implementation / Execution	4
3. Assessment of Outcomes	***rating***	**4. Sustainability**	***rating***
Relevance	2	Financial resources	3
Effectiveness	3	Socio-economic	4
Efficiency	3	Institutional framework and governance	3
Overall Project Outcome Rating	4	Environmental	4
		Overall likelihood of sustainability	3

*The rating scales table is provided in section 5.6.

Conclusions, recommendations and lessons

<u>Conclusions</u>

Effectiveness

1) The project demonstrated that the Fuel Cell Bus operation is technically viable and the vehicles can be fully integrated to commercial bus lines using a variety of energy sources, such as diesel and electricity (trolleybus). From the engineering point of view the project was successfully completed. Four fuel cell buses have been successfully built and operated in the metropolitan corridor with passengers on board, which is a major challenge in terms of technology, legislation and passenger safety. Although the sum of the distances covered by the buses (20,520 km) has been considerably lower than the target (1 million km), this was due to delays in the completion of the construction of buses and the hydrogen station, and not because of technical reasons.

2) The bus version developed in Phase II. 3 can be considered as the state-of-the-art of hydrogen fuel cells buses in the world, even though this bus design (drawings, specifications, equipment selection) was made in 2013. The buses are advanced prototypes, but several improvements were required during the tests of Phase II.3. The development and tests of one or two additional fuel cell bus prototypes would be necessary to achieve the commercial stage from a technical point of view. Complementary assessments of capital and operating costs for buses and hydrogen supply is also required before beginning the commercial production of the fuel cell buses.

3) With the experience gained in this project, it would be possible to develop a new bus design with significantly better characteristics, such as body, chassis, other items already mentioned above, energy efficiency and cost. Therefore, the continuation of hydrogen bus projects in the country is highly recommended.

4) The project enabled not only the transfer of technology between companies from different countries, but also technological development and innovation. Some remarkable examples are: i) the control and monitoring software; ii) the electric motor and inverter, made of aluminum and water cooled, and their latest versions have compliance with automotive use; iii) better management of the state of charge of batteries; iv) several improvements in the bus body to allow better cooling of the batteries and components without water infiltration; v) improved internal design to facilitate the flow of passengers.

Relevance

5) The project is relevant for Brazil and for Fuel Cell Bus development in general. There is a certain demand for FCB in the world, still small, but growing, as several countries have shown interest in experimenting with the technology without having to make all the necessary investments in time, money and human resources to come up with a good design. Brazil has the necessary and sufficient conditions to succeed in this market, since it is one of the world's major bus suppliers, and has a well-prepared industry to offer products with excellent quality at a reasonable cost.

Project design

6) Statistical analysis methods, such as Failure Mode Analysis (FMA) and Mean Time Between Failures (MTBF), mentioned in ProDoc, are appropriate tools to evaluate the performance of projects in the automotive sector. But they are not as useful for evaluating basic technological development projects, as in this case. As an alternative, evaluation of project results can always be done through the opinion of experts or peer review. It is important to be careful when establishing objectives and targets for a basic technology development project. In case of doubt, independent experts should be consulted in advance to validate the objectives and targets. Extensive testing may require specific infrastructure and must be carried out at a later stage of technological development.

7) The design, targets and throughput time for the Fuel Cell Bus project were overly optimistic. In the early 2000s, there was a great enthusiasm for fuel cells, both in academia and industry around the world, and the period was marked by the emergence of new companies, joint ventures and much propaganda. By the same reasons, the schedule can be considered tight, 3 buses built in the first year and 5 buses in the second

year. Therefore, other established indicators were also high, as for example: the decrease of 1,560 tons of CO_2 emissions during the project's life-time; 50,000 km between breakdowns; training of 430 drivers, 126 mechanics, and 12 specialized electronics technicians.

8) A risk not anticipated by the project team concerns the hydrogen supply and how it could affect the FCB development and tests. In fact, the refueling station took a long time to operate and this has negatively impacted the project schedule and results. The ProDoc includes a discussion about hydrogen shortage, but more attention should be given to the deployment of the station, and perhaps a gas company or a local technical support might be involved in the partnership or contracted in order to mitigate risks.

9) The proposal for Phase III was not eliminated during the substantive revision, but was canceled as explained in the item 3.2.1 iii), p. 26. The main document was not corrected as suggested because of the short time available.

Sustainability

10) Regarding the hydrogen supply, it is necessary to establish an agreement or contract with a gas company for backup. If consumption increases, it will be necessary to decide between buying a new electrolyzer or hiring a hydrogen supplier. As a starting point, large regular hydrogen customers can benefit from lower prices. In addition, this project presents an important marketing appeal, which must be properly negotiated with the gas companies.

11) The buses developed in the Phase II.3 had more significant components produced locally. It demonstrated the consortium's ability to develop local suppliers, enabling better sustainability, lower costs and shorter time to obtain spare parts, since the import process is bureaucratic and costly in Brazil.

12) To avoid interruption of project activities after its official closure, it is necessary to start negotiations between partners and to plan the continuation well in advance. To the date, negotiations are still underway. In spite of the interest to continue project's benefits after termination, it would require a long-term commitment from involved stakeholders for the implementation of a new phase of the Project.[1] This would require the construction of a follow-up project with new institutional arrangements and financing, which would pervade federal and local governments for years.

Project implementation and management

13) Key points to the success of the Brazilian Fuel Cell Bus project were the strong institutional arrangement and the persistent commitment of all stakeholders of the public and private sectors in order to ensure proper operation and maintenance of the buses, safety, supply of hydrogen, support in administrative issues, and public education activities. Even though the design of a new phase was envisaged, this could not be accomplished during project implementation.

14) The process of importing spare parts, components and equipment caused some delays. Although the overall delay was of a few months, the problem was very inconvenient, interrupting ongoing activities and increasing costs. Other delays were related to malfunctions of components that had to be replaced or repaired. However,

[1] Please refer to items 4.3.1 and 4.3.2 in the main text for specific suggestions.

administrative and financial issues, for example, had a greater influence. The project team matured during the execution of Phase II.2 (first prototype, with more imported components) and proposed to build a new bus model with greater national content in Phase II.3 (three buses). But they probably did not evaluate all the difficulties that would occur or the time required to develop a new bus design, to develop local suppliers, and the time required for tests, repair and replacement of new components.

15) Failures in infrastructure can contribute to reducing the efficiency and safety of experimental activities, although no issues related to the transport service delivered to customers were identified. Project design should preview the complementary infrastructure necessary for maintenance during project execution.

Knowledge management

16) Much knowledge was generated during the planning and execution of this project, related to the bus and the hydrogen station. This knowledge covers several areas (legislation, management, finance, engineering) and is distributed among many participants, including stakeholders, consortium members, government agencies, and suppliers. There is a real opportunity for this technology to be used commercially in the near future, since the research, development and innovation are permanent and do not terminate with this project.

17) The project team should interact more frequently with other teams around the world, including managers and technical staff. In addition, it would be beneficial for some partners to participate in specific technical events to better understand the challenges, pros and cons of the fuel cell buses and hydrogen technologies. There are several projects, programs and interventions within the sector in the world, and the project team (or stakeholders) should be updated on these initiatives in order to compare results, exchange information, and take advantage of the opportunities of cooperation and training. Probably, the establishment of a council with the participation of specialists could contribute with information, new ideas and orientations.

<u>Recommendations</u>

1) It is recommended keeping the three buses developed in Phase II. 3 in operation because it can bring additional knowledge to increase performance, reduce hydrogen consumption, and improve operation and maintenance. This would also attract the public attention needed to develop educational projects for sustainability, environment and public health.

2) The hydrogen refueling station can support three buses in operation as planned. However, if beyond this project there is an intention to increase the hydrogen fuel cell bus fleet, it is recommended to carry out an assessment of the cost of hydrogen considering the expansion of the station, and compare it with the market price.

3) A lightning system is usually present in flammable gas facilities, and an adequate technical evaluation of the hydrogen station is recommended with respect to this item.

4) Partners interested in producing fuel cell buses should negotiate and develop a business plan. It is necessary to select the institutions, agencies and private companies in Brazil and abroad which can contribute for RD&I projects, as well as to the production of commercial fuel cell buses.

5) Item “5.3 Formulate Brazilian standards for hydrogen fuel cell buses for urban transport” should be treated opportunely as a separate project, because it requires a specific team of specialists, appropriate financial resources and time frame. There are institutions in Brazil responsible for the development of Regulation, Codes and Standards, such as ABNT and INMETRO. Brazil is also signatory of ISO and IEC.

6) It is important to correctly classify the knowledge generated in this project, according to the guidance of GEF, the main funder. In general, there is information that can be shared with other groups and countries interested in developing fuel cell buses. But there is also confidential information belonging to suppliers, stakeholders or partners.

7) The knowledge generated in this project should be incorporated into a next generation bus design, making those vehicles closer to the commercialization stage from a technical point of view. This recommendation is supported by the fact that several small improvements were made in the buses during the tests of Phase II.3, and by the testimony of important stakeholders collected during the interviews for this TE.

<u>Lessons learned</u>

1) In 2011, an inconsistency between the MME/FINEP agreement and the ProDoc regarding the administrative fee of co-financing resources was detected leading to a joint search for a legal solution to the problem. In future projects involving financial support from FINEP, UNDP must negotiate terms and conditions in advance directly with the agency, even if there is an intermediary partner. FINEP’s technical analysts can provide good advice on how to proceed to avoid problems

2) During the planning phase, projects involving technological development require special attention to the current state of the technologies to be employed. In this project, some of the technologies, such as the fuel cells and hybrid control, were not developed as expected.

3) Projects and collaboration arrangements should bring a benefit to the partners, hence their position should be properly understood at project design stage. At first sight, there was no guarantee that they would get financial or technological advantages at the end of the project, so it took some time for the most interesting companies to be attracted to the project, to talk to each other and to understand that participation would be beneficial for all parties

4) Ideally, the objectives and the M&E indicators established at the beginning of a project should remain unchanged until its completion. However, if the project is submitted to a substantive revision, it is recommended that all objectives and indicators are reevaluated by all partners (Executing, Implementing and Funding Agencies). Regarding this project, although the 2005 Substantive Revision H, was submitted to all partners, the indicators were not updated to reflect the important changes made in the project.

5) Experimental Projects may require additional infrastructure, such as: a warehouse for electrical and mechanical components; a machine shop; a suitable location for storage and disposal of waste; and a lightning protection system. These items should be included in the initial planning. Regarding this FCB project, these items were not considered, bringing some difficulties with the maintenance activities of the hydrogen station.

6) The risks related to delays in the import, replacement and repair of components and equipment should never be underestimated at project design, because they have great impact on project implementation.

7) With respect to externalities, even though problems are expected to import goods and to obtain work visas in a project involving international participation, no risks were attributed to those activities. Special attention to these points might have contributed to reducing their consequences.

III. Table of Contents

IV. Acronyms and Abbreviations

ABC	Brazilian Cooperation Agency
APR	annual project report
CEO	chief executive officer
CO	UNDP country office
CPAP	UNDP country programme action plan
CPD	UNDP country programme document
CGU	Union General Controllership (in Portuguese, *Controladoria Geral da União*)
EA	executing agency
EMTU/SP	São Paulo Urban Transportation Metropolitan Enterprise
ERC	Evaluation Resource Centre
ET	evaluation team
FCB	Hydrogen Fuel Cell Bus
FINEP	Brazilian Projects and Studies Financing Agency
FSP	full size project
GEF	Global Environment Facility
GEF EO	GEF Evaluation Office
IA	implementing agency LFA logframe analysis
IB	Itaipu Binacional
IPHE	International Partnership for Hydrogen and Fuel Cells in the Economy
LFA	Logical Framework Approach
M&E	monitoring and evaluation
MME	Brazilian Ministry of Mines and Energy
MOU	memorandum of understanding
MSP	medium size project
MTE	midterm evaluation
NGO	non-governmental organization
OFP	GEF operational focal point
PDF-A	preparatory development assistance block A
PIF	project identification form
PIMS	UNDP GEF project information management system
PIR	project implementation report
POPP	UNDP Programme and Operations Policies and Procedures
ProDoc	project document
PSC	project steering committee
PT	project team
PTA	principal technical advisor
RCU	UNDP/GEF regional coordinating unit
ROAR	results oriented annual report
SAT	Site Acceptance Test
TE	terminal evaluation
TER	terminal evaluation review
TPR	tripartite review
ToR	terms of reference
UNDAF	UN development assistance framework
UNDP	United Nations Development Programme
UNDP EO	UNDP Evaluation Office
UNEP	United Nations Environment Programme
UNOPS	United Nations Office for Project Services

1. Introduction

1.1. Purpose of the evaluation

The overall objective of the TE is to analyze the implementation of the project, and review the achievements made by the project to deliver the specified objectives and outcomes. It will establish the relevance, performance and success of the project, including the sustainability of the results. The evaluation will also collate and analyze specific lessons and best practices pertaining to the strategies employed, and implementation arrangements, which may be of relevance to other projects in the country and throughout the world.

Evaluations for UNDP Supported GEF financed projects have the following complementary purposes:

a) To promote accountability and transparency, and to assess and disclose the extent of project accomplishments.

b) To synthesize lessons that can help to improve the selection, design and implementation of future GEF financed UNDP activities.

c) To provide feedback on issues that are recurrent across the UNDP portfolio and need attention, and on improvements regarding previously identified issues.

d) To contribute to the overall assessment of results in achieving GEF strategic objectives aimed at global environmental benefit.

e) To gauge the extent of project convergence with other UN and UNDP priorities, including harmonization with other UN Development Assistance Framework (UNDAF) and UNDP Country Programme Action Plan (CPAP) outcomes and outputs.

1.2. Scope & Methodology

The Brazil Fuel Cell Bus project was developed under the fuel cell bus (FCB) commercialization support program established by the UNDP and GEF beginning in the late 1990s. This program was created to help ensure that FCBs would become available for developing country markets in a timely, economically viable, and sustainable way. The UNDP/GEF program was designed with three stages. Stage I was completed around 2000 and the goal was to identify potential host countries based on the strength of their local bus markets, industry capabilities to develop new bus technologies, availability of hydrogen supplies, and engagement to develop strategic plans for the next two stages. Five countries were identified as strong candidates for Stage II, the demonstration phase: Brazil, China, Egypt, India, and Mexico. Despite all efforts made by UNDP/GEF, only Brazil and China have developed projects. While the Chinese project acquired the buses abroad and focused on testing them, the Brazilian project focused on developing a more advanced FCB technology using locally produced components whenever possible.

The ProDoc was signed in October, 2001, and the closing date was set for November, 2006. The total budget for the project was US$ 21.2 million, with US$ 12.3 million provided by the GEF.

According to the ToR for this terminal evaluation, it should cover the five major criteria which are relevance, effectiveness, efficiency, results and sustainability. These criteria should be further defined through a series of questions covering all aspects of the project intervention, broken out in three main sections:

a) Project Formulation: Logical framework, Assumptions and Risks, Budget (co-finance) and Timing.

b) Project Implementation: IA/EA supervision and support, monitoring (including use of tracking tools) and evaluation, stakeholder participation, adaptive management, co-financing and baseline.

c) Achievement of Results: Outcomes, Impacts, Catalytic Effect, Sustainability, Mainstreaming (e.g. links to other UNDP priorities, including related support programmes set out in the UNDAF and CPD, as well as cross cutting issues).

The methodology of this TE was defined by the evaluator in agreement with Mr. Oliver Page – UNDP/GEF Regional Technical Advisor, and the Country Office representatives, Mrs Rose Diegues and Mrs Luana Lopes. Considering the short time available – according to the ToR it would take 25 days maximum – the mid-term evaluation report made by Dr. Eric Larson was considered an important starting point. Based on this report, a quick review of the documents provided, conversations with Mrs. Monica Panik (Project Manager for the Consortium), and specially with the UNDP agents mentioned above, the following issues were identified as deserving special attention during the interviews with the main stakeholders: i) extension of the project deadline; ii) decrease in Brazilian government resources; iii) difficulties in achieving some of the goals defined in ProDoc; iii) the technological advances in the buses achieved by this project; iv) advantages and disadvantages of institutional arrangements made; vi) special comments and suggestions that might improve this project and future projects; vii) field visits to check the buses and the hydrogen station in operation; viii) compliance with the UNDP/GEF objectives.

After the interviews with the stakeholders, summarized in sections 5.2 to 5.4,the information was compiled and compared with each other and with the available documents. Whenever necessary, further clarification was requested from the stakeholders by phone or email.

1.3. Structure of the evaluation report

The structure of the evaluation report follows the scheme summarized in pages 36 and 37 of the document GUIDANCE FOR CONDUCTING TERMINAL EVALUATIONS OF UNDP-SUPPORTED, GEF-FINANCED PROJECTS, GEFTE Guide ENG; Evaluation Office, 2012. All items included in this report are listed in section 0 - Conclusions

Effectiveness

18) The project demonstrated that the Fuel Cell Bus operation is technically viable and the vehicles can be fully integrated to commercial bus lines using a variety of energy sources, such as diesel and electricity (trolleybus). From the engineering point of view the project was successfully completed. Four fuel cell buses have been successfully built and operated in the metropolitan corridor with passengers on board, which is a major challenge in terms of technology, legislation and passenger safety. Although the sum of the distances covered by the buses (20,520 km) has been considerably lower than the target (1 million km), this was due to delays in the completion of the construction of buses and the hydrogen station, and not because of technical reasons.

