Assessment and Recommendations of Policies in the Context of UNDP-GEF Fuel-Cell Bus Programme Countries

Prepared for:
The Global Environment Facility

Prepared by:
Steve Bernow
Bill Dougherty
Sivan Kartha
Nancy Odeh

Stockholm Environment Institute – Boston Center
11 Arlington St
Boston, MA 02116
USA
T: 617-266-5400

February 2002
# Table of Contents

Executive Summary ................................................................. vi

1 Introduction .................................................................................. 7

2 Policy Assessment Framework ........................................................... 8
   2.1 Preconditions for Future FCB Investments in Developing Countries .......... 10
      2.1.1 Precondition #1: Near-Competitive Cost .............................................. 11
      2.1.2 Precondition #2: Institutionalization of Demand Drivers ....................... 11
      2.1.3 Precondition #3: Indigenization of the Supply Chain ......................... 12
      2.1.4 Precondition #4: Sustainable O&M and Fuel Infrastructure .................. 13
   2.2 Policies to Support Preconditions .................................................. 13
      2.2.1 Policies to Meet Precondition #1: Near-Competitive Cost ..................... 13
      2.2.2 Policies to Meet Precondition #2: Institutionalization of Demand Drivers ...... 15
      2.2.3 Policies to Meet Precondition #3: Indigenization of the Supply Chain .......... 16
      2.2.4 Policies to Meet Precondition #4: Sustainable O&M and Fueling Infrastructure ... 17
      2.2.5 Cross-cutting policy: Stakeholders Training & Other Capacity Building Efforts ... 18

3 Country Assessment Framework .................................................... 18
   3.1 China ......................................................................................... 20
      3.1.1 Technical Capacity and Infrastructure .................................................... 20
      3.1.2 Indigenous development and manufacturing capability .......................... 21
      3.1.3 Urban Air Quality And Transport Policy Responses ............................... 21
      3.1.4 Fuel Supply and Technology .......................................................... 21
   3.2 Brazil ......................................................................................... 21
      3.2.1 Technical Capacity and Infrastructure .................................................... 22
      3.2.2 Indigenous development and manufacturing capability .......................... 22
      3.2.3 Urban air quality and transport policy responses .................................... 22
      3.2.4 Fuel Supply and Technology .......................................................... 22
   3.3 Egypt ......................................................................................... 23
      3.3.1 Technical Capacity and Infrastructure .................................................... 23
      3.3.2 Indigenous development and manufacturing capability .......................... 23
      3.3.3 Urban air quality and transport policy responses .................................... 23
      3.3.4 Fuel Supply and Technology .......................................................... 24
   3.4 India ......................................................................................... 24
      3.4.1 Technical Capacity and Infrastructure .................................................... 24
      3.4.2 Indigenous development and manufacturing capability .......................... 24
List of Tables
Table 1: Areas of O&M expertise required for FCBs
Table 2: Summary of enabling factors and characterization of information available
Table 3: R&D collaboration in China specializing in fuel cell research
Table 4: R&D organizations in India specializing in fuel cell research
Table 5: Preliminary recommendations for country-specific policy choices

List of Figures
Figure 1: FCB investment assessment framework
Figure 2: Defining “Near-Competitive”
Figure 3: An Example of a Conceptual Model of Institutionalized Demand for FCBs
## List of Acronyms

<table>
<thead>
<tr>
<th>Acronym</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>CNG</td>
<td>Compressed natural gas</td>
</tr>
<tr>
<td>CAIP</td>
<td>Cairo Air Improvement Program</td>
</tr>
<tr>
<td>CECRI</td>
<td>Central Electrochemical Research Institute</td>
</tr>
<tr>
<td>CO</td>
<td>Carbon monoxide</td>
</tr>
<tr>
<td>CO₂</td>
<td>Carbon dioxide</td>
</tr>
<tr>
<td>CPCB</td>
<td>Central Pollution Control Board</td>
</tr>
<tr>
<td>DMFC</td>
<td>Direct methanol fuel cell</td>
</tr>
<tr>
<td>EC</td>
<td>European Commission</td>
</tr>
<tr>
<td>EIAA</td>
<td>Egyptian Environmental Affairs Agency</td>
</tr>
<tr>
<td>EMTU/SP</td>
<td>Empresa Metropolitana de Transportes Urbanos de Sao Pauolo</td>
</tr>
<tr>
<td>FCB</td>
<td>Fuel cell bus</td>
</tr>
<tr>
<td>GEF</td>
<td>Global Environment Facility</td>
</tr>
<tr>
<td>GHG</td>
<td>greenhouse gas</td>
</tr>
<tr>
<td>HC</td>
<td>Hydrocarbons</td>
</tr>
<tr>
<td>IISC</td>
<td>Indian Institute of Science</td>
</tr>
<tr>
<td>ISO</td>
<td>International Standards Organization</td>
</tr>
<tr>
<td>KW</td>
<td>kilowatt</td>
</tr>
<tr>
<td>LPG</td>
<td>liquefied petroleum gas</td>
</tr>
<tr>
<td>MCFC</td>
<td>Molten carbonate fuel cell</td>
</tr>
<tr>
<td>NGO</td>
<td>Non-governmental organization</td>
</tr>
<tr>
<td>NOₓ</td>
<td>Nitrogen oxides</td>
</tr>
<tr>
<td>O&amp;M</td>
<td>Operations and maintenance</td>
</tr>
<tr>
<td>PAFC</td>
<td>Phosphoric acid fuel cell</td>
</tr>
<tr>
<td>R&amp;D</td>
<td>research and development</td>
</tr>
<tr>
<td>PEM</td>
<td>proton exchange membrane</td>
</tr>
<tr>
<td>SOFC</td>
<td>Solid oxide fuel cell</td>
</tr>
<tr>
<td>SOₓ</td>
<td>Sulfur oxides</td>
</tr>
<tr>
<td>SSTC</td>
<td>State Science and Technology Commission (China)</td>
</tr>
<tr>
<td>STE</td>
<td>Electric Transport Service</td>
</tr>
<tr>
<td>TERI</td>
<td>Tata Energy Research Institute</td>
</tr>
<tr>
<td>UNDP</td>
<td>United Nations Development Programme</td>
</tr>
<tr>
<td>WHO</td>
<td>World Health Organization</td>
</tr>
</tbody>
</table>
Executive Summary

Fuel cells represent a promising clean and efficient energy conversion technology for urban bus fleets throughout the world. Currently, UNDP/GEF-supported demonstration projects are underway in five countries: China, Brazil, Egypt, India, and Mexico. The aim is to not only deploy a small fleet of FCBs, but also to stimulate the overall market for fuel cell buses. The desired result is to yield experience in each country that will help to inform technology developers internationally, give rise to FCB-supporting infrastructure domestically, and ultimately help to build markets for FCBs globally.

At the end of the GEF project’s lifetime, it is expected that the FCB initiative will have helped to bring fuel cell buses closer to commercialization and make them more attractive to other donors, and – ultimately – to private investors. Commercialization efforts that follow the initial demonstration phase will likely still require the involvement of multilateral agencies and other donors. Such organizations will be inclined to invest in FCBs in a given country to the extent that its ambient economic, policy, technical and institutional conditions are conducive to the success of such investments.

This report presents an approach to evaluating investments in FCBs steps in a subsequent commercialization phase. We developed a policy framework to assess the country context favoring the continued support of multilateral institutions and other sources of investment in fuel cell buses. This framework consisted of identifying preconditions favorable to subsequent FCB investment, specifying FCB-supporting policies that can help to meet the particular preconditions, and identifying enabling factors in countries that can make the FCB-supporting policies feasible. These preconditions, policies, and enabling factors have strong linkages that are likely to be highly mutually reinforcing.