19) The bus version developed in Phase II. 3 can be considered as the state-of-the-art of hydrogen fuel cells buses in the world, even though this bus design (drawings, specifications, equipment selection) was made in 2013. The buses are advanced prototypes, but several improvements were required during the tests of Phase II.3. The development and tests of one or two additional fuel cell bus prototypes would be necessary to achieve the commercial stage from a technical point of view. Complementary assessments of capital and operating costs for buses and hydrogen

supply is also required before beginning the commercial production of the fuel cell buses.

20) With the experience gained in this project, it would be possible to develop a new bus design with significantly better characteristics, such as body, chassis, other items already mentioned above, energy efficiency and cost. Therefore, the continuation of hydrogen bus projects in the country is highly recommended.

21) The project enabled not only the transfer of technology between companies from different countries, but also technological development and innovation. Some remarkable examples are: i) the control and monitoring software; ii) the electric motor and inverter, made of aluminum and water cooled, and their latest versions have compliance with automotive use; iii) better management of the state of charge of batteries; iv) several improvements in the bus body to allow better cooling of the batteries and components without water infiltration; v) improved internal design to facilitate the flow of passengers.

Relevance

22) The project is relevant for Brazil and for Fuel Cell Bus development in general. There is a certain demand for FCB in the world, still small, but growing, as several countries have shown interest in experimenting with the technology without having to make all the necessary investments in time, money and human resources to come up with a good design. Brazil has the necessary and sufficient conditions to succeed in this market, since it is one of the world's major bus suppliers, and has a well-prepared industry to offer products with excellent quality at a reasonable cost.

Project design

23) Statistical analysis methods, such as Failure Mode Analysis (FMA) and Mean Time Between Failures (MTBF), mentioned in ProDoc, are appropriate tools to evaluate the performance of projects in the automotive sector. But they are not as useful for evaluating basic technological development projects, as in this case. As an alternative, evaluation of project results can always be done through the opinion of experts or peer review. It is important to be careful when establishing objectives and targets for a basic technology development project. In case of doubt, independent experts should be consulted in advance to validate the objectives and targets. Extensive testing may require specific infrastructure and must be carried out at a later stage of technological development.

24) The design, targets and throughput time for the Fuel Cell Bus project were overly optimistic. In the early 2000s, there was a great enthusiasm for fuel cells, both in academia and industry around the world, and the period was marked by the emergence of new companies, joint ventures and much propaganda. By the same reasons, the schedule can be considered tight, 3 buses built in the first year and 5 buses in the second year. Therefore, other established indicators were also high, as for example: the decrease of 1,560 tons of CO2 emissions during the project's life-time; 50,000 km between breakdowns; training of 430 drivers, 126 mechanics, and 12 specialized electronics technicians.

25) A risk not anticipated by the project team concerns the hydrogen supply and how it could affect the FCB development and tests. In fact, the refueling station took a long time to operate and this has negatively impacted the project schedule and results. The

ProDoc includes a discussion about hydrogen shortage, but more attention should be given to the deployment of the station, and perhaps a gas company or a local technical support might be involved in the partnership or contracted in order to mitigate risks.

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Sustainability

27) Regarding the hydrogen supply, it is necessary to establish an agreement or contract with a gas company for backup. If consumption increases, it will be necessary to decide between buying a new electrolyzer or hiring a hydrogen supplier. As a starting point, large regular hydrogen customers can benefit from lower prices. In addition, this project presents an important marketing appeal, which must be properly negotiated with the gas companies.

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Project implementation and management

30) Key points to the success of the Brazilian Fuel Cell Bus project were the strong institutional arrangement and the persistent commitment of all stakeholders of the public and private sectors in order to ensure proper operation and maintenance of the buses, safety, supply of hydrogen, support in administrative issues, and public education activities. Even though the design of a new phase was envisaged, this could not be accomplished during project implementation.

31) The process of importing spare parts, components and equipment caused some delays. Although the overall delay was of a few months, the problem was very inconvenient, interrupting ongoing activities and increasing costs. Other delays were related to malfunctions of components that had to be replaced or repaired. However, administrative and financial issues, for example, had a greater influence. The project team matured during the execution of Phase II.2 (first prototype, with more imported components) and proposed to build a new bus model with greater national content in Phase II.3 (three buses). But they probably did not evaluate all the difficulties that would occur or the time required to develop a new bus design, to develop local suppliers, and the time required for tests, repair and replacement of new components.

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customers were identified. Project design should preview the complementary infrastructure necessary for maintenance during project execution.

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34) The project team should interact more frequently with other teams around the world, including managers and technical staff. In addition, it would be beneficial for some partners to participate in specific technical events to better understand the challenges, pros and cons of the fuel cell buses and hydrogen technologies. There are several projects, programs and interventions within the sector in the world, and the project team (or stakeholders) should be updated on these initiatives in order to compare results, exchange information, and take advantage of the opportunities of cooperation and training. Probably, the establishment of a council with the participation of specialists could contribute with information, new ideas and orientations.

Recommendations

8) It is recommended keeping the three buses developed in Phase II. 3 in operation because it can bring additional knowledge to increase performance, reduce hydrogen consumption, and improve operation and maintenance. This would also attract the public attention needed to develop educational projects for sustainability, environment and public health.

9) The hydrogen refueling station can support three buses in operation as planned. However, if beyond this project there is an intention to increase the hydrogen fuel cell bus fleet, it is recommended to carry out an assessment of the cost of hydrogen considering the expansion of the station, and compare it with the market price.

10) A lightning system is usually present in flammable gas facilities, and an adequate technical evaluation of the hydrogen station is recommended with respect to this item.

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Lessons learned

8) In 2011, an inconsistency between the MME/FINEP agreement and the ProDoc regarding the administrative fee of co-financing resources was detected leading to a joint search for a legal solution to the problem. In future projects involving financial support from FINEP, UNDP must negotiate terms and conditions in advance directly with the agency, even if there is an intermediary partner. FINEP’s technical analysts can provide good advice on how to proceed to avoid problems

9) During the planning phase, projects involving technological development require special attention to the current state of the technologies to be employed. In this project, some of the technologies, such as the fuel cells and hybrid control, were not developed as expected.

10) Projects and collaboration arrangements should bring a benefit to the partners, hence their position should be properly understood at project design stage. At first sight, there was no guarantee that they would get financial or technological advantages at the end of the project, so it took some time for the most interesting companies to be attracted to the project, to talk to each other and to understand that participation would be beneficial for all parties

11) Ideally, the objectives and the M&E indicators established at the beginning of a project should remain unchanged until its completion. However, if the project is submitted to a substantive revision, it is recommended that all objectives and indicators are reevaluated by all partners (Executing, Implementing and Funding Agencies). Regarding this project, although the 2005 Substantive Revision H, was submitted to all partners, the indicators were not updated to reflect the important changes made in the project.

12) Experimental Projects may require additional infrastructure, such as: a warehouse for electrical and mechanical components; a machine shop; a suitable location for storage and disposal of waste; and a lightning protection system. These items should be included in the initial planning. Regarding this FCB project, these items were not considered, bringing some difficulties with the maintenance activities of the hydrogen station.

13) The risks related to delays in the import, replacement and repair of components and equipment should never be underestimated at project design, because they have great impact on project implementation.

14) With respect to externalities, even though problems are expected to import goods and to obtain work visas in a project involving international participation, no risks were attributed to those activities. Special attention to these points might have contributed to reducing their consequences.

Table of Contents.

2. Project description and development context

2.1. Project start and duration

This ProDoc was signed by the stakeholders listed in Table 2, page 24, in November 2001. It established a five-year project aimed at the construction and testing of eight buses. In 2005, the private-sector consortium was formed with the companies listed in Table 4, page 36, which would be responsible for developing the buses and the hydrogen refueling station, in Phase II. 2. Discussions for project implementation led to the Substantive Revision H ProDoc BRA/99/G32, signed in December, 2005, by the following representatives: i) Government: Ambassador Lauro Barbosa da S. Moreira, General Director, Brazilian Cooperation Agency (ABC); ii) Executing Agency: João José de Nora Souto, Adjunct Secretary of Petroleum, Natural Gas and Renewable Fuels, Ministry of Mines and Energy (MME); Implementing Partner: Joaquim Lopes da Silva Junior, President Director, São Paulo Urban Transportation Metropolitan Enterprise (EMTU); UNDP: Lucien Muñoz, Acting Resident Representative. Based on a better understanding of the technology and equipment costs, goals and schedule were reassessed and the project was reconfigured according to the available budget. Among other decisions the number of vehicles was reduced to up to five buses and the project duration was extended to December 31th, 2010.

The closing date, however, was successively postponed until December 31st, 2015, the actual project closure date, through project revisions signed in 2010, 2011, 2014 and 2015. In fact, an important reason for the delays was related to the 2005 Substantive Revision H where the Steering Committee decided to develop an improved bus design with several components produced locally, in order to reduce costs and mitigate problems associated with imported items. This change of plans helped the project to better address the objectives of UNDP/GEF for its fuel cell bus program, the sustainable commercial deployment of fuel cell buses in developing country megacities.

Concerning the development context, it is worth mentioning that fuel cells for vehicle applications, as well as batteries, and the technology for electric and hybrid vehicles have progressed significantly over the past 15 years. Delays in project implementation, and the development in two stages have been conveniently used by the project team to design a technologically more advanced FCB than the eight buses expected when this project was launched.

2.2. Problems that the project sought to address

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

2.3. Immediate and development objectives of the project

The immediate objective of the project was to demonstrate the operational viability of fuel cell drives in urban buses, together with the required refueling infrastructure, under Brazilian conditions. The development objective of the project was to reduce GHG emissions through the introduction of a new energy source and propulsion technology for urban buses based upon fuel-cells operating on hydrogen.

This project was designed to initiate and accelerate the process of the development and commercialization of fuel cell buses in Brazil. Together with similar initiatives that would occur subsequently in other countries, it was intended to provide a major push to the accelerated development of relatively clean technology in the megacities of developing countries.

Over the longer term, assuming that this project and its successors performed as designed, this project would lead to an increased production in fuel cell propelled buses, and eventually, the reduction in their costs to the point where they would become commercially competitive with conventional, diesel buses. It had been designed to be consistent with GEF Operational Program 11 "Promoting Sustainable Transport".

2.4. Baseline Indicators established

The Table 1 presents the logical framework (logframe) matrix defined in ProDoc, containing the project summary, baseline indicators, means of verification and external factors.

The main indicators of the project related to the FCB were the decrease of CO_2 emissions from São Paulo buses by 1560 tones, and one million vehicle-km to be traveled by eight buses during the project's life-time, and 50,000 km between breakdowns. Regarding the development of human resources ProDoc established training seminars for 430 drivers, 126 mechanics, and 12 specialized electronics technicians. Some of the additional indicators were: quarterly reports, professional publications and reports in media, national and international workshops.

Table 1: The logical framework (logframe) matrix, established in ProDoc (Annex B, Table 2.1 of that document)				
	(1) PROGRAM OR PROJECT SUMMARY	**(2) INDICATORS**	**(3) MEANS OF VERIFICATION**	**(4) EXTERNAL FACTORS (ASSUMPTIONS AND RISKS)**
Development Objective	To reduce GHG emissions via the introduction of a new energy source and propulsion technology for urban buses	CO_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	Significant demonstration of the operational viability of fuel cell drives in urban buses and their refueling infrastructure under Brazilian conditions.			
Activities	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 prespecified levels (hours 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	Cadre of bus operators and staff trained in the operation, maintenance, and management of fuel cell buses			

Activities	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	Accumulation of a substantial body of knowledge about reliability, failure modes and opportunities for improving the design of fuel cell buses for Brazil			
Activities	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	Assessment of the performance of the electrolysis unit			
Activities	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	Proposal for Phase III of the Brazilian Fuel-cell Bus program			
Activities	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	Increased awareness and support of the public for an increased role for fuel cell buses in Brazil's urban transport system			
Activities	6.1 Hold workshops & seminars to publicize results 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$ 21 million			

Main stakeholders

Table 2: Main stakeholders and their function in the project	
Stakeholder	**Function**
UNDP	GEF Implementing Agency
Brazilian Cooperation Agency (ABC)	International cooperation agency
Brazilian Ministry of Mines and Energy (MME)	Executing Agency
São Paulo Urban Transportation Metropolitan Enterprise (EMTU-SP)	Implementing Partner
Private sector consortium companies	**Function**
EPRI International	Consortium management
Petrobras Distribuidora S.A.	Hydrogen Station operation
Tutto Indústria de Veículos e Implementos Rodoviários Ltda.	Bus integrator
Marcopolo S.A.	Body of the bus
Ballard Power Systems Inc.	Fuel cells
Hydrogenics Corp.	Hydrogen Station supplier and integrator

The United Nations Development Programme (UNDP) is the GEF Implementing Agency for this project, which is consistent with the GEF Operational Program 11: "Promoting Sustainable Transport".

The Brazilian Cooperation Agency (ABC) is an arm of the Ministry of Foreign Affairs (MRE) and has the attribution to negotiate, coordinate, implement and monitor the Brazilian programs and projects of technical cooperation implemented on the basis of agreements signed by Brazil with other countries and international organizations. The agency also signed the ProDoc and gave a full support on international issues related to the project since its beginning.

The Ministry of Mines and Energy (MME) is a ministry of the Brazilian federal government. It has the overall responsibility for the project execution at national level and it is responsible for managing the co-financing from the government to the project through an agreement with Brazilian Projects and Studies Financing Agency (FINEP). MME is the representative of Brazil in IPHE, therefore have all the information to make strategic decisions on hydrogen issues at the federal level, and on how to implement this renewable fuel in the Brazilian energy matrix. The Ministry contributed with its vision for the main objectives of the project also met the national interest, and it devoted every effort to the project was completed successfully

The São Paulo Urban Transportation Metropolitan Enterprise (EMTU) is the São Paulo State agency responsible for planning and regulation of public transportation between cities in the metropolitan region of São Paulo. It played a key role in implementing the project at the state level, contributing to the institutional arrangements that allowed the installation of the hydrogen fueling station at its premises and the operation of the FCBs in the metropolitan corridor along with the regular operation of trolleybuses and diesel buses. Thus, the EMTU bus garage facility in São Bernardo do Campo is the site of the hydrogen refueling station, and the FCB maintenance facility and operations center.

2.5. Expected Results

The results of the project are expected to be:

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

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

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

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

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

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

3. Findings

At the beginning of this section it is important to make the following comments. This project was designed between the late 1990s and early 2000s and therefore it followed the guidelines of existing UNDP guides at the time. A quick review of the documents available on the Internet indicates that there has been significant progress since then in the design and evaluation of UNDP projects. Considering the “Guidance for Conducting Terminal Evaluations of UNDP-Supported, GEF-Financed Projects”, 2012, apparently, some information requested by the guide may not be included in ProDoc because they were not requested at the time, especially with regard to M&E. It is important to keep this in mind when interpreting the comments and reviewing the assigned ratings, especially in the M&E questions, because this assessment is probably being performed with a different standard than when the project was designed.

3.1 Project Design / Formulation

3.1.1. Analysis of LFA/Results Framework (Project logic /strategy; Indicators)

The project was formulated in accordance with the strategic objectives of GEF, the project’s funder, in promoting sustainable transport. Based on the logframe matrix shown in Table 1 the project logic/strategy regarding the FCBs was well designed and the objectives, outputs, summary, indicators, and means of verification are clear and capable of assessing the success of the project.

The ProDoc contains a long discussion to justify the number of buses that should be built and other indicators used in this project. The arguments were well founded on consultations with potential bus suppliers, lessons learned from other projects, and the operational data of the public transport in São Paulo metropolitan area (provided by EMTU/SP). At this point, it is necessary to clarify that in the early 2000s, there was a great enthusiasm for fuel cells, both in academia and industry around the world, and the period was marked by the emergence of new companies, joint ventures and much propaganda. Some researchers and technology analysts, however, as in the case of this reviewer, expected that the maturation of the technology would occur at a slower pace, which happened in practice. Thus, considering the technological stage of the fuel cells and the hybrid vehicles at the time, the number of buses established in this project, eight, can be considered high. By the same reasons, the schedule can be considered tight, 3 buses built in the first year and 5 buses in the second year. Therefore, other established indicators were also high, as for example: the decrease of 1,560 tons of CO_2 emissions during the project's life-time; 50,000 km between breakdowns; training of 430 drivers, 126 mechanics, and 12 specialized electronics technicians.

It is important to mention that the project team recognized the difficulties of implementing the project as planned in ProDoc, and reviewed some indicators, including the number of buses, before starting the experimental phase, as explained in section 3.2.

Statistical analysis methods, such as Failure Mode Analysis (FMA) and Mean Time Between Failures (MTBF), mentioned in ProDoc, are appropriate tools to evaluate the performance of projects in the automotive sector. But they are not as useful for evaluating basic technological development projects, as in this case.