We also developed a country framework to begin to assess the extent to which to which the unique enabling factor context exists in each of the five Programme countries that would help to inform whether a particular policy would be suitable. Preliminary recommendations have been offered to indicate a rough sense of policy viability, and promising areas for further investigation. Ultimately, the suitability of specific policies will depend upon the economic, institutional, technical, and resource context of a given country and should be carefully supported with country-specific assessments.

In conclusion, the key to making the right policy choices today -- and thus reaping the associated local and global environmental benefits tomorrow -- will depend on a clear understanding of the range of country-specific factors that influence the suitability of particular policies. The policy assessment framework described in this paper attempts to identify some of the key issues (e.g., costs, risks, fit with local capacity, potential for market transformation) that can help guide potential investors before committing funds to future FCB projects. The preliminary recommendations presented in this paper point to promising policy directions that should be explored as experience is garnered from the FCB demonstration phase.
Introduction

This paper assesses a set of policies that can facilitate conditions in developing countries to help ensure that fuel cell bus (FCB) investments would be competitive with other measures that achieve comparable environmental benefits, and could merit the continued support of multilateral institutions and other sources of investment. The range of relevant policies have been identified and discussed in a previous report (Bailie et al., 2001). This assessment focuses on the five Programme countries (i.e., China, Brazil, Egypt, India, and Mexico) in which GEF-supported efforts are underway to implement and monitor FCBs in key urban centers. These five countries share certain common characteristics, such as high-growth, mega-urban centers, the emergence of environmental regulation, and recent interest in cleaner public transport technologies. These countries’ transit bus sectors differ in important ways that will influence the selection of policies and their implementation.

In each of these countries, the FCB demonstration project is intended not only to deploy a small fleet of FCBs, but also to stimulate the overall market for fuel cell buses. It is anticipated that the GEF effort will yield experience in each country that will help to inform technology developers internationally, give rise to FCB-supporting infrastructure domestically, and ultimately build markets for FCBs globally. At the end of the GEF project’s lifetime, it is expected that the FCB initiative will have helped to bring fuel cell buses closer to commercialization and make them more attractive to other donors, and – ultimately – to private investors.

As the GEF demonstration phase eventually draws to a close, it can be assumed that subsequent commercialization efforts will still require the involvement of multilateral agencies and other donors. Such actors will consider several factors to gauge the attractiveness of FCB investments in a particular country. This report discusses these “preconditions” for attracting FCB investments, as articulated by the World Bank in a recent presentation to the GEF. This report also discusses a set of ten policies available to Programme countries that can help to create these preconditions. Moreover, these ten policies can generally help foster a favorable policy environment for FCBs – i.e., one that recognizes transport-related environmental problems and is conducive to technically advanced solutions.

In turn, the feasibility of these policies depends upon a number of factors relating to the economic, institutional, technical, and resource context of a given country. The presence or absence of these “enabling factors” will determine which policies might be successfully adopted and implemented in a particular country. For example, a skilled pool of local technicians with electric system skills could represent an enabling local context for a new policy promoting specialized training in fuel cell bus operations, maintenance and fuel infrastructure. In turn, such a policy would help to meet a possible precondition that there exist well-trained and sustainable local capacity specializing in fuel cell bus maintenance and infrastructure issues.

A characterization of enabling factors can help policy makers understand whether there exists a suitable basis for meeting the requirements for the success of these policies. That is, feasibility of a set of suitably tailored policies and implementation modes will depend on the “fit” of the policy with the evolving environmental, regulatory, institutional, and technical capacity of the country. Enabling factors and policies have strong linkages that are likely to be highly mutually reinforcing. The linkages between preconditions, policies, and enabling factors, as shown in Figure 1, can offer insight into identifying the most appropriate next steps in a particular country for facilitating FCB investments.
This remainder of this report comprises three major parts. Section 2 addresses the policy assessment framework and discusses the preconditions – and specific policies to help meet those preconditions – necessary to induce confidence on the part of future FCB investments in developing countries. Section 3 addresses the underlying contexts in each of the five countries where the GEF FCB demonstration projects are to take place, with the aim of assessing the extent to which key enabling factors exist in the five countries. Finally, section 4 provides a set of conclusions and some preliminary recommendations. Areas for further work are also highlighted.

2 Policy Assessment Framework

This section presents a policy assessment framework for informing the selection of policies to enhance country readiness for future FCB project investments – i.e., the necessary preconditions. In particular, this section discusses policies to fostering conditions in developing countries to help ensure that multilaterals and other investors find FCB investments to be competitive with other measures that achieve environmental benefits. More broadly, it is hoped that a suitably designed set of policies could help pave the way for successful investments that help bring fuel cells closer to commercial readiness, while promoting a transition to more sustainable transport in developing countries.

However, the primary burden of commercializing FCBs must presumably fall on the industrialized countries. Bringing fuel cell buses to the market will require continued research and development (R&D), integration and engineering, further demonstrations, manufacturing
scale-up, and significant capital cost buy-down. The cost of a FCB currently exceeds that of a conventional diesel bus by up to US$1 million. This is a cost that few developing countries are prepared to incur for a technology that is commercially unproven, albeit promising. The cumulative buy-down cost is roughly estimated at $1.2 billion, as presented in the GEF FCB strategy document (UNDP/GEF, 2000). This would require the subsidized purchase of approximately five thousand buses, (of which approximately 50 FCBs will arise from the five GEF FCB demonstration projects). Efforts to commercialize fuel cell technologies are already underway within industrialized countries. The US and Europe currently have ambitious R&D and demonstration programs in fuel cell technology in general and FCBs in particular. Driven by the public sector and – increasingly – by the private sector, these efforts will provide the main impetus for the commercialization of FCBs (EC, 1998).

In this context, the rationale for developing countries to invest in the near term in promoting fuel cells is not straightforward. Indeed, Ministries of Transport in developing countries are resource-constrained and hard-pressed to meet their primary responsibility: reliably providing transport services. Their immediate concerns are acquiring buses, expanding routes, expanding infrastructure, and procuring stable fuel supplies. One might surmise that policy-makers in developing countries will adopt policies in the near term to promote fuel cell buses only to the extent that there are synergies with more pressing local objectives as well. For example, such policies might be implemented if higher costs of FCBs were offset by the savings in other costs such as public health impacts from air pollution. The main local objectives that might provide a concurrent stimulus to FCBs as they approach commercial competitiveness are presented in Box 1. The level of host government commitment to the demonstration phase of the GEF FCB program suggests that there is indeed significant host country interest in seeing FCBs commercialized (UNDP/GEF, 2000). Host government support for the GEF FCB demonstrations amounts to roughly half of the $133 million cost, which includes a significant fraction of the incremental cost of the FCB demonstrations.
Box 1. Local benefits of Fuel cell buses. There are several local environmental, economic, and other benefits that have synergies with global benefits. Pursuing these local benefits might involve implementing no-regret policies that support FCBs. A set of local benefits is itemized below, together with possible policies that would be needed to achieve them.

- **Improving transport services**: policies that improve the transport planning process, and secure additional funds for the transport sector (e.g., training & education, fiscal policies).
- **Improving urban air quality**: policies that support cleaner transport (e.g., emissions standards), policies that help shift from vehicles to public transport.
- **Developing domestic capacity for assessing and adopting advanced transport technologies**: policies that build the capacity to assess the role for advanced technologies in transport planning, and as appropriate to develop, adapt, and deploy technologically advanced alternatives to conventional transport options (e.g., R&D support, demonstrations, certification).
- **Positioning for future marketing of advanced technologies**: policies that support private sector roles in advanced technologies (e.g., public private partnerships, training & education, procurement targets) and public sector promotion.
- **Benefiting from economic efficiencies**: policies that help introduce rational pricing into transport and fuel markets – (e.g., targeted taxes and rational subsidies).
- **Building relations among constituencies**: policies that provide positive public relations between transport entities and its partners and customers though high profile public activities (e.g., demonstrations).