In summary, regarding the FCBs, the objectives, components and indicators at the project formulation are clear, but they were not practicable and feasible to be achieved with the available financial resources and within the established time frame.

Regarding the water electrolysis unit, the activities were reasonably well described, although the indicators refer only to the frequency of reports and the publication of results. With respect to the safety aspects, it is not clear which activities were included, as for example: hydrogen safety, chemicals and electricity, safety of hydrogen supply, or environmental issues.

The item "5.3 Formulate Brazilian standards for hydrogen fuel cell buses for urban transport" in Table 1 should be treated opportunely as separate project, because it requires a specific team of specialists, appropriate financial resources and time frame.

3.1.2. Assumptions and Risks

Three main assumptions and the associated risks were made in ProDoc (quoted text), as indicated below:

First Assumption: "A demonstration fleet of fuel cell buses can be procured through commercial avenues." Risk: "Given the substantial work that has gone into investigating the technologies and the suppliers, this risk is considered to be relatively insignificant."

Second Assumption: "The vendors may not be able to deliver on cost recovery or quality improvement in the production of this technology." Risk: The risk was considered small because the FCB would be co-developed by the vendor and EMTU, which had a large experience in developing novel equipment, particularly in the context of the trolleybus program. Additionally, "Brazilian bus operators have a strong record of effective cooperation with their supplier industries, and the international suppliers welcome the opportunity to work with Brazil on this innovative initiative.

Third Assumption: "Probability of obtaining one million vehicle kilometers of experience with a demonstration fleet of 8 buses in a short enough period of time to provide relevant feedback to the design of the next generation of fuel-cell buses and stacks." Risk: "The project staff can only mitigate against this by continually monitoring bus performance. If it is found that the necessary experience will not be gained from the eight buses, some adjustments to the project will have to be made while the project is under implementation."

As mentioned in the previous section, considering the technological stage of the fuel cells and the hybrid vehicles at the time this project was launched, the assumptions can be considered too optimistic. In fact, there were few vendors who could supply eight prototypes of FCBs, and the price would probably be higher than expected due to the guarantees required for the buses to run on a commercial basis. It is important to mention again that the project team recognized the difficulties of implementing the project as planned and reviewed the number of buses and the financial planning, as explained in section 3.2.

Obtaining one million vehicle kilometers with experimental buses in the time frame established in ProDoc would be a formidable challenge, considering that three buses would be delivered in the first year and five buses in the second.

A risk not anticipated by the project team concerns the hydrogen supply and how it could affect the FCB development and tests. In fact, the refueling station took a long time to operate and this has negatively impacted the project schedule and results. The ProDoc includes a discussion about hydrogen shortage, but more attention should be given to the deployment of the station, and perhaps a gas company or a local technical support might be involved in the partnership or contracted in order to mitigate risks.

With respect to externalities, even though problems are expected to import goods and to obtain work visas in a project involving international participation, no risks were attributed to those activities. Special attention to these points might have contributed to reducing their consequences.

3.1.3. Lessons from other relevant projects (e.g., same focal area) incorporated into project design

The design of this project was benefited from the experiences of previous fuel cell bus demonstration projects, particularly the Chicago and Vancouver projects. Considering that the Vancouver project used electrolytic hydrogen, much of the design work, experience data and costing of the hydrogen refueling system for the Brazilian proposal was based on this project. But the Chicago project also offered several lessons learned. First, it was not advisable to have less than three buses in a demonstration set, since it is statistically impossible to tell whether an operational problem was attributable to the individual unit or to the overall design. Second, the measured availability of FCBs was about 30% compared to diesel buses. This figure was increasing over time for the buses used in this initial demonstration, but also for this generation of fuel cells, and probably for future generations. Third, the fuel cells durability was about 4000 h between rehabilitations, but for the new generations this figure was expected to increase dramatically. In summary, all the parameters and assumptions used in the preparation of the Brazilian project were obtained from previous demonstration projects, and incorporated expectations of future technological improvements.

This project also benefited from the EMTU's experience of developing trolleybuses over several years, through an iterative process, for use in the São Paulo Metropolitan area. This process provided an important first lesson: it was important to gain some experience with a new bus-propulsion technology before attempting to customize or improve it. A second lesson provided by EMTU indicated that it was essential to operate vehicles under commercial conditions to develop the technology properly.

3.1.4. Planned stakeholder participation

Although ProDoc does not mention specifically a "planned stakeholder participation", it adequately defines their roles and responsibilities.

At the initial phase of the project the stakeholders who signed PRODOC had an important participation in the project design, being responsible for the specific characteristics of the Brazilian FCB project, always in good agreement with the strategic objectives of GEF, the project's donor. In 2005, the consortium of private companies began, and since then played an important role in bringing the project design to its final configuration, with fewer buses, but more locally produced content in terms of components and technology.

In its design and, the project properly took into account the national realities in terms of institutional and policy framework. MME has played an important role as the project executing agency at the federal level. The project was in good agreement with national policies for the environment, public health, sustainability, and the development and use of renewable fuels in transport.

The implementing partner EMTU/SP played and continuous to play a key role at São Paulo State level, controlling public transport in five metropolitan regions with a total population of about 30 million people. The agency has a clear vision of the importance of the FCB project, and its objectives are clearly aligned with the policy of the agency and of the São Paulo State in terms of sustainability, public health and the environment.

3.1.5. Replication approach

As designed, the FCB project could be replicated in other regions or countries, providing favorable conditions were met in the following aspects: political, financial, technological, and public acceptance.

Technological and administrative difficulties that have arisen during this project are likely to occur in other technical projects in Brazil or abroad. Therefore, the lessons and experiences learned so far should be discussed during future project planning to help anticipate or resolve these difficulties.

Before replicating the FCB project, however, it is recommended the elaboration of a new bus design to take advantage of all the technological experience gathered in this project. This new vehicle could reach a commercial level, or near commercial, the corrective maintenance would be occasional and the staff could dedicate more time to other interesting aspects of the project. In this situation, it would be possible to deploy commercial fleets of FCBs with all benefits envisioned by UNDP and GEF for transport in large cities with respect to the environment, quality of life and public health.

Key points to the success of the Brazilian FCB project were the strong institutional arrangement and the persistent commitment of all stakeholders of the public and private sectors to ensure proper operation and maintenance of the buses, safety, supply of hydrogen, support in administrative issues, and public education activities. Even though the design of a new phase was envisaged, this could not be accomplished during project implementation.

3.1.6. UNDP comparative advantage

The comparative advantage of UNDP lies in its experience to propose and support programs and projects of high interest for society, through the mobilization of local, regional and national governments, the involvement of public and private enterprises, and the establishment of regional and international partnerships.

The Brazilian FCB project was part of a program for sustainable transport, which proposed the development of hydrogen fuel cell buses in order to replace diesel buses, contributing to improve the quality of life and public health by reducing the emission of greenhouse gases and air pollutants in large cities.

The technical and scientific basis of the program, the credibility and the organizational and financial support provided by UNDP are also comparative advantages. They were essential to attract national and international partners to participate in the institutional arrangement that allowed the successful execution of this project in Brazil.

The involvement of the UNDP in the project also facilitated the obtaining of relevant technical information, both for the hydrogen refueling station and buses, through technical visits in several countries, for example: the Hydrogen Station in Hamburg (Hamburger Hochbahn), Germany; the Hydrogen Station in Amsterdam, Netherlands; Hydrogenics, in Mississauga, Canada; and Ballard. The visits involved Brazilian licensing authorities, technical and administrative personnel, and these experiences constituted major contributions to the project.

3.1.7. Linkages between project and other interventions within the sector

As mentioned in the Mid-Term Evaluation, phase II.2 of this project was based in the CUTE project held in Europe. The bus design was accessed and re-engineered for demonstration in Brazil with key alterations as per lessons learned from that program.

In addition, this project was part of a UNDP/GEF strategy for fuel cell bus (FCB) commercialization support program in five countries and linkages between those projects were foreseen at project design.

There is a certain demand for FCB in the world, still small, but growing, as several countries have shown interest in experimenting with the technology without having to make all the necessary investments in time, money and human resources to come up with a good bus design. Brazil has the necessary and sufficient conditions to succeed in this market, since it is one of the world's major bus suppliers, and has a well-prepared industry to offer products with excellent quality at a reasonable cost. The project demonstrated that the FCB operation is technically viable and can be fully integrated to commercial bus lines with different technologies, such as diesel and trolleybus.

Although the time available to complete this TE report does not allow a thorough analysis of projects, programs and interventions within the sector in the world nowadays, the following publications contain information that deserve a mention, and a few relevant comments are provided about them. This information has been included because it may valuable to the technical personnel who will have access to this report.

a) Fuel Cell Electric Buses – Potential for Sustainable Public Transport in Europe, Heiko Ammermann and colleagues, September 2015. http://chic-project.eu/wp-content/uploads/2015/04/150909_FINAL_Bus_Study_Report_OUT.pdf

This report has focus on the characteristics of Fuel Cell Buses and informs the efforts of the European Union in pursuing an emissions reduction agenda as well as measures to preserve local air quality and to reduce harmful noise levels in public transport. The report contains an instigating cost analysis along with a list of benefits for investing in Fuel Cell buses right now. The current status of standard bus cost is between US$ 740,000 and US$ 834,000, estimated by the evaluator based on values provided in euros.

b) Fuel Cell Buses in U.S. Transit Fleets: Current Status 2015. Leslie Eudy and Matthew Post, NREL; and Christina Gikakis, FTA. http://www.afdc.energy.gov/uploads/publication/fc_buses_2015_status.pdf

This report is published annually and summarizes the progress of fuel cell electric bus development in the United States and discusses the achievements and challenges of introducing fuel cell propulsion in transit. The report informs that in August 2015 there were 24 Fuel Cell Electric Buses active in demonstrations at several locations throughout the country, which focus on identifying improvements to optimize reliability and durability. It is also informed that the status of bus cost was US$ 2.1 to US$ 2.4 million, and the target for 2016 is considered US$ 1.0 million.

It is worth mentioning that bus cost comparisons are always a challenge, because to get a fair comparison, it is necessary to take into account a large number of parameters and weigh them properly, which is not being done in this case. Anyway, the costs informed in the previous paragraphs can be used as references when analyzing the cost of the bus developed in this project.

3.1.8. Management arrangements

Since the very beginning the actions that resulted in this project were conducted by entities and companies from national and regional governments. The basis for this project started in early 1993, when the Ministry of Mines and Energy (MME), the National Department of Water and Electric Energy (DNAEE), the Energy Company of São Paulo (CESP), the São Paulo Urban Transportation Metropolitan Enterprise (EMTU/SP) and the University of São Paulo (USP) signed an agreement to launch a pilot project aimed at the use of surplus electricity in the southeast of Brazil to produce hydrogen by water electrolysis, and using this hydrogen as fuel in buses of the urban transport system. The first phase was a feasibility study that took place from 1997 to 2000, with the national coordination of the MME, supported by UNDP and financed by GEF. Management arrangements for the next phase followed a similar approach with the host government, represented by the MME, assuming the overall responsibility for the project as the executing agency at national level.

A strong and committed group of stakeholders from the Brazilian public-sector came together to participate in the project. Relying on the administrative and technical support provided by UNDP and with GEF as the founder and main financial sponsor, this arrangement was essential to ensure the development of the project. The stakeholders of the Brazilian public-sector are shown in Table 2, page 24.

Additional information about management arrangements is provided in section 3.2.3.

3.2. Project Implementation

Figure 1 summarizes the administrative and financial arrangements established in the original project, Figure 2 indicates the final situation, and Figure 3 shows the agreements signed by EMTU to coordinate and implement the project. According to the legend, ProDoc was signed between UNDP, ABC, MME and EMTU. Additionally, MME signed separated agreements with FINEP and with EMTU. The composition of the consortium of private companies and their function in the project are explained in section 3.2.2 and in Table 4.

Figure 1. Administrative and financial arrangements: situation previewed in the original project

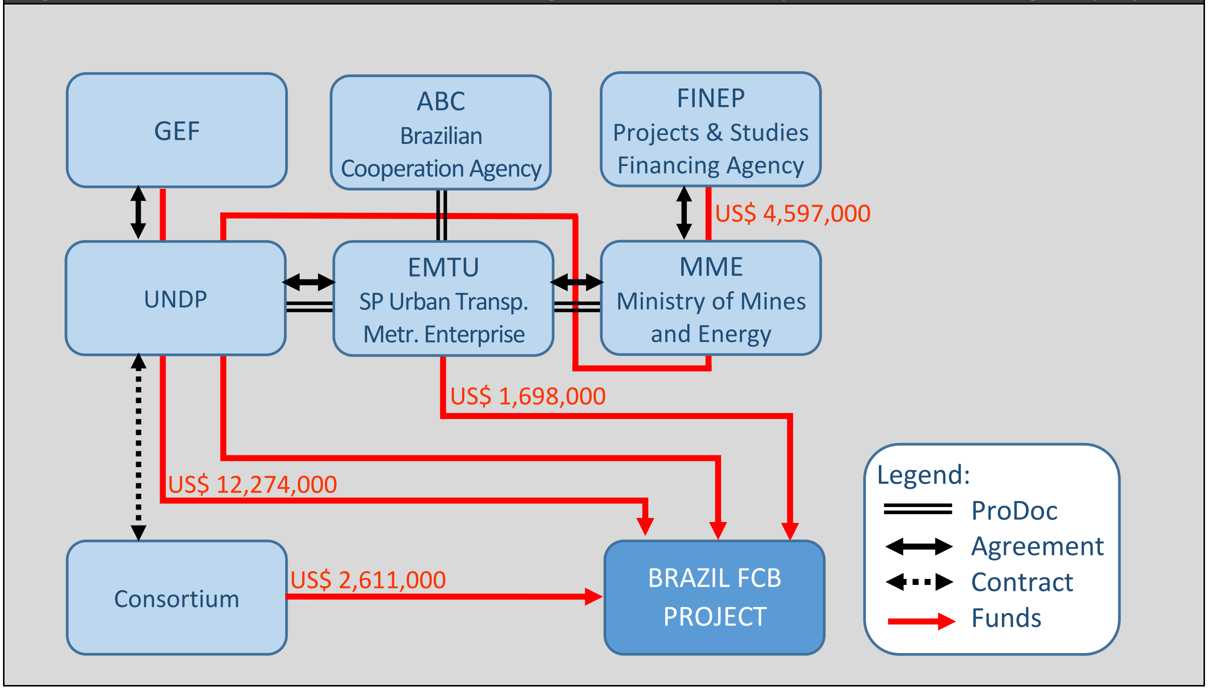


Figure 2: Administrative and financial arrangements: actual situation

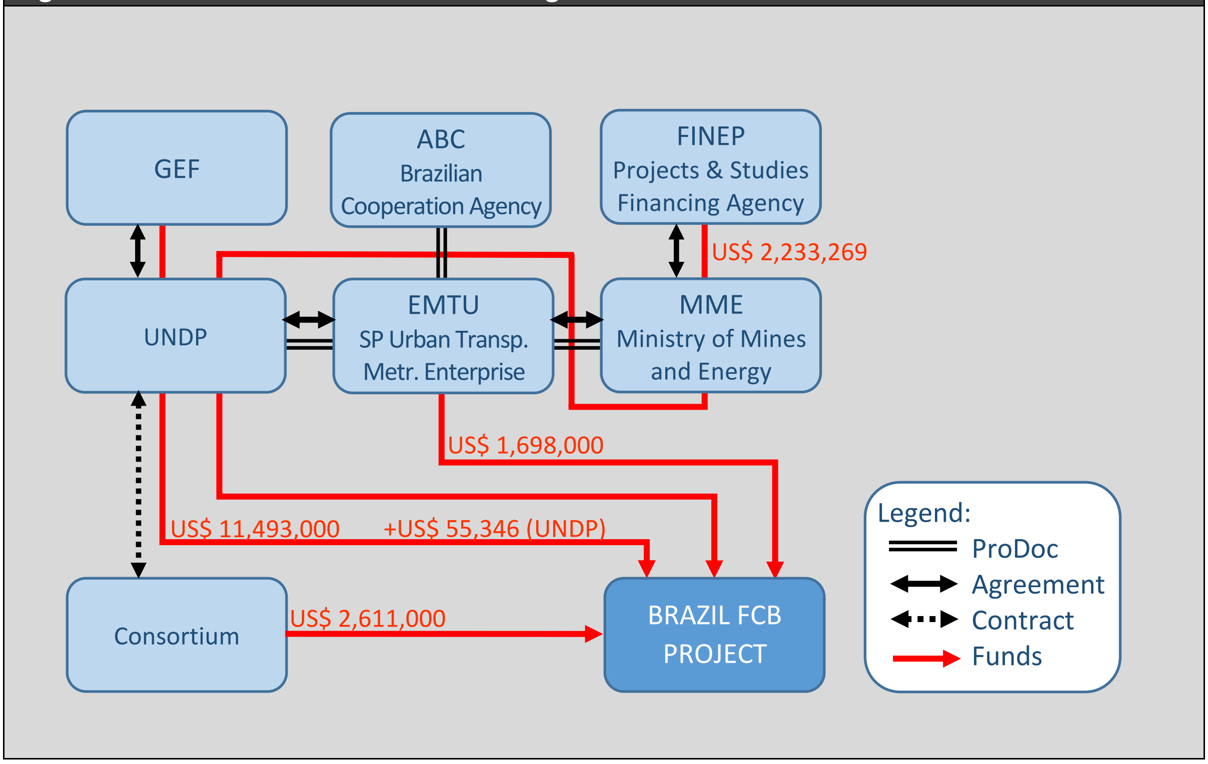
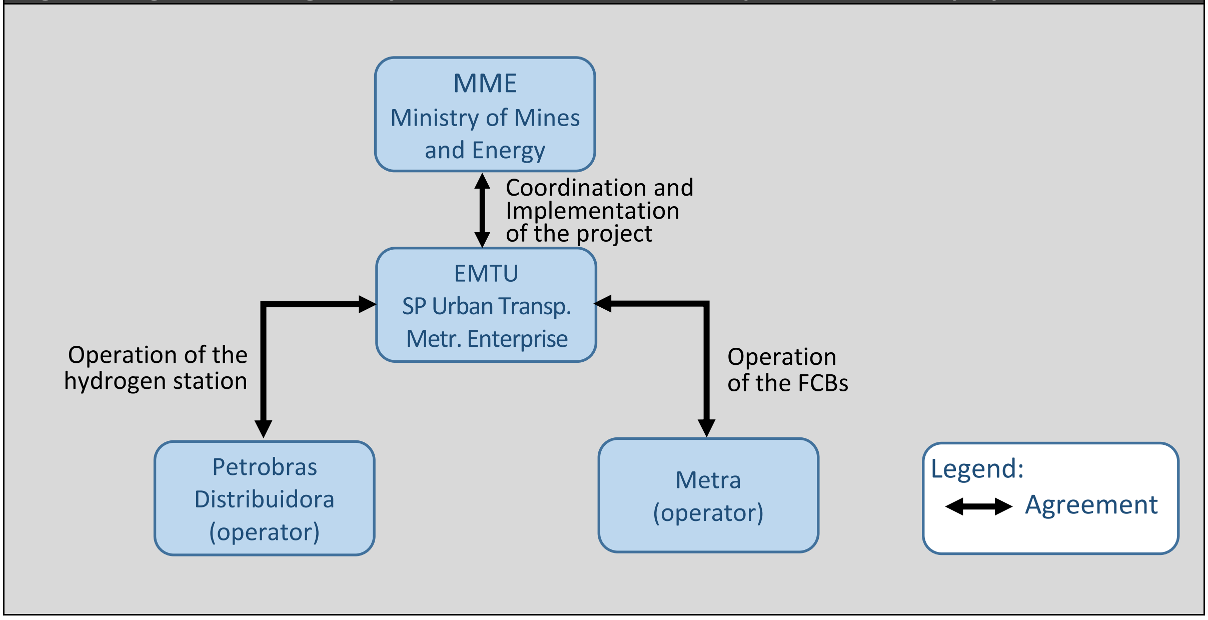


Figure 3: Agreements signed by EMTU to coordinate and implement the FCB project



3.2.1. Adaptive management (changes to the project design and project outputs during implementation)

The most important changes to the project design and project outputs during the implementation were related to the following issues, which are explained in the next paragraphs: i) reduction of the number of buses targeted, based on a better understanding of the technology and equipment costs; ii) considerable improvement of bus design; iii) reduction in FINEP co-financing funds; iv) delays in the development of the bus; v) delays in the deployment of the hydrogen refueling station.

i) Reducing the number of buses was decided based on technical and budgetary aspects, according to the following facts.

The ProDoc BRA/99/G32 established the construction and tests of eight buses for a period of four years. This document was signed by the stakeholders listed in Table 2, page 24, in November 2001. In 2005, the private-sector consortium was formed with the companies listed in Table 4, page 36, which would be responsible for developing the buses and the hydrogen refueling station in Phase II. 2. Discussions for project implementation led to the Substantive Revision H ProDoc BRA/99/G32, signed in December 2005. Based on a better understanding of the technology and equipment costs, goals and schedule were reassessed and the project was reconfigured according to the available budget. Among other decisions the number of vehicles has been reduced from eight to up five buses (sic) and the project duration was extended to December 31st, 2010. Discussions to specify the design of Phase II. 3 buses started when testing the prototype built in Phase II. 2. The practical experience with the prototype led the project team to realize that only three vehicles with an improved design could be built, reaching a total of four buses built in the project.

ii) Changes in bus design and use of more locally produced components.

When the private consortium was formed in 2005, discussions led to the decrease in the number of buses and to important changes in the implementing strategy. It was decided that the first bus prototype would be developed based on the model Citaro used in the Clean Urban Transport for Europe (CUTE) project, but with Brazilian body and chassis. The next three buses would have an improved design with several components produced by local suppliers. Fortunately, UNDP/GEF have accepted this important change, despite the challenges it entailed.

Implementing this strategy required extensive engineering, testing and know-how transfer activities (all at added costs), but its successful implementation brought a 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 comprised the design, construction and tests of the first prototype that was based in the previous generation of fuel cell buses demonstrated in the CUTE project. Phase II.3 took advantage of all the experience gained from the first prototype to elaborate a new bus design with the largest possible number of components provided by local suppliers.

iii) FINEP co-financing contribution was reduced.

The Technical Note Nº7/2015-DGN/SPG-MME, elaborated by MME, and Dr. Larson's mid-term evaluation report explain in detail the facts that led to the reduction of the FINEP co-financing. This TE report will just highlight some of the most important points.

In 2001, MME, EMTU, ABC, and UNDP sign ProDoc and one clause stipulated that 3% of total project funds from GEF and co-financing sources have to be paid to UNDP as its General Management Support (GMS) administrative fee.

In 2002, MME and FINEP signed an agreement that formalized co-financing for the project. MME and EMTU also signed a separate agreement for EMTU to be the implementer of FINEP funds. In 2011, an inconsistency between the MME/FINEP agreement and the ProDoc regarding the administrative fee of co-financing resources was detected leading to a joint search for a legal solution to the problem. A series of meetings were held between MME, EMTU, FINEP and UNDP, and the legal department of each institution was consulted as well. Finally, the matter was submitted to the Union General Controllership (CGU in Portuguese). On November 5th, 2013, the CGU decided that the reimbursement of UNDP with FINEP funds was legal, because it was "an expense related to the provision of technical assistance and knowledge transfer to the recipient of the International Technical Cooperation", in free translation from Portuguese to English. This is a typical administrative financial issue and the maximum audit body should be consulted immediately, in this case, CGU.

In the Steering Committee meeting of November 26th, 2014, MME reported that FINEP agreed the accountability was made under the previous rules, but the next installments should follow the new rules. It was noted that a new installment could only be made with a minimum of three months prior to the closing date of the MME/FINEP Agreement, December 30th, 2014. Therefore, a new installment would require a term extension. In this case, the release of funds would have to respect the end of fiscal year 2014, the publication of the financial programming decree and the schedule of disbursements by the federal government for the following year. All these steps indicated that FINEP resources would be made available to the UNDP only in March or April 2015. Considering the UNDP and GEF had established that the project closing date would be extended to June 2015, there would be little time to use the resources.

The FINEP resources would be mainly used in the dissemination of project activities and bus insurance, which would not compromise the bus development and testing. Therefore, after assessing the pros and cons the Steering Committee decided not to request an extension of the MME/FINEP Agreement.

All those facts led the total contribution of FINEP (Government co-financing) for the project to decrease from US$ 4.6 million, as initially established in ProDoc, to US$ 2.2 million. In addition, this value was revised several times during the project to reflect exchange rate fluctuation over the years as indicated below:

Table 3: Financial contribution of FINEP throughout the project			
Document	**Section**	**Signature Date**	**Value (US$)**
ProDoc, BRA/99/G32	Annex A, Table I-1	Aug/2001	4,597,000
Substantive Revision	Title Page	Dez/2005	3,346,612
Substantive Revision	Title Page	Jun/2011	4,501,783
Substantive Revision	Title Page	May/2015	2,166,822

This reduction of the budget and the full engagement of the project team in the development of buses and the hydrogen refueling station resulted in the cancellation of the following activities listed in Work Plan 2015: Activity 5.3 – To formulate Brazilian Standards for Hydrogen Fuel Cell Buses for urban transport; and Activity 5.4 – To elaborate a proposal for Phase III of the project.

iv) Delays in the development of the bus

Here are some of the main facts that caused delays in the schedule, along with comments on these delays.

The time between the signing of ProDoc, November 2001, and the Substantive Revision H, in December 2005, should not be considered as a simple delay in the schedule. It is important to remember that there were few companies with technological capacity, interest and availability of time and human resources to engage in such a project. Moreover, at first sight, there was no guarantee that they would get financial or technological advantages at the end of the project, so it took some time for the most interesting companies to be attracted to the project, to talk to each other and to understand that participation would be beneficial for all parties. Their contribution promoted changes in the project's development strategy in accordance with the objectives of the UNDP/GEF, as already mentioned.

With regard to the development of the buses, the process of importing spare parts, components and equipment caused some delays. Although the overall delay was of a few months, the problem was very inconvenient, interrupting ongoing activities and increasing costs. Other delays were related to malfunctions of components that had to be replaced or repaired. Those facts were expected, considering that two different bus designs were developed: the Phase II.2 prototype bus and the Phase II.3 improved design.

v) Delays in the deployment of the hydrogen refueling station

The construction and commissioning of the hydrogen refueling station took years instead of months. Although the dispenser can be considered a novelty, all other equipment of the station is commercial, such as: alkaline water electrolyzer, the high-pressure compressor and storage tanks. Concerns that licensing would be an issue have not been confirmed, since the project team organized a technical workshop with the licensing authorities (November 2006) and also led them to technical visits to European hydrogen refueling stations (May 2007). In January 2008, all the equipment of the station arrived at the site, but the installation only began in January 2010. No company appeared in the first bidding held for the civil works of the hydrogen station. It was necessary to conduct an updated quotation, a reallocation of financial resources and a new bidding, which caused a major delay.

Another difficulty was the authorization to acquire potassium hydroxide, which in Brazil is controlled by the Federal Police. In addition, several incidents were still to come, hampering the full commissioning of the station. In November 2011, Hydrogenics applied for work visas for their engineers to come to Brazil from Canada to commission the station. The visas release took nearly one year and finally the commissioning began in August 2012. Four travels were necessary in order to make all the repairs to commission the electrolyzers. Then the compressor (PPI) presented problems, and after that, the storage tanks supplied by Hydrogenics presented leaks. In August 6th, 2013, the Hydrogenics engineer returned to Brazil to repair the leaks, but he was not allowed to enter the country because he had not registered his visa with Federal Police on his first entry in Brazil.

In July 24th 2015, the SAT Report was signed. The hydrogen refueling station was operating properly with only two hydrogen storage banks, B and C, and was able to support the operation of the FCBs in the metropolitan corridor from January until March 22th, 2016, when a diaphragm of the hydrogen compressor broke, preventing the operation of the buses in the last week of March. In July 2016, Hydrogenics sent an engineer to fix the storage bank A and the broken diaphragm, and to turn off the station conveniently. After that, Petrobras approved the services provided by Hydrogenics, and EMTU agreed with the conclusion of work by communicating the UNDP that Hydrogenics had fully complied with the contract.

3.2.2. Partnership arrangements (with relevant stakeholders involved in the country/region)

In January 2002 UNDP/CO published a request for expressions of interest to implement the Brazil FCB project. The only response was received in February 2002 from a partnership comprised of two Canadians companies, Ballard Inc. (fuel cells) and Stuart Energy (hydrogen generators by water electrolysis), and a Brazilian company, Marcopolo (bus bodies). They asked for two years to form a consortium as requested by UNDP. Discussions continued and in November 2004 UNDP published a tender with the technical specification of the Project BRA/99/G32. A consortium with eight companies, including those already mentioned, responded promptly with technical and commercial proposals, and in January 2006 the final version of the contract was signed between UNDP and the Consortium for the implementation of Phase II.2. The consortium was comprised of the companies indicated in Table 4, which are explained briefly in the following paragraphs.

Table 4: Private-sector Consortium		
Company	Function	Country
▪ EPRI International	Consortium Management	USA
▪ Tutto Indústria de Veículos e Implementos Rodoviários Ltda.	Bus: integrator	BRA
▪ Marcopolo S.A.	Bus: body builder	BRA
▪ Ballard Power Systems Inc.	Bus: fuel cells supplier	CAN
▪ Nucellsys	Bus: fuel cell systems and integration	GER
▪ Hydrogenics Corp.	Hydrogen Station: supplier and integrator	CAN
▪ Petrobras Distribuidora S.A.	Hydrogen Station: operator	BRA
▪ AES Eletropaulo	Hydrogen Station: electricity supplier	BRA

After answering the first request from UNDP Stuart Energy was acquired by Hydrogenics in November 2004. Nucellsys was acquired by Daimler Chrysler in 2005, but continued to provide limited support for the development and operation of the prototype bus, even though it had left the consortium. AES Eletropaulo joined the consortium at the beginning to ensure adequate specifications of the electrical substation to supply the hydrogen station, and left after that.

EPRI is the consortium leader, and it had an enormous capacity to contribute to the objectives of the project so they were successfully achieved. The consortium was composed of large companies, exponents in their fields, and the EPRI acted as a facilitator between them.

Ballard Power Systems is a leading company in research, development and manufacturing of proton exchange membrane (PEM) fuel cells for vehicle applications and is involved in several important projects for vehicle development in the world. Other auto maker companies also have development programs on hydrogen fuel cell vehicles, but they are very closed to cooperation, and apparently not interested in the markets of developing countries at this time. On the other hand, Ballard is open minded company and its products have demonstrated the necessary quality and endurance to operate in heavy-duty vehicles.

Marcopolo is the biggest builder of bus bodies in the Americas. The company supplied the bodies for the four FCBs developed in this project, providing the necessary adaptations required to accommodate the hydrogen fuel cell equipment.

Tutto is a company with extensive experience 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. In this project, Tutto had an important contribution in adapting the chassis and integrating imported electrical and mechanical systems into the prototype bus. Its major role, however, was in developing local solutions to replace imported components and software, notably from Nucellsys and Siemens. The company was able to absorb the technology, understand the hybrid concept involving hydrogen fuel cells and batteries, and how to manage electrical energy and mechanical power in the vehicle. Based on the experience of the prototype bus, relevant improvements were introduced in the design of Phase II.3 buses. After the completion of this project, Tutto is ready to produce a new design with many technical improvements and innovations that will make the Brazilian FCB reach a higher level of maturity, very close to the commercialization stage. These improvements will not increase costs, on the contrary, the projections made indicate that bus prices are consistently below the current standards. It is worth mentioning that although not a stakeholder, the WEG company had an important role in supplying the electric motors and inverters for the three buses of Phase II.3, which were implemented with Tutto support.

Hydrogenics is a leading Canadian company engaged in hydrogen generation, fuel cell applications and energy storage. The company acts with great focus to insert hydrogen and fuel cells in the economy, by means of high quality products and services. Acquiring Stuart Energy company reinforced its role as a world leader in hydrogen production by water electrolysis.

Petrobras Distribuidora, which brand and logo is "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.

In general, the establishment of the international consortium to supply and support the development of the bus and the deployment of the hydrogen fueling station was highly satisfactory. Although the time required to gather all those companies has not been short, four years can be considered reasonable, because the original project was considerably improved with regard to the bus design and taking into account that several technologies have undergone major improvements in the period, such as batteries, fuel cells, and electric and hybrid vehicle technologies.

Besides the partnership with consortium members, the project team attended events to interact with hydrogen, fuel cell and FCBs specialists and to disseminate the project. The following activities deserve a mention:

i) Event: 6th International Fuel Cell Bus Workshop

   Local: Vancouver, Canada   Date: June 4th, 2009

   Participant: Carlos Zündt, EMTU/SP, National Coordinator of the GEF Project BRA/99/G32

   Summary: The participation was by invitation of the organizers of the event, which was funded by the Federal Transit Administration, United States, as part of the National Fuel Cell Bus Program. It brought together representatives of demonstration projects from around the world to share technological information and performance results to evaluate the state of the art of hydrogen fuel cell bus technology. At that time, BC Transit was in the process of implementing a fleet of 20 fuel cell buses to be operated in Whistler, Canada, beginning with the 2010 Olympic Winter Games. Discussions during the workshop were very rich and the Brazilian project also attracted much attention from participants due to the innovations introduced in the bus design and the project formulation.

ii) Event: 7th International Fuel Cell Bus Workshop

   Local: San Francisco, USA   Date: February 2011

   Participants: Ivan Regina, EMTU/SP, National Coordinator of the GEF Project BRA/99/G32; and Rose Diegues, UNDP/CO, Programme Analyst and GEF Advisor.