It is worth noting that these benefits are largely technology-neutral; they do not a priori imply the promotion of a specific technological option such as fuel cells. Policy makers in developing countries will presumably gauge the policies discussed in this report primarily with respect to their ability to promote these local benefits, and only secondarily with respect to their capacity to stimulate commercialization of FCBs, *per se,* or meet the investment preconditions of multilateral/bilateral funding organizations, or private financial institutions.

### 2.1 Preconditions for Future FCB Investments in Developing Countries

The GEF FCB program is an initial demonstration phase that is expected to be followed by further commercialization efforts in each host country. These subsequent commercialization efforts will presumably require the involvement of multilateral agencies and other donors. Such organizations will be inclined to invest in FCBs in a given country to the extent that its ambient economic, policy, technical and institutional conditions are conducive to the success of such investments.

At the May 2001 UNEP/GEF Workshop on Fuel Cell Commercialization in Paris, the World Bank offered a checklist of the ambient conditions that it would consider indicative of a favorable environment for subsequent FCB investments (Mathur, 2001). With minor modifications, the four “preconditions” discussed in Section 2.1 are those suggested by the World Bank checklist. Section 2.2 enumerates a set of policies that that can help bring about each precondition. (Bailie *et al*, 2001 have described these policies in more detail in a paper).

Two additional items appeared on the World Bank checklist but were not included here as preconditions. These items pertain to (i) the host country’s need to share in the technology risks
and (ii) the need for credit to finance FCB projects. Since a presupposition of this policy assessment is that the technology will not yet be mature and commercial at the end of the UNDP-GEF FCB projects, one can assume that investing in FCBs will still entail technology risks and incremental costs that will need to be shared by an external funder. These are not conditions that Programme countries must ensure by implementing policies, so they need not figure into this assessment.

### 2.1.1 Precondition #1: Near-Competitive Cost

This precondition refers to the extent to which the incremental costs of FCBs have decreased to the point that the technology is market-ready. The relevant market might be the market for transport services, in which case the life-cycle FCB cost will need to be near-competitive with conventional diesel buses. Alternatively, the relevant market might be the market for greenhouse gas (GHG) mitigation services, in which case the incremental life-cycle costs of FCBs (compared to the conventional diesel bus) will need to be competitive with other mitigation options on a cost per unit of saved carbon basis (see Figure 2). This cost will depend in large part on the source of hydrogen fuel for the FCBs. For example, in a country where hydrogen would be produced using electrolysis primarily using renewable resources, substantial carbon reductions would accrue. In contrast, if hydrogen supply were to rely on on-board reforming using gasoline, minimal carbon reductions would arise.

At present, the lifecycle cost of an FCB is several times that of conventional diesel-fueled buses. With continued R&D investments, experience gained through FCB demonstrations, learning in the manufacturing process, and scale-up, it is anticipated that the costs of FCBs will decrease significantly over the mid- to long-term (Ogden, 2001; Bernow et al, 2000; GEF, 2000)). Certain institutions (such as GEF), whose objectives include promoting the development of advanced technologies, will not require strict competitiveness with other mitigation options, but rather will require evidence of progress and the promise of future competitiveness.

### 2.1.2 Precondition #2: Institutionalization of Demand Drivers

This precondition refers to the extent to which institutional and technical capacity exists within a developing country for promoting a transition to sustainable transport options. The existence of such a precondition would allow markets to make the most of advanced transport technologies. Several initiatives are underway at the global level (e.g., Rio+10; climate change enabling activities, etc) for strengthening local capability to quantify the costs and benefits of implementing measures to achieve global environmental benefits. In many developing countries,
these are complemented by a set of activities, programs, and in some cases legislation, designed to both achieve local environmental benefits, ultimately affecting long-term technology choice.