   Summary: The participation in the workshop was of great value to this project. International experiences on the development of the technology brought a valuable contribution to the implementation of Phase II. 3 of the project. Presentations were made by representatives of Canada, United States and Germany. Additionally, there were technical visits to hydrogen refueling stations in San Francisco. The overview of projects around the world contributed to the development of Brazilian specifications on hydrogen technologies.

iii) Event: International Workshop on Hydrogen and Fuel Cells

Local: University of Campinas, Campinas, Brazil Date: 2008, 2010, and 2012

Summary: This conference was organized by the Brazilian Reference Center for Hydrogen Energy and the Hydrogen Laboratory at the University of Campinas. It was the main conference in South America on hydrogen and fuel cells, and it occurred every two years from 2002 and 2014 with the participation of leading researchers from the United States, Canada, Germany, France, Portugal, Italy, England, Spain, Denmark, Brazil, Argentina, Uruguay, Paraguay. Among other relevant invited speakers, various stakeholders and companies involved in this project participated in different editions of this conference, i.e.: MME, EMTU/SP, FINEP, Petrobras, Tutto, Hydrogenics, and Ballard. In addition to the project have been mentioned by all these speakers, three lectures were held with focus on this project: in 2008, Carlos Zündt, EMTU/SP, National Coordinator of the GEF Project BRA/99/G32; in 2010, Ivan Regina, EMTU/SP, National Coordinator of the GEF Project BRA/99/G32; and in 2012, Sidney Gonçalves, Tutto, Project Manager.

3.2.3. Feedback from M&E activities used for adaptive management

Among the mechanisms used for M&E of the project is the Project Board, that is constituted by UNDP, ABC, MME and EMTU. This board was responsible for regular monitoring of project activities and approved adaptive management changes throughout the project. The ProDoc established that the Brazilian government, represented by MME, and the State of São Paulo government, represented by EMTU/SP, were responsible to prepare Progress Reports (including PIRs) to be submitted for the analysis of participants at annual Tripartite Review meetings.

Another monitoring instance which was put in place was the Steering Committee formed by all members of the consortium. Nevertheless, the stakeholders UNDP/CO, MME and EMTU participated in all meetings, entitled to vote the deliberations, and contributing to the management and evaluation of the project activities.

The Steering Committee met regularly two or three times per year since November 14th, 2006, with about 26 meetings in total. Where necessary, other companies, suppliers, government agencies or authorities were invited to attend the meetings in order to provide or obtain clarification on technical, administrative or legal aspects of the project.

Minutes of the meetings are a good report of the project status at the time, and contains detailed information on the current situation, resolutions and measures to implement in order to achieve the project objectives.

In some documents examined for this evaluation and during interviews with stakeholders from public and private sectors, sometimes it was mentioned that simpler management arrangements would bring more agility to the project. Apparently, this could be achieved by means of small changes, such as allowing a little more autonomy to the implementing partner, EMTU, and to the consortium manager, EPRI, to make decisions within certain limits.

In 2014 the Mid Term Evaluation provided guidance for further implementation, in particular negotiations with FINEP for availability of funds and timing for bus operation which resulted in adaptive management measures.

3.2.4. Project Finance

Global Environment Facility (GEF) was the funder and main sponsor of the Brazilian Fuel Cell Bus project. The funds were disbursed to the project through the United Nations Development Programme, 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 develop, supply and support operation of equipment in the project.

Brazilian Projects and Studies Financing Agency (FINEP) is a public enterprise of the Federal Government, under the Ministry of Science, Technology and Innovation. The agency provided a substantial amount of co-financing (Table 6), and has a clear vision of the importance of the project and how the FCBs can contribute to improve sustainability in public transport in Brazil.

The management of FINEP resources by MME was perfectly performed in institutional and legal terms. It seems, however, that the accountability would have been easier and faster if the MME and FINEP had established a Term of Cooperation rather than a Cooperation Agreement. The interruption of FINEP funds to the project was also related to the reimbursement of UNDP operating expenses regarding these funds. The subject became too complex because of the legal aspects involved. After several meetings and consultations to the legal departments of each part involved, the Brazilian Union General Controllership (CGU in Portuguese) was consulted. On November 5th, 2013, the CGU decided that the refund was legal, because it was "an expense related to the provision of technical assistance and knowledge transfer to the recipient of the International Technical Cooperation", in free translation to English.

Some additional delays still occurred, related to the establishment of an amendment to the project, and the approval of the mid-term accountability by FINEP. Finally, on November 26th, 2014, agencies taking part in a ProDoc meeting decided to terminate the MME/FINEP Agreement considering there was no time for another disbursement. All those facts contributed to decrease the total contribution of FINEP to the project from US$ 4.6 million to US$ 2.2 million. It is important to note that UNDP received funds directly from GEF to apply in the project, while FINEP funds have been transferred to MME and posteriorly to UNDP. Greater agility probably would have been achieved if transference of the FINEP funds and its accountability had been done between FINEP and EMTU without intermediation.

The evaluator made an independent assessment with available data about co-financing by consortium members and the results presented in Table 6 are consistent with the figures of the mid-term evaluation, US$ 2.6 million. Table 5 presents the co-financing by stakeholders comparing estimated amounts in PRODOC vis a vis actual expenditure. presents the

The project was regularly audited during implementation with unqualified results and no recommendations to be observed, which indicates the adequate project management and compliance through the years.

Table 5: Co-financing and GEF Resources		
COMPANY/EVENT	ESTIMATED CONTRIBUTION (US$)	TOTAL CONTRIBUTION (US$)
FINEP	4,597,000	2,233,269
EMTU/SP, Services and material	1,306,000	1,306,000
EMTU/SP, funds	392,000	392,000
Private Sector	2,611,000	2,600,617
UNDP/CO	0	55,347
SUB-TOTAL	8,906,000	6,587,233
GEF	12,274,000	11,597,478
TOTAL	21,180,000	18,184,711

Table 6: Co-financing table, consortium members			
COMPANY/EVENT	CONTRIBUTION (R$)	CONTRIBUTION (US$)	TOTAL CONTRIBUTION (US$)
BALLARD INC		1,403,000	1,403,000
BR PETROBRAS	775,738		503,508
HYDROGENICS		377,213	377,213
TUTTO	242,185		131,981
Bus launching event	84,104		35,072
AES ELETROPAULO	50,000		28,409
EPRI		31,366	31,366
Project Management	4,950		2,113
NUCELLSYS		N/A	N/A
MARCO POLO	154,800		87,954
TOTAL	R$ 1,311,777	US$ 1,811,579	US$ 2,600,617

Table 7: Project Annual Expenditures (resources channeled through UNDP finance)				
YEAR	GEF CONTRIBUTION (US$)	FINEP CONTRIBUTION (US$)	UNDP CONTRIBUTION (US$)	TOTAL CONTRIBUTION (US$)
2002	18,832	8,443		27,275
2003		1,324		1,324
2004	4,129			4,129
2005	17,715			17,715
2006	1,090,678	58,519		1,149,197
2007	3,579,197	168,530		3,747,727
2008	762,132	31,065		793,197
2009	1,376,394	4,354		1,380,748
2010	- 635,782	1,511,600		875,818
2011	443,248	438,528	55,347	937,124
2012	1,693,277	10,621		1,703,898
2013	817,205	142		817,347
2014	1,281,047	143		1,281,189
2015	698,752			698,752
2016	450,653			414,653
TOTAL	11,597,478	2,233,269	55,347	13,886,094

3.2.5. Monitoring and evaluation (M&E): design at entry and implementation (*)

Rating: 4- Moderately Satisfactory

The monitoring and evaluation plan for the project was clearly defined in the ProDoc, and it was based on the logframe and the workplan (annex A and B of ProDoc), consistent with the project objectives and procurement specifications. A set of reports listed below was established in the M&E plan:

1. Quarterly reports on achievement of hours and kilometers of operation by individual vehicles and the fleet;
2. Quarterly reports on the availability of vehicles and on fuel consumption;
3. Quarterly reports on MTBF (minimum time between failures) and FMA (failure mode analysis), for both vehicles and the fueling system;
4. Quarterly reports on proposed engineering modifications and the communication of these to vendors, plus confirmation of actions taken;
5. Quarterly reports on operator and maintenance personnel training and achievement;
6. Annual review of progress towards cost reduction, reliability improvement and increased durability;

7. Annual records of communication activities: participation in international meetings, information dissemination within Brazil, and

8. Final report with the independent evaluation of the project.

The changes made in the project through the Substantive Revision H, in 2005, made it difficult to issue the quarterly reports with operational data, and the achievement of the targets related to the mileage. These quantitative goals should have been reviewed at that time in order to better capture the project's achievements in terms of development and innovation of the bus, such as: the improvements in bus design; the replacement of imported components; the development of a new hardware and software, which improved operating and safety conditions.

Besides the above mentioned reports, M&E was made through the following instruments, which worked very well: Steering Committee meetings; annual Tripartite Reviews; PIRs and AOPs; a Mid Term Evaluation, in August 2013; and this Terminal Evaluation, in March 2016.

3.2.6. UNDP and Implementing Partner implementation / execution (*) coordination, and operational issues Rating: 5 – Satisfactory

Despite the delays and the changes in the original plan defined by the Substantive Revision H in 2005 (the number of buses was reduced and a new design was developed), the project was well implemented, executed and coordinated.

The author received several documents from UNDP/CO such as ProDoc, PIRs, Steering Committee's minutes, Annual Operational Plans and financial data reports and spreadsheets. Other technical reports received from Monica Panik/EPRI, were comprised of FCB test results and engineering, hydrogen fueling station SAT and service, Project History and Timeline. The Technical Note Nr. 7/2015-DGN/SPG-MME, received from Fernando Matsumoto/MME, is a detailed and extremely valuable report of the project, and the PIR-2015 received from the UNDP/CO was able to capture and evaluate the essence of the work done in the project. Those documents indicate that the project was well implemented, continuously monitored and evaluated by the team, under close supervision of the UNDP, MME and EMTU. Section 5.5 presents a list with the main documents reviewed, separated by Corporation.

3.3. Project Results

3.3.1. Overall results (attainment of objectives) (*) Rating: 4 – Moderately Satisfactory

Table 8 below shows the Baseline Indicators established in the project and the targets to be met, as informed in the PIR-2015-GEFID6_PIMS543, which is more complete than Table 1, which was extracted from ProDoc. The table also shows the actual results achieved.

Table 8: Baseline Indicators as established in PIR-2015-GEFID6_PIMS543		
BASELINE INDICATOR	**TARGET AT THE END OF PROJECT**	**ACTUAL**
OUTCOME 1	Significant demonstration of the operational viability of fuel cell drives in urban buses and their refueling infrastructure under Brazilian conditions.	
1. CO_2 emissions from São Paulo buses decreased by 1,560 tones	8 buses; 1,560 tons of CO_2 emissions avoided.	CO_2 emissions decreased by 21.4 t, considerably less than the target, for the following reasons: i) the number of vehicles was reduced to four; ii) delays in the construction of the buses; iii) delays in deploying the hydrogen refueling station, and operational problems with it. It seems that this target as well as other targets related to the total distance of one million kilometers to be traveled by the eight buses, established in the original project, should have been redefined to comply with the changes carried out in project by the Substantive Revision H, in 2005. This would capture some of the most important achievements of this project, such as: the local engineering content; the improved design, which makes this bus the simplest vehicle in its class in terms of assembly and maintenance; and a very good relationship between cost and quality of the FCBs. Changes redefined some of the objectives of the project with emphasis on the development of the bus, the innovation in design, the nationalization of components and the integration of components, while other FCB projects in the world pay more attention to the operation of the buses and statistical data related to failures. Anyway, the main problems that caused delays in the project could not be anticipated at the time.

2. Buses are operated for 1,000,000 vehicle-km, that operational statistic can be gathered.	1 million km	The bus prototype traveled 8,274 km; and the three buses of Phase II.3 traveled 12,246 km
3. The amount of vehicle-km obtained in the prototype operation	256,000 km	8,274 km
4. The amount of vehicle-km obtained in up to 4 buses operation	744,000 km	20,520 km
5. Prototype operation level in km per year	30,000 km per year	N.A.
6. Up to 4 buses operation level in km per year	40,000 km per year	N.A.
7. Refueling station operated satisfactorily to supply sufficient H2 at reasonable cost. Indicator: system availability percentage	100% (20 h/day operation)	The maximum operation time was about 10 h/day, although there were no technical obstacles to achieve the target, that was 20 h/day. The difficulty in reaching a greater number of consecutive operating hours was related to the employment contract of the staff and the operating rules established by Petrobras to the site.
8. Prototype breakdown level under 20,000 km	20,000 km	The total distance traveled by the buses was not enough to obtain this information.
9. Up to 4 buses breakdown level under 50,000 km	50,000 km	The total distance traveled by the buses was not enough to obtain this information.
OUTCOME 2:	Cadre of bus operators and staff trained in operation, maintenance and management of fuel cell buses.	
10. Number of operators / maintenance staff trained for the prototype	4 employees trained	22
11. Number of operators / maintenance staff trained for the up to 4 buses	10 employees trained	10
12. Enrollment in training seminars	15 training seminars	3
OUTCOME 3:	Accumulation of a substantial body of knowledge about reliability, failure modes and opportunities for improving the design of fuel cell buses for Brazil.	
13. Development of quarterly reporting forms	100%	40%

Evaluation: development completed = 100%		
14. Persons consulted in formulating reporting guidelines; quarterly reports collection. Evaluation: task done = 100%	100%	100%
15. Publication of documents demonstrating accumulated experience and knowledge. Evaluation: task done = 100%	100%	50%
OUTCOME 4:	Assessment of performance of electrolysis unit.	
16. Development of quarterly reporting forms Evaluation: development completed = 100%	100%	50%
17. Persons consulted in formulating reporting guidelines; quarterly reports collection Evaluation: task done = 100%	100%	100%
18. Publication of documents demonstrating accumulated experience and knowledge. Evaluation: task done = 100%	100%	0%
OUTCOME 5:	Proposal for Phase III of the Brazilian Fuel Cell Bus Program	
19. Satisfactory preparation of the Phase III proposal based upon Phase II experience, reconfigured bus design, Brazilian standards and continued dialogue with vendors. Evaluation: task done = 100%	100%	0% (Comment: two proposals to continue the Brazilian FCB project, made by the evaluator on a voluntary basis, are presented at the end of this TE report, section 4.3.)
OUTCOME 6:	Increased awareness and support of the public for an increased role for fuel cell buses in Brazil urban transport system	
20. Number of local, national and international workshops/seminars held and attended	At least 80	80
21. Number of professional publications produced	At least 300	320, approximately.

This project has contributed to advance a big step towards achieving the objectives of the UNDP/GEF for its fuel cell bus program, the sustainable commercial deployment of fuel cell buses in developing country megacities. Despite the difficulties and delays, the project was a success from the engineering point of view, and the bus design developed in Phase II. 3 can be considered as the state of the art of hydrogen fuel cells buses in the world, although this bus design (drawings, specifications, equipment selection) was made in 2013. Four buses were built and successfully operated in the metropolitan corridor with passengers onboard.

As explained in section 3.2.1, letter i), after producing a prototype in Phase II.2 based on the model used in the CUTE project, a new bus design was developed in Phase II.3 with more locally produced components and engineering. The result achieved is impressive and it can be verified in Table 9, where some of the key characteristics of both models are compared.

Table 9: Comparison of characteristics of Hydrogen Fuel Cell Buses Phase II.2 and Phase II.3

PARAMETER	PHASE II.2 (PROTOTYPE)	PHASE II.3 (3 BUSES)
Number of passengers	60	76
Communication protocols	Different types of communication protocols and different transference rates.	A commercial board from National Instruments was employed, and a single protocol was used for communication between devices. It enabled the development of a proprietary software and decreased malfunction risk during the operation of the buses.
Control Software	Produced by Siemens. Only the technician of the company could make changes to the software, making the procedure to adjust the operating parameters of the buses too slow and inefficient.	Developed by Tutto, the new software allowed great flexibility and agility in adjusting operational parameters of the buses, including batteries, fuel cells, and regenerative braking for energy recovery.
Braking	Braking resistor: operation was not satisfactory and its use implied in high energy consumption.	Regenerative breaking was adopted. During braking the electric motor functions as a generator and batteries store regenerative energy.
Batteries	Power: 106 kW Zebra type, brand MES-DEA, molting salt technology. These batteries demand preheating because operate at medium temperatures, around 250°C. They consume approximately 14% of its nominal capacity per day to maintain operational temperature when not in use.	Power: 105 kW Ion-Li technology. The batteries operate at ambient temperature and can store electricity from current peaks. The project team was very successful in managing the state of charge and operating temperature of these batteries using the control

		software developed by Tutto for this project.
Electric motor drive and power inverters	Siemens	The WEG company, Brazil, developed both equipment for the Brazilian FCB project.
Fuel Cells	2 x 68 kW, model XCS-HY-80, brand Ballard	1x 150 kW, model HD6, brand Ballard
Hydrogen consumption	13 kg / 100 km The state of charge of the batteries was not controlled and the hydrogen consumption was difficult to measure accurately.	(13,8 ± 1,5) kg / 100 km, in operation with passengers. The state of charge of the batteries was well controlled providing the hydrogen consumption was measured accurately.
Power Train and Engineering (design, engineering, maintenance & service)	Nucellsys (Germany)	Tutto (Brazil)
Body	Viale BRS, brand Marcopolo (Brazil), 12.6 m length	Viale BRT, brand Marcopolo (Brazil), 12.6 m length
Chassis	Volkswagen/MAN, low floor	Volkswagen/MAN, low floor
Hydrogen stored in the bus	45 kg	31 kg

Table 10 shows the distance traveled by each bus and the total distance covered by the four buses built in this project, which is 20,520 km. In comparison with the originally established target, 1 million km, the result might be considered modest. This target, however, and other related targets such as CO2 emissions, failure modes, km per year, for example, probably should have been changed along with the important modifications introduced in the project in 2005. In fact, they became too ambitious for a project focused on technological development and innovation. It is important to keep this information in mind not to underestimate the overall results compared to the original target. In addition, the technological development of FCBs made in this project is a key step towards achieving development, in a broader sense, as understood by UNDP and GEF.

Similarly, the reduction of carbon dioxide emissions expected in this project was 1,560 t, but it was not achieved for the following reasons: reduction of the number of vehicles; delays in the construction of buses due to the development of an improved design; delays in the import process; delays in the deployment of the hydrogen refueling station; and an over optimistic target for a project focused on development and innovation.

Table 10: Total distance (km) traveled by the four buses built in the project	
BUS NUMBER	TOTAL DISTANCE TRAVELED (km)

Prototype	8,274
#4020	5,044
#4021	1,182
#4022	6,020
TOTAL	20,520

The hydrogen consumption measured for the bus prototype measured in Phase II. 2 was about 13 kg/100 km. The average hydrogen consumption of the three Phase II.3 buses was (13.8 ± 1,5) kg/100 km, measured for buses in operation with passengers. It is an impressive value for this stage of development, compared with other results worldwide, as far as can be verified. The energy management in the vehicles was significantly improved in Phase II.3, which included the monitoring and control of the state of charge of the batteries. It simplified the calculation procedures and allowed to obtain the real hydrogen consumption of the buses.

With regard to energy management used in the vehicles, currently it has been chosen to start and finish the journey with batteries full-charged. It is recommended to verify if this mode of operation is the most appropriate or if there are other ways to achieve greater energy savings or increase the durability of batteries and fuel cells. For example: batteries may finish the journey partially empty and be charged by the grid during free time.

Regarding the hydrogen refueling station it was inaugurated in June 2015 and the Site Acceptance Test Report was signed on July 24th, 2015. The station operated properly with only two hydrogen storage banks, B and C, and was able to support the operation of the three FCBs in the metropolitan corridor from January to March, 2016. The Petrobras operation staff was trained by Hydrogenics and was able to operate the station, although had limited capacity to make corrective maintenance. The storage bank A and the broken diaphragm of the hydrogen compressor were repaired by a Hydrogenics engineer in July, 2016, and after that the station was adequately turned off, since the project was concluded.

The maximum operation time of the station was about 10 h/day, although there were no technical obstacles to achieve the established target, that was 20 h/day. The difficulty in reaching a greater number of consecutive operating hours was related to the employment contract of the staff and the operating rules established by Petrobras to the site. Due to the short period that the station operated consecutively, no cost assessment of the hydrogen produced is available.

The other indicators established in the original project were attended satisfactorily, Outcomes 2 to 4, namely: training of bus operators; training of technicians for bus and fuel cells maintenance; training of operators of the hydrogen fueling station; publication of documents.

At the evaluator’s request, Tutto made a preliminary assessment of the new bus production costs, incorporating the expertise gained in this project. It was found that to produce 1, 10 or 20 buses the cost reduction was estimated at 25%, 33% and 36%, compared to the cost of each unit built in Phase II.3, that was around US$ 1.01 million. This value is similar to the target for 2016, US$ 1.0 million, informed in the report of the USA project, mentioned in section 3.1.7, item b.

Thus, the Brazilian FCBs costs would be US$ 750,000, US$ 675,000 and US$ 637,500, respectively, to produce 1, 10 or 20 buses. The cost to produce a single bus is similar to the minimum cost informed in the European project mentioned in section 3.1.7, item a, US$ 740,000. As already mentioned, it is necessary to evaluate the specifications of both vehicles for a fair comparison. But for small fleets, the figures provided by Tutto seem to be a new global benchmark, or at least, very competitive.

The cost of production of FCBs will be higher than the conventional buses in the short to medium term, and spending on fuel should also be greater for hydrogen compared to diesel. But there are also economic advantages, such as: the durability of diesel engines is less than electric motors and, in this project, the cost of maintenance of FCBs was found to be less than conventional buses.

3.3.2. Relevance (*) Rating: 2 – Relevant

Brazil is among the largest urban world transit bus market, it has a strong industry in this sector, and the FCB developed in this project has shown very good results in terms of engineering, design and relationship between cost and quality.

The share of wind energy and solar photovoltaics is growing consistently in the country and will contribute with hydropower to keep the share of renewable energies around 84% in the electric sector in the period 2017-2023.

Appropriate use of water electrolyzers are known to help stabilize the electrical grid by fluctuations introduced by wind energy, solar photovoltaics, or even the change in consumption by other users. In this project, the hydrogen is produced in a sustainable way, and interesting research work could be developed to determine the lowest cost of production in view of important parameters, as the variation of electricity tariff throughout the day, the daily demand for hydrogen, FCBs refueling schedule, the availability of hydrogen station operators, and storage capacity of hydrogen.

Regarding diesel buses, they are important contributors to local air pollution in large cities and the replacement by a large fleet of FCBs would contribute decisively to mitigate greenhouse gas emissions and improve public health. With all these aspects in mind, the pursuit of clean FCBs remains highly relevant to the Brazilian context, as well as to other countries with similar characteristics.

3.3.3. Effectiveness & Efficiency (*) Rating: 3 – Moderately Unsatisfactory

Several objectives established in ProDoc have been achieved, except for the targets established in Outcome 1, related to 1 million km bus operating target. It is not critical, however, considering that many hydrogen fuel cell cars and buses have proven their durability.

In fact, it seems that the indicators of the original project should be redefined to comply with the modifications carried out in the project in 2005. That could contribute to capture some of the most important achievements of this project, such as: the local engineering content; the improved design, which makes this bus the simplest vehicle in its class in terms of assembly and maintenance; and a good relationship between cost and quality of the FCBs. But those aspects were not quantitatively defined as indicators.

Research, development and innovation are difficult to assess with respect to efficiency. However, in this case the procedures established by the funding agencies were followed accurately. Generally, expenditures were made through bidding for the lowest cost, and the project went through audits of various stakeholders. In addition, as reported previously, the estimated cost for each Phase II.3 bus was similar or cheaper than other projects, at US$ 1.01 million, and calculations made at the end of the project indicate that to produce 1, 10 or 20 buses of the next generation the cost reduction was estimated at 25%, 33% and 36%, respectively, which is excellent. Based on these facts, Effectiveness & Efficiency rating would be 5.

Regarding the hydrogen refueling station, it took a long time to be deployed and commissioned. It operated up to 10 h/day consecutively, although there was no technical issue preventing it to achieve the target, which was 20 h/day. In July 2016, the storage bank A and the broken diaphragm of the hydrogen compressor were fixed, and the station was conveniently turned off. Unfortunately, no cost assessment of the hydrogen produced was informed to the evaluator.

FINEP resources transferred to UNDP were converted from real to dollar and then back to real, causing a financial loss to the project. The problem occurred due to circumstantial changes of exchange rates, difficult to predict, and the concept of the project should not be penalized for that.

The other targets were satisfactorily attended. Thus, based on all activities, Effectiveness & Efficiency rating is 4.

3.3.4. Country ownership

The Ministry of Mines and Energy (MME) is the Brazilian organ with overall responsibility for project execution. It is the representative of Brazil in IPHE, and can assist the federal government to make strategic decisions on hydrogen issues, for example, providing guidance on how to implement this renewable fuel in the Brazilian energy matrix.

The Brazilian government is sensitive to new technologies that can improve the sustainability of the transport sector. Recently the External Commerce Chamber published the Resolution CAMEX Nº 97, October 26, 2015, reducing the import tax from 35% to zero for hydrogen fuel cell electric vehicles (FCEV). For hybrid electric vehicles, the import tax was reduced to rates between 0% and 7%, depending on the energy consumption. New policies and incentives can also be published and balance the game in favor of hydrogen and fuel cells. However, it is necessary to determine what incentives are needed to promote the FCBs and propose that the local and national Governments take the necessary measures to implement them. Additionally, the good results achieved by this project may facilitate public funding agencies for science, technology and innovation to support the development of FCBs in the next phase

During the visit to FINEP for the interviews of this terminal evaluation, the matter was discussed and it seems there would be no obstacles for the agency to support a new phase of the FCB project in view of the good results obtained so far.

A proposal for a Stage III project is described in this report and may contribute to the discussion to proceed with FCB development in Brazil.

The engagement of EMTU/SP in this project was very important, and the expectations is that the enterprise will contribute with its experience in the next phase. It is worth mentioning that the company's involvement with sustainability in public transport is not limited to this project. Among other initiatives, it is responsible for the technical supervision and approval of projects related to the Sustainable Transport and Air Quality – STAQ program, an initiative of the World Bank sponsored by the GEF.

The Brazilian companies directly involved in the FCB development, including Tutto and Marcopolo, not only absorbed technology but also developed new proprietary solutions to improve the FCB design. These companies are certainly interested in establishing a new agreement between companies and institutions to participate in the next phase of the project. International companies, particularly Ballard, have an enormous contribution to make and are certainly interested in participating as well.

The support of UNDP and the GEF to a new phase of the project would help to revive the interest of all levels of the government in hydrogen technologies and could lead the country to adopt a more proactive attitude towards achieving the objectives of the UNDP/GEF for its fuel cell bus program: the sustainable commercial deployment of fuel cell buses in developing country megacities.

3.3.5. Mainstreaming

This project was designed and implemented in alignment with UNDP Country Programme strategies and GEF Operational Programme 11 on sustainable transportation. In particular, it was important to UNDP Brazil approach to promote development of new technologies for GHG emissions mitigation.

It is an extremely important initiative to promote the improvement of the urban bus fleet, replacing conventional buses for more sustainable vehicles. The use of FCB allows to significantly reduce emissions of greenhouse gases, air pollutants and noise, contributing to improving the environment and public health.

Vehicle emissions also promote acid rain, which in addition to causing respiratory problems to humans and animals, causes damage to the leaves of the trees, reduces soil fertility and degrades vegetation cover, which ultimately compromises soil stability. In fact, landslide is becoming common events in urban areas of important Brazilian cities, as well as in other countries, and vehicle emissions may be contributing to aggravate the consequences.

This project is in line with other initiatives aimed at sustainability in urban public transport at federal, state and municipal levels. In particular, it is aligned with the goals, initiatives and projects undertaken by EMTU/SP to improve public transport in the State of São Paulo, and Metra, the concessionary company that operates the bus lines in the metropolitan corridor of São Paulo city and other cities of the metropolitan area.

The educational aspect of the project is very important and it should be properly exploited in order to increase knowledge and awareness of the public about the different modes of transport of passengers in large cities. Interesting points to note are the advantages of large mass transport vehicles compared to private cars, and the benefits of zero-emission vehicles (such as FCB) compared to conventional diesel buses in terms of the environment and public health.

Regarding social-economic aspects, the new technologies associated with the FCB can also help to increase the technical capacity and training of the public transport sector workers, with job creation and better income.

3.3.6. Sustainability (*) Rating: 3 – Moderately Likely

i) Financial risks Rating: 3 – Moderately Likely

From a financial point of view, the operation of FCBs could continue normally, since the preliminary assessment carried out by Tutto company, at the evaluator’s request, indicated that the revenue earned by FCBs in regular service could be sufficient to pay the operating costs (to Metra concessionaire) and the maintenance costs (to Tutto company). It was also found during the interviews that there is a stock of spare parts for maintenance. In addition, it was found in this project that the FCBs maintenance costs were lower compared to diesel buses, although the data have not been disclosed by the company up to the moment.

With regard to operating and maintenance costs of the hydrogen refueling station, it was found that there is a stock of spare parts for the station, and that the electricity consumed is paid by the *Secretaria dos Transportes Metropolitanos do Estado de São Paulo* (STM), in the same way it is done for trolleybuses. These two factors greatly reduce the cost of hydrogen production. Other expenses that contribute to the cost of hydrogen are remuneration of operators, which has so far been supported by Petrobras, and of maintenance services, so far paid by the project and carried out by Hydrogenics.

In summary, although it is necessary to conduct more in-depth financial evaluation of both, the FCBs and hydrogen refueling station, and compare them with the figures for conventional diesel buses, apparently, the operation of FCBs can be performed profitably, since the capital costs of buses and the station were paid by the project and therefore will represent no cost on the cash flow of future activities.

ii) Socio-economic risks Rating: 4 – Likely

Mass transit is a critical element of the urban infrastructure in Brazil. The project reviewed here 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 São Paulo. The planned expansion of dedicated bus corridors and bus rapid transit systems presents an ideal context for deployment of FCB fleets. [BRA-99-G32 MTE by E Larson FINAL 18Jan2014, without Annex 3].

In spite of the interest to continue project's benefits after termination, it would require a long-term commitment from involved stakeholders for the implementation of a new phase of the Project (please refer to items 4.3.1 and 4.3.2 for specific suggestions). This would require the construction of a follow-up project with new institutional arrangements and financing, which would pervade federal and local governments for years. To the date, negotiations are still underway.

It would be very important that UNDP and GEF have a dialogue with all stakeholders and the Brazilian government at federal, state and municipal levels, to emphasize that they have high expectations about the next phase of the project. It would be also very important to contribute to the new institutional arrangement and the consortium creation. After all, the financial resources invested by GEF were significant and the preliminary feasibility study for the new phase has shown encouraging results. Missing the next phase means wasting a great opportunity to advance the development of FCBs.

iii) Institutional framework and governance risks Rating: 3 – Moderately Likely

The good results achieved, the operational experience gained, the technological improvements and the mature relationship among stakeholders offer good prospects for a new phase of the project to succeed, probably based on an improved institutional arrangement.

According to ProDoc, the buses and the hydrogen refueling station will be donated to EMTU/SP at the end of the project. The enterprise presents the necessary expertise to continue the operation of the buses and the station, with support of Tutto, Marcopolo, Metra, Hydrogenics, local suppliers and other stakeholders. While it is necessary to provide human and financial resources for the activities to be undertaken, understandings have been initiated among stakeholders to continue.

Many legal and institutional challenges have occurred during this project and the team worked well to find appropriate solutions in all cases. This indicates a high probability of success in creating a new and efficient institutional arrangement, with the necessary and sufficient experience to achieve the objectives of a possible next phase.

iv) Environmental risks Rating: 4 - Likely

Currently, there are no ongoing activities that may pose an environmental threat to the sustainability of project outcomes.

3.3.7 Catalytic role

There is no doubt that this project has a catalytic role that needs to be properly harnessed. According to the interviews, the scaling up or replication of this project in the country and abroad is intended for companies involved in the FCB development and also by some stakeholders. This will require knowledge transfer, dissemination of lessons learned, training workshops, and information exchange. Discussing the next phase of the project can be a good opportunity to define strategies and planning to achieve these intents.

Section 4.3 presents proposals for future directions that take into account the catalytic role of this project.

3.3.7. Impact

Although it is increasingly relevant to discuss the extent to which the projects are achieving impacts, it is necessary to consider that some important changes were made to the original project, reducing the number of FCBs built, as explained in section 3.2.1. Consequently, expected impacts, such as reducing carbon dioxide emissions and other outputs related to the distance traveled by vehicles, were not achieved.

This project was a success from the engineering point of view, as shown in the section 3.3.1, the reference provided in the section 5.5.5, a video reporting a spontaneous testimony of a Ballard engineer who worked on this project and other important FCB projects around the world. It can be said that an important step was taken in order to enable the use of FCBs and the construction of zero-emission bus fleets, in accordance with the objectives of UNDP/GEF for its hydrogen FCB program.

Therefore, this project is a very important intermediate step that can facilitate the achievement of significant outputs related to Outcome 1, since more FCB are incorporated into the fleet through future projects or replication of this work.

4. Conclusions, Recommendations & Lessons

<u>Conclusions</u>

Effectiveness

1) The project demonstrated that the Fuel Cell Bus operation is technically viable and the vehicles can be fully integrated to commercial bus lines using a variety of energy sources, such as diesel and electricity (trolleybus). From the engineering point of view the project was successfully completed. Four fuel cell buses have been successfully built and operated in the metropolitan corridor with passengers on board, which is a major challenge in terms of technology, legislation and passenger safety. Although the sum of the distances covered by the buses (20,520 km) has been considerably lower than the target (1 million km), this was due to delays in the completion of the construction of buses and the hydrogen station, and not because of technical reasons.

2) The bus version developed in Phase II. 3 can be considered as the state-of-the-art of hydrogen fuel cells buses in the world, even though this bus design (drawings, specifications, equipment selection) was made in 2013. The buses are advanced prototypes, but several improvements were required during the tests of Phase II.3. The

development and tests of one or two additional fuel cell bus prototypes would be necessary to achieve the commercial stage from a technical point of view. Complementary assessments of capital and operating costs for buses and hydrogen supply is also required before beginning the commercial production of the fuel cell buses.

3) With the experience gained in this project, it would be possible to develop a new bus design with significantly better characteristics, such as body, chassis, other items already mentioned above, energy efficiency and cost. Therefore, the continuation of hydrogen bus projects in the country is highly recommended.

4) The project enabled not only the transfer of technology between companies from different countries, but also technological development and innovation. Some remarkable examples are: i) the control and monitoring software; ii) the electric motor and inverter, made of aluminum and water cooled, and their latest versions have compliance with automotive use; iii) better management of the state of charge of batteries; iv) several improvements in the bus body to allow better cooling of the batteries and components without water infiltration; v) improved internal design to facilitate the flow of passengers.

Relevance

5) The project is relevant for Brazil and for Fuel Cell Bus development in general. There is a certain demand for FCB in the world, still small, but growing, as several countries have shown interest in experimenting with the technology without having to make all the necessary investments in time, money and human resources to come up with a good design. Brazil has the necessary and sufficient conditions to succeed in this market, since it is one of the world's major bus suppliers, and has a well-prepared industry to offer products with excellent quality at a reasonable cost.

Project design

6) Statistical analysis methods, such as Failure Mode Analysis (FMA) and Mean Time Between Failures (MTBF), mentioned in ProDoc, are appropriate tools to evaluate the performance of projects in the automotive sector. But they are not as useful for evaluating basic technological development projects, as in this case. As an alternative, evaluation of project results can always be done through the opinion of experts or peer review. It is important to be careful when establishing objectives and targets for a basic technology development project. In case of doubt, independent experts should be consulted in advance to validate the objectives and targets. Extensive testing may require specific infrastructure and must be carried out at a later stage of technological development.

7) The design, targets and throughput time for the Fuel Cell Bus project were overly optimistic. In the early 2000s, there was a great enthusiasm for fuel cells, both in academia and industry around the world, and the period was marked by the emergence of new companies, joint ventures and much propaganda. By the same reasons, the schedule can be considered tight, 3 buses built in the first year and 5 buses in the second year. Therefore, other established indicators were also high, as for example: the decrease of 1,560 tons of CO2 emissions during the project's life-time; 50,000 km between breakdowns; training of 430 drivers, 126 mechanics, and 12 specialized electronics technicians.

8) A risk not anticipated by the project team concerns the hydrogen supply and how it could affect the FCB development and tests. In fact, the refueling station took a long time to operate and this has negatively impacted the project schedule and results. The ProDoc includes a discussion about hydrogen shortage, but more attention should be given to the deployment of the station, and perhaps a gas company or a local technical support might be involved in the partnership or contracted in order to mitigate risks.

9) The proposal for Phase III was not eliminated during the substantive revision, but was canceled as explained in the item 3.2.1 iii), p. 26. The main document was not corrected as suggested because of the short time available.

Sustainability

10) Regarding the hydrogen supply, it is necessary to establish an agreement or contract with a gas company for backup. If consumption increases, it will be necessary to decide between buying a new electrolyzer or hiring a hydrogen supplier. As a starting point, large regular hydrogen customers can benefit from lower prices. In addition, this project presents an important marketing appeal, which must be properly negotiated with the gas companies.

11) The buses developed in the Phase II.3 had more significant components produced locally. It demonstrated the consortium's ability to develop local suppliers, enabling better sustainability, lower costs and shorter time to obtain spare parts, since the import process is bureaucratic and costly in Brazil.

12) To avoid interruption of project activities after its official closure, it is necessary to start negotiations between partners and to plan the continuation well in advance. To the date, negotiations are still underway. In spite of the interest to continue project's benefits after termination, it would require a long-term commitment from involved stakeholders for the implementation of a new phase of the Project.[2] This would require the construction of a follow-up project with new institutional arrangements and financing, which would pervade federal and local governments for years.

Project implementation and management

13) Key points to the success of the Brazilian Fuel Cell Bus project were the strong institutional arrangement and the persistent commitment of all stakeholders of the public and private sectors in order to ensure proper operation and maintenance of the buses, safety, supply of hydrogen, support in administrative issues, and public education activities. Even though the design of a new phase was envisaged, this could not be accomplished during project implementation.

14) The process of importing spare parts, components and equipment caused some delays. Although the overall delay was of a few months, the problem was very inconvenient, interrupting ongoing activities and increasing costs. Other delays were related to malfunctions of components that had to be replaced or repaired. However, administrative and financial issues, for example, had a greater influence. The project team matured during the execution of Phase II.2 (first prototype, with more imported components) and proposed to build a new bus model with greater national content in Phase II.3 (three buses). But they probably did not evaluate all the difficulties that would occur or the time required to develop a new bus design, to develop local suppliers, and the time required for tests, repair and replacement of new components.

15) Failures in infrastructure can contribute to reducing the efficiency and safety of experimental activities, although no issues related to the transport service delivered to customers were identified. Project design should preview the complementary infrastructure necessary for maintenance during project execution.

[2] Please refer to items 4.3.1 and 4.3.2 in the main text for specific suggestions.

Knowledge management

16) Much knowledge was generated during the planning and execution of this project, related to the bus and the hydrogen station. This knowledge covers several areas (legislation, management, finance, engineering) and is distributed among many participants, including stakeholders, consortium members, government agencies, and suppliers. There is a real opportunity for this technology to be used commercially in the near future, since the research, development and innovation are permanent and do not terminate with this project.

17) The project team should interact more frequently with other teams around the world, including managers and technical staff. In addition, it would be beneficial for some partners to participate in specific technical events to better understand the challenges, pros and cons of the fuel cell buses and hydrogen technologies. There are several projects, programs and interventions within the sector in the world, and the project team (or stakeholders) should be updated on these initiatives in order to compare results, exchange information, and take advantage of the opportunities of cooperation and training. Probably, the establishment of a council with the participation of specialists could contribute with information, new ideas and orientations.

Recommendations

1) It is recommended keeping the three buses developed in Phase II. 3 in operation because it can bring additional knowledge to increase performance, reduce hydrogen consumption, and improve operation and maintenance. This would also attract the public attention needed to develop educational projects for sustainability, environment and public health.

2) The hydrogen refueling station can support three buses in operation as planned. However, if beyond this project there is an intention to increase the hydrogen fuel cell bus fleet, it is recommended to carry out an assessment of the cost of hydrogen considering the expansion of the station, and compare it with the market price.

3) A lightning system is usually present in flammable gas facilities, and an adequate technical evaluation of the hydrogen station is recommended with respect to this item.

4) Partners interested in producing fuel cell buses should negotiate and develop a business plan. It is necessary to select the institutions, agencies and private companies in Brazil and abroad which can contribute for RD&I projects, as well as to the production of commercial fuel cell buses.

5) Item “5.3 Formulate Brazilian standards for hydrogen fuel cell buses for urban transport” should be treated opportunely as a separate project, because it requires a specific team of specialists, appropriate financial resources and time frame. There are institutions in Brazil responsible for the development of Regulation, Codes and Standards, such as ABNT and INMETRO. Brazil is also signatory of ISO and IEC.

6) It is important to correctly classify the knowledge generated in this project, according to the guidance of GEF, the main funder. In general, there is information that can be shared with other groups and countries interested in developing fuel cell buses. But there is also confidential information belonging to suppliers, stakeholders or partners.

7) The knowledge generated in this project should be incorporated into a next generation bus design, making those vehicles closer to the commercialization stage from a technical point of view. This recommendation is supported by the fact that several small

improvements were made in the buses during the tests of Phase II.3, and by the testimony of important stakeholders collected during the interviews for this TE.

Lessons learned

1) In 2011, an inconsistency between the MME/FINEP agreement and the ProDoc regarding the administrative fee of co-financing resources was detected leading to a joint search for a legal solution to the problem. In future projects involving financial support from FINEP, UNDP must negotiate terms and conditions in advance directly with the agency, even if there is an intermediary partner. FINEP's technical analysts can provide good advice on how to proceed to avoid problems

2) During the planning phase, projects involving technological development require special attention to the current state of the technologies to be employed. In this project, some of the technologies, such as the fuel cells and hybrid control, were not developed as expected.

3) Projects and collaboration arrangements should bring a benefit to the partners, hence their position should be properly understood at project design stage. At first sight, there was no guarantee that they would get financial or technological advantages at the end of the project, so it took some time for the most interesting companies to be attracted to the project, to talk to each other and to understand that participation would be beneficial for all parties

4) Ideally, the objectives and the M&E indicators established at the beginning of a project should remain unchanged until its completion. However, if the project is submitted to a substantive revision, it is recommended that all objectives and indicators are reevaluated by all partners (Executing, Implementing and Funding Agencies). Regarding this project, although the 2005 Substantive Revision H, was submitted to all partners, the indicators were not updated to reflect the important changes made in the project.

5) Experimental Projects may require additional infrastructure, such as: a warehouse for electrical and mechanical components; a machine shop; a suitable location for storage and disposal of waste; and a lightning protection system. These items should be included in the initial planning. Regarding this FCB project, these items were not considered, bringing some difficulties with the maintenance activities of the hydrogen station.

6) The risks related to delays in the import, replacement and repair of components and equipment should never be underestimated at project design, because they have great impact on project implementation.

7) With respect to externalities, even though problems are expected to import goods and to obtain work visas in a project involving international participation, no risks were attributed to those activities. Special attention to these points might have contributed to reducing their consequences.

4.1. Corrective actions for the design, implementation, monitoring and evaluation of the project

4.1.1. Simpler institutional arrangements would be desirable for future projects, allowing the whole process to run faster, as decision-making, accountability, payments, purchases of goods and services, and import.

4.1.2. With respect to other sponsors except for GEF and UNDP, preferably the funds should go from the sponsor to the implementing partner without intermediation, in order to simplify procedures and accountability.

4.1.3. It is necessary to use tools that allow greater flexibility in purchasing materials and services, but still maintaining the audit of spending within the expectations of funding agencies. In Brazil, some difficulties with the legislation can be circumvented by a strong technical justification, allowing the purchase of products and services that are best suited to the project and not necessarily the least expensive.

4.1.4. In general, the objectives and the M&E indicators established at the beginning of the project should remain unchanged until its conclusion. However, if the project is submitted to a substantive revision before the experimental phase begins, it is recommended that the objectives and indicators are reevaluated by all partners (Executing, Implementing and Funding Agencies). Regarding this project, the indicators should have been updated during the Substantive Revision H, conducted in 2005.

4.2. Actions to follow up or reinforce initial benefits from the project

Keeping the three buses developed in Phase II. 3 in operation can bring additional knowledge to increase performance, reduce hydrogen consumption, and improve operation and maintenance. This would also attract the public attention needed in order to develop educational projects for sustainability, environment and public health. However, with the experience gained in this project, it would be possible to develop a new bus design with significantly better characteristics, such as body, chassis, control and monitoring software, communication between electric components, electric motor and inverter, internal design to facilitate passenger flow, energy efficiency and cost.

4.3. Proposals for future directions underlining main objectives

There is a real opportunity for this technology to be used commercially in a close future, since the research, development and innovation are permanent and do not terminate with this project. There is a certain demand for FCB in the world, still small, but growing, as several countries have shown interest in experimenting with the technology without having to make all the necessary investments in time, money and human resources to come up with a good design. Brazil has the necessary and sufficient conditions to succeed in this market, since it is one of the world's major bus suppliers, and has a well-prepared industry to offer products with excellent quality at a reasonable cost.

The project demonstrated that the FCB operation is technically viable and can be fully integrated to commercial bus lines with different technologies, such as diesel and trolleybus. The project enabled not only the transfer of technology between companies from different countries, but also technological development and innovation. Some remarkable examples are: i) the control and monitoring software; ii) the electric motor and inverter, made of aluminum and water cooled, and their latest versions have compliance with automotive use; iii) better management of the state of charge of batteries; iv) several improvements in the bus body to allow better cooling of the batteries and components without water infiltration; v) improved internal design to facilitate the flow of passengers.

A larger national content on buses developed in Phase II. 3 demonstrated the consortium's ability to develop local suppliers, enabling better sustainability, lower costs and shorter time to obtain spare parts, since the import process is bureaucratic and costly in Brazil.

Keeping the three buses developed in Phase II. 3 in operation can bring additional knowledge to increase performance, reduce hydrogen consumption, and improve operation and maintenance. This would also attract the public attention needed in order to develop educational projects for sustainability, environment and public health.

With the experience gained in this project, it would be possible to develop a new bus design with significantly better characteristics, such as body, chassis, control and monitoring software, communication between electronic components, electric motor and inverter, internal design to facilitate passenger flow, energy efficiency and cost.

The hydrogen refueling station and the metropolitan corridor constitute an extraordinary laboratory infrastructure to continue this very important experiment.

At the end of this work, after talking with the stakeholders and almost all members of the consortium, it can be said that some respondents are very interested in continuing the project, although many questions remained about its operation, stakeholder's involvement, consortium composition and funding. Based on the positive results of the project and the experience of the evaluator in hydrogen and fuel cell projects, two proposals to continue the Brazilian FCB project are presented. The ideas are given on a voluntary basis under the sole responsibility of the evaluator, and aim to contribute to the design of an eventual next phase of the project.

4.3.1. Suggestion #1: To continue operation of the FCBs and development of new FCB designs.

The main idea is to use all the infrastructure, the management experience and the links already established between stakeholders and members of the consortium to form a new project team with the ability to drive the next phase of the Brazilian FCB project focused on well-established goals, and with an emphasis on achieving the GEF objectives in its FCB program.

- Objectives:

  i) To keep the hydrogen refueling station and three buses in operation in order to get technical and economic data to enable better assessment of FCBs produced in this project, and provide new ideas for bus design improvement.

  ii) To maintain training of human resources for the development and operation of the FCBs and the operation of the hydrogen refueling station.

  iii) To maintain research and development on FCBs, elaborating new designs from the knowledge gained in this project.

  iv) To build a new FCB fleet to operate regularly in the metropolitan corridor of São Paulo. As a starting point, it is proposed to build two buses per year for five years, totaling 10 FCBs. This strategy would give the opportunity to make small improvements in bus design every year, if necessary. In the interviews, EMTU mentioned that it would be reasonable to have a fleet of 20 FCBs operating in the metropolitan corridor in the next phase.

  v) To evaluate the cost of hydrogen produced at the refueling station, and compare it with the market price, in order to define the best strategy for the supply and back-up of hydrogen to the FCB fleet.

  vi) To carry out technical and financial assessments of FCB fleet and compare to other fleets developed in the world.

- Complementary objectives to be developed through partnerships with Institutions of Science, Technology and Innovation (ICT in Portuguese):

  vii) To develop educational projects on public transportation, with a focus on sustainability, the environment and public health.

  viii) To develop scientific and technological studies based on FCB operational data, comparing the results obtained with other technologies, such as buses running on diesel, natural gas and ethanol, and trolleybuses. Some aspects of interest are: energy efficiency, greenhouse gas emissions, impacts to the environment and public health.

- Possible sources of funding: GEF, FINEP, EMTU
- Estimated value of the project: US$ 8.5 million
- Accumulated distance by 10 FCBs: 1.0 million km
- Carbon dioxide avoided emissions: 1.1 million t.

4.3.2. Suggestion #2: To continue operation of the FCBs or replicate in other location.

If the operation of the hydrogen refueling station and the fleet of FCBs cannot continue in the Metropolitan corridor of São Paulo, one should take into account the possibility of transferring or replicating the project in another region.

For the FCB project to be able to operate satisfactorily, the following key conditions need to be fulfilled promptly: i) a city or location that has a path with adequate infrastructure for the FCB circulation; ii) a medium or large-sized company with an interest in hydrogen technologies, which can receive and operate the hydrogen refueling station and all the infrastructure to house and maintain the FCBs; iii) sufficient funding; iv) a consortium of companies for the development, operation and maintenance of FCBs.

Of course, other prerequisites may be required for the success of the initiative, such as the involvement of the local and state governments, and the support of organized sectors of society.

A promising alternative that apparently meets the conditions is the city of Foz do Iguaçu and the company Itaipu Binacional (IB), which has a close relationship with the Itaipu Technological Park (PTI, in Portuguese).

The city of Foz do Iguaçu has about 264,000 inhabitants and is among the five most visited tourist destinations in Brazil, probably ranking third. It is located in the state of Paraná, in the tri-border region between Argentina, Brazil and Paraguay, which receives more than five million tourists a year. The main tourist attraction of the region is the Iguaçu National Park, where the Iguaçu Falls are located, which receives about 2.5 million tourists a year on both sides, Brazil and Argentina.

Another attraction is the IB located on the Paraná River, between Brazil and Paraguay, and belonging to both countries. This plant is a monumental work of engineering and technology, and the worldwide leader in generating hydroelectricity, with 20 generating units and 14,000 MW of installed power, providing about 15% of the electricity consumed in Brazil and 75% in Paraguay. Between 2009 and 2015, it produced an average of 92,000 GWh per year of electricity. Between the years 2012 and 2015 there was a significant increase in the number of visitors, reaching an annual average of 885,000.

The Itaipu Technological Park Foundation (FPTI) manages the Itaipu Technological Park (PTI), which presents a multidisciplinary character and an important local and regional actuation. PTI comprises three higher education institutions, research units and a start-up business incubator.

The IB has great interest in hydrogen technologies because in some periods of the year there is a huge availability of surplus energy that could be transformed into hydrogen, which would be stored and then reused. The company and the PTI have invested in the training of human resources and many scientific papers and master's and doctoral theses have been produced on the subject.

Since 2014, Itaipu Binacional, Eletrobras and Itaipu Technological Park Foundation have a hydrogen pilot plant consisted of 0.9 kg/h alkaline water electrolyzer and a 6 kW PEM fuel cell. This pilot plant is part of a R&D project to study the production of hydrogen, gas purification, compression, storage, transport and the reconversion to electricity. The results of this study aim to identify the hydrogen production feasibility near hydroelectric power plants, obtaining practical technical data to be used in future projects supported by Eletrobras.

The PTI is also involved in research and development activities well related to the FCB project, such as the Project of Advanced Sodium Battery Technology Development, and the Intelligent Electric Mobility Center.

Regarding the FCB project, so far, only an informal contact was made between the evaluator and one of his contacts in IB, and the idea had great receptivity. The conditions for the implementation of a FCB project in the region look excellent and would bring great impact, helping the continuity of Brazilian FCB project and the achievement of GEF objectives in its FCB program.

4.4. Best and worst practices in addressing issues relating to relevance, performance and success

Relevance and success are the strengths of this project, which showed high degrees of difficulty in technological, legal, institutional and management aspects. It was a tremendous challenge to put an experimental vehicle, based on a new technology and with hydrogen as the energy source, in regular service in the public transport system of a city like São Paulo. To accomplish this, the processes adopted to form the institutional arrangement and to set up the consortium of private companies were fundamental to enable the implementation and completion of the project successfully.

Regarding performance, the main difficulties were related to the deployment of the hydrogen station, which is a commercial equipment, although technologically advanced. Some specific features of the country may have contributed to this, but it is very important to pay attention to the following aspects in order to avoid significant delays in the schedule: obtaining work visas for foreigners; purchase of chemicals that can be controlled sale; difficulties with the import of spare parts; and obtaining appropriate local support.

Regarding the financial aspects, the following points deserve attention: to ensure that financial resources are available in time; to have a little more flexibility for the payment of suppliers; and to transfer funds directly to the implementing partner, whenever possible.

5. Annexes

5.1. ToR

ToR is provided as a separate document.

5.2. Itinerary

Table 11: Itinerary of Meetings		
DATE	CITY	LOCAL/PERSONNEL
March 16th 2016	Brasilia – DF	UNDP/CO: Rose Diegues, Luana Lopes MME: Symone Christine Araújo, Aldo Cores, Fernando Matsumoto ABC: Alessandra Ambrósio, Tania Jardim
March 21th 2016	São Bernardo do Campo – SP	EMTU, bus operation center, hydrogen refueling station, and metropolitan corridor EMTU: Alysson Bernabel TUTTO: Vinícius Padilha PETROBRAS: Marco Anjos, Fábio METRA: Dimas (FCB driver)
March 22th 2016	São Paulo – SP	EMTU headquarters: Ivan Regina, Marcos Lopes, Alysson Bernabel
March 29th 2016	São Bernardo do Campo – SP	EMTU; last session of PSC meeting
April 07th 2016	Rio de Janeiro – RJ	FINEP: Laercio de Sequeira, Roberto Neves, Victor Odorcyk

5.3. List of persons interviewed

Table 12: List of persons interviewed, locations and forms of communication					
#	STAKEHOLDER	CONTACT NAME	MEETING DATE/LOCATION	POSITION	Phone Skype E-Mail Meeting
1	EPRI International Inc.	Monica Panik	29/Mar/2016: PSC meeting at SBCampo. Various contacts	Project Manager for the Consortium	S/E/M
2	UNDP / CO Brazil	Rose Diegues	16/Mar/2016: UNDP, Brasília 29/Mar/2016: SBCampo Various contacts	Programme Analyst and GEF Advisor	P/S/E/M
		Luana Lopes	16/Mar/2016: UNDP, Brasília 29/Mar/2016: SBCampo, Consortium Meeting at SBCampo	Programme Analyst	P/E/M

	UNDP	Oliver Page	15/Mar/2016	Regional Technical Advisor	S
3	Brazilian Cooperation Agency (ABC)	Alessandra Ambrosio	16/Mar/2016: ABC, Brasília	ABC	M
		Tânia Jardim			
4	Ministry of Mines and Energy (MME)	Symone Araújo	16/Mar/2016: MME, Brasília	Director of the Natural Gas Department	M
		Aldo Barroso		General Coordinator for Processing, Infrastructure and Logistics	
		Fernando Matsumoto	16/Mar/2016: MME, Brasília 19/Apr/2016: P	Project Manager	M P
5	São Paulo Urban Transportation Metropolitan Enterprise (EMTU/SP)	Ivan Regina	22/Mar/2016: São Paulo 29/Mar/2016: SBCampo	Developing Manager	M
		Marcos Lopes		Department Chief	P/E/M
		Alysson Bernabel	21/Mar/2016: SBCampo 22/Mar/2016: São Paulo 29/Mar/2016: SBCampo	Project Analyst	M
6	Projects and Studies Financing Agency (FINEP)	Roberto Neves	07/Apr/16: FINEP, Rio de Janeiro	Project Analyst	E/M
		Laércio Sequeira		Technical Secretary	
		Felipe Gelelete	N.A.		N.A.
		Joanna Bastos	15/Apr/16	Analyst, Accounting Department (DPC)	E
7	Ballard Power Systems Inc.	Silvano Pozzi	05/Apr/16	Director of After Sales Support	S
8	Marcopolo S.A.	Leandro Sodré	29/Mar/2016: SBCampo	Consultant for Business Operations	M
9	BR Petrobras Distribuidora S.A.	Paulo Cesar Ribeiro			N
		André Queiroz	29/Mar/2016: SBCampo		M
		Marco Antonio Anjos	21/Mar/2016: SBCampo 29/Mar/2016: SBCampo	Hydrogen Station Operator	M
		Fábio	21/Mar/2016: SBCampo	Hydrogen Station Operator	V
10	Hydrogenics Corporation	Salim Pirani	N.A.		

11	Tutto Indústria de Veículos e Implementos Rodoviários Ltda.	Eduardo Silva	29/Mar/2016: SBCampo	Owner Partner	E/M
		Vinícius Padilha	21/Mar/2016: SBCampo 29/Mar/2016: SBCampo	Full Electronic Technician	M
		Sidney Gonçalves	11/Apr/2016	Project Manager	S/P

Legend of Locations:

Abbreviation	Location	Address
SBCampo	EMTU/SP Office; bus operation; hydrogen refueling station	Rua Joaquim Casemiro, 290 - Bairro Planalto São Bernardo do Campo, SP, 09890-050
São Paulo	EMTU/SP Headquarters	Rua Quinze de Novembro, 244 - 5º andar - Centro São Paulo, SP
FINEP, Rio de Janeiro	FINEP Headquarters	Avenida Chile, nº 330 - 15º andar Rio de Janeiro, RJ
UNDP, Brasilia	UNDP/CO Headquarters	Setor de Embaixadas Norte – Q 802, Conj. C, L 17, Brasília, DF
MME, Brasilia	MME Office	Esplanada dos Ministérios – Bloco U, Sala 940 Brasília, DF

Legend of the forms of Communication:

N.A.	Not Available
P / S / E / M	Phone / Skype /E-Mail /Meeting

5.4. Summary of field visits

The visits listed in were all very productive and with sufficient time to clarify any doubts. The atmosphere of the interviews was always very welcoming and all issues were addressed directly and with great transparency by the participants. All respondents made themselves available for additional information by email, phone calls or Skype, which was made when necessary, as indicated in . Comments on the issues addressed in the interviews appear throughout this report, and it is not necessary to reproduce them in this section.

Only the visit to EMTU/SP, held on March 21st, 2016, deserves additional comments. The city of São Bernardo do Campo is the location of the operational base of the FCBs, the hydrogen refueling station and the metropolitan corridor, where the following activities were carried out:

i) Interview with technical staff responsible for implementing the project, the operation of the hydrogen refueling station and maintenance of buses. Participants: Alysson Bernabel, EMTU/SP; Vinícius Padilha, Tutto; Marco Antonio Anjos and Fabio, Petrobras. At the meeting the participants had the opportunity to make comments about the technical difficulties that had to be overcome in developing the project. Apparently, some technical activities were hampered due to administrative issues, such as import and purchase of goods and services, and difficulties with suppliers, resulting in schedule delays. As far as possible, the recommendation is that the technical team should be less involved with administrative issues in order to have more time for technical activities.

ii) Visit to the hydrogen generation plant. It can be said that the facilities are of high technical level, including the container, the design of electrical and hydraulic circuits, water electrolyzers, peripherals, and instrumentation. The container is well organized and apparently has all the necessary and sufficient items for safe operation of the hydrogen generation plant. As a suggestion, one should provide the installation with, or improve, some external items, such as: warehouse for electrical and mechanical components; a small machine shop; straps or chains to properly secure nitrogen gas cylinders outside the container; proper storage and disposal of waste. One should also verify the need to install a lightning protection system. The monitoring software installed by Hydrogenics greatly facilitated the operation of the hydrogen generation plant, and should have been used since the start of operations. It is recommended that the hydrogen generation plant operates for long periods, at least several hours, rather than intermittently.

iii) Testing the bus in the metropolitan corridor .
After visiting the hydrogen generation plant, the group boarded the FCB #4020 to travel through the metropolitan corridor. This bus is beautifully painted in orange and brown colors, and was conducted by one of the professional FCB drivers, Mr. Dimas. The bus has a great interior trim and does not look like an experimental vehicle. Unfortunately, inside the bus there is no indication that it runs on hydrogen and fuel cells, neither that it is zero-emission vehicle. The ride took 15 minutes and went perfectly, with the bus having a great performance, even with the air conditioning turned on all the time. As indicated in technical reports of the vehicle operational tests, two non-conformities were observed during the tour: one of the doors did not close properly and the bus had to be restarted once. Along the way, we crossed with other diesel buses and trolleybuses that also operate in the corridor. The FCB is much quieter than a conventional diesel vehicle, and according to the comments of the technical staff this characteristic makes some of the body noises noticeable, which can be fixed in an upcoming version. Anyway, the acoustic comfort is appreciated by the regular passengers. Although the running test was short, it was very gratifying to see the FCB operating normally on a commercial bus route.

iv) Refueling the FCB with hydrogen.
Soon after the tour, it was carried out a complete refueling of the FCB # 4022, green and yellow colors, with hydrogen. The operation is very simple and safe. After connecting grounding to the bus and dispenser, the nozzle is connected to the bus tank, and the “Start” button is pressed in the dispenser. The equipment automatically performs all the necessary leak testing and start the supply of hydrogen without the need for human intervention. The complete refueling process took about 18 min to transfer 14.0 kg of hydrogen to the bus. It was very gratifying that the refueling worked perfectly and that the procedure was executed easily and safely.

5.5. List of documents reviewed (listed by Corporation – Agent)

5.5.1. UNDP – Rose Diegues, Luana Lopes, Monica Azar

- ProDoc

- ToR Final Evaluation BRA99G32 December 2015
- PIR-2015-GEFID6-PIMS543
- Minutes Steering Committee: March 29th, 2011; February 16th, 2012; August 7th, 2012; August 29th, 2012; April 4th, 2013.
- BRA99G32 Revisão Substantiva ass junho 2015, (Substantive Revision, June 2015)
- Substantive Revision H, December 2005, (RevisaoH_ProDoc)
- GEFTE Guide ENG, Evaluation Office, 2012, United Nations Development Programme
- BRA-99-G32 MTE by E Larson FINAL 18Jan2014, without Annex 3

5.5.2. EPRI – Monica Panik

- UNDP Consortium Agreement - FINAL Version 06-06-05
- Cost reduction - Project contributions of each company for the Phase II 3 Nov 2010
- SAT Report July 24th,2015
- Co-financing of the Project by the Consortium Members
- Minutes Steering Committee, March 29th, 2016
- Project Story and Timeline Updated March 2016
- *Diario de Bordo* (logbook with the operational data of the three buses from January to March 2016)

5.5.3. EMTU – Marcos Lopes

- Proj PNUD BRA_99_G32; Projeto PNUD BRA/99/G32 – Ônibus a célula a combustível hidrogênio para transporte urbano no Brasil. Presentation with 32 slides. Received on March 23rd, 2016.

5.5.4. Ministry of Mines and Energy – Fernando Matsumoto

- Nota Técnica Nº7/2015-DGN/SPG-MME. Fernando Massaharu Matsumoto, Project Manager, Ministry of Mines and Energy, 69 pages, April 14th, 2015.

5.5.5. TUTTO – Eduardo Silva, Sidney Gonçalves

- Private communication with Eduardo Silva by e-mails, about cost assessment and FCB technical information, from March 30th to April 08th, 2016.
- Sidney Gonçalves and Ferdinand Panik. Technical Report "Verification Tests Report First Bus (Milestone P9)", March 30th, 2016, 11 pages. Received on April 12th, 2016.
- Video with technical comments about the Brazilian Fuel Cell Bus project, provided by Byron Somerville, the Customer Service Manager at Ballard Power Systems, who was involved in the project and other important FCB projects around the world. Available

at: https://www.youtube.com/watch?v=HuGPVtiKYKA. Published on August 18th, 2014.

5.5.6. BALLARD – Silvano Pozzi

- Roland Berger GmbH, "FCH JU – Commercialization Strategy for Fuel Cell Electric Buses in Europe", June 05th, 2015. Presentation with 51 slides. Received on April 07th 2016.
- Table of Prices Export. Prices of Fuel Cell Buses in the world, elaborated by Ballard. Received on April 07th, 2016.
- 150602_Bus_Study_Report_Cost_Chapter_OUT.PDF. FCH JU – Commercialization Strategy for Fuel Cell Electric Buses in Europe. Received on April 07th, 2016.

5.5.7. FINEP – Joanna Bastos

- Instrução Normativa STN Nº1, art. 28, §1º. Comments: The Regulation and additional clarifications on the agreement FINEP and MME were provided by Ms. Joanna Bastos, through e-mails, from April 12th to April 18th, 2016.

5.5.8. Additional documents

- Eudi, L.; Post, M.; Jeffers, M. "Zero Emission Bay Area (ZEBA) Fuel Cell Bus Demonstration Results: Fifth Report". Technical Report NREL/TP-5400-66039. June 2016. Available at: <http://www.nrel.gov/docs/fy16osti/66039.pdf>. Received from NREL mailing list on June 30th, 2016.
- Roland Berger GmbH. "Fuel Cell Electric Buses – Potential for Sustainable Public Transport in Europe". September 2015. Available at: <http://www.fch.europa.eu/sites/default/files/150909_FINAL_Bus_Study_Report_OUT_0.PDF >. Accessed on December 28th, 2015.
- Leslie, E.; Post, M.; and Gikakis, C. "Fuel Cell Buses in U.S. Transit Fleets: Current Status 2015". Technical Report NREL/TP-5400-64974. December 2015. Available at: http://www.nrel.gov/docs/fy16osti/64974.pdf. Received from NREL mailing list on December 28th 2015.
- Melaina, M. and Penev, M. "Hydrogen Station Cost Estimates", Technical Report NREL/TP-5400-56412, September 2013. Available at: <http://www.nrel.gov/docs/fy13osti/56412.pdf>. Last access on April 20th, 2016.
- Neves, N.P.; Pinto, C.S. (2011). Licensing a fuel cell bus and a hydrogen fueling station in Brazil. International Journal of Hydrogen Energy, v. 38, p. 8215-8220, 2013.
- Tomaz, S.R; Michelino, G.G. and Neves Jr., N.P. Hydrogen Risk Assessment in São Paulo State – Brazil. In: ICHS 2011 - 4th International Conference on Hydrogen Safety, 2011, San Francisco. Proceedings of ICHS 2011 - 4th International Conference on Hydrogen Safety, 2011.
- Plano Decenal de Expansão de Energia 2023 / Ministério de Minas e Energia. Empresa de Pesquisa Energética. Brasília: MME/EPE, 2014.

5.6. Rating Scales

Ratings Scales		
Ratings for Outcomes, Effectiveness, Efficiency, M&E, I&E Execution	**Sustainability ratings:**	**Relevance ratings**
6: Highly Satisfactory (HS): The project had no shortcomings in the achievement of its objectives in terms of relevance, effectiveness, or efficiency 5: Satisfactory (S): There were only minor shortcomings 4: Moderately Satisfactory (MS):there were moderate shortcomings 3. Moderately Unsatisfactory (MU): the project had significant shortcomings 2. Unsatisfactory (U): there were major shortcomings in the achievement of project objectives in terms of relevance, effectiveness, or efficiency 1. Highly Unsatisfactory (HU): The project had severe shortcomings	4. Likely (L): negligible risks to sustainability 3. Moderately Likely (ML):moderate risks 2. Moderately Unlikely (MU): significant risks 1. Unlikely (U): severe risks	2. Relevant (R) 1.. Not relevant (NR) Impact Ratings: 3. Significant (S) 2. Minimal (M) 1. Negligible (N)
Additional ratings where relevant: Not Applicable (N/A) Unable to Assess (U/A		