An institutionalization of demand drivers for more sustainable transport technologies, possibly FCBs, will arise in those countries in which there have been advances along several fronts. Among these are an understanding of the ecological and public damages from urban transport systems, a capacity to identify and quantify sustainable alternatives to conventional (e.g. diesel bus) technologies, and evidence of coordinated action across relevant ministries and agencies to implement sustainable solutions (see Figure 3). The presence of such elements will likely reflect an institutional commitment to take concrete steps to achieve progress in environmental quality. It would also indicate an institutional capacity to appraise FCBs within the overall context of sustainable transport planning.

2.1.3 Precondition #3: Indigenization of the Supply Chain.

This precondition refers to the extent to which the provision of fuel cell buses and fueling infrastructure can be achieved domestically. The extent to which a value-added supply chain can be established spans a continuum, ranging from the complete importing of buses, fueling infrastructure, and expertise; to their local assembly from imported components; to local development and fabrication of all major components based on largely indigenous expertise. In many countries, there exists local supply chains that could form the basis for bringing value-added to the production of components associated with FCBs and their infrastructure. Ideally, FCB projects will build upon well-established local suppliers, augmenting or establishing the capacity to refine fossil fuels, produce hydrogen, fabricate fuel cell stacks and auxiliaries, and manufacture buses. Such efforts can contribute to local job creation and eventually serve international markets.

For developing countries in which conventional buses are currently manufactured, the value-added supply chain in which the fabrication of conventional components (e.g., chassis, wheels, electronics) could be expanded to include the fabrication of additional components subject to new FCB specifications. One can also imagine that where an existing hydrogen production industry already exists (e.g., for fertilizer production), it could be expanded to meet incremental hydrogen demand for FCBs. If the relevant patents for the fuel cell technology itself remain under the control of companies in industrialized countries, joint ventures or licensing agreements with foreign companies could enable major parts of the FCB supply chain to be indigenized, yielding a competitive advantage. Indigenization would need to be pursued in a highly strategic
manner, identifying and capitalizing on (existing or anticipated) technical, manufacturing, human, and commercial resources and avoiding inefficient allocation of productive capacity.

2.1.4 **Precondition #4: Sustainable O&M and Fuel Infrastructure.**

This precondition refers to the availability of a pool of technicians and vehicle operators, trained in the maintenance of FCBs and the associated infrastructure. Several new areas of expertise in the upkeep of FCBs will need to be integrated into existing fleet management practices. Some of these are indicated in Table 1. Countries with GEF’s demonstration FCB projects will need to create a cadre of skilled O&M workers, and sustain them so long as the FCBs are in circulation. Additional FCB activities will require that this cadre and its capabilities is robust and can be expanded further.

<table>
<thead>
<tr>
<th><strong>Table 1: Areas of O&amp;M expertise required for FCBs</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>• FC stack monitoring, inspection, maintenance and replacement.</td>
</tr>
<tr>
<td>• O&amp;M of other components unique to FCBs (e.g., regenerative brakes, on-board fuel storage and/or reforming, power conditioning electronics, electric motor)</td>
</tr>
<tr>
<td>• O&amp;M of fueling infrastructure</td>
</tr>
<tr>
<td>• Adherence to stringent safety standards for fueling infrastructure and fuel storage equipment</td>
</tr>
</tbody>
</table>

2.2 **Policies to Support Preconditions**

A total of ten policies have been identified as having significant potential for creating a market and institutional environment conducive to future FCB investments (Bailie *et al.*, 2001). In this section, we link these policies to the preconditions specified in the previous section. This will establish which policies are most able to help establish the particular preconditions (understanding, however, that a given policy might support more than one precondition.) We also discuss ambient factors within the host country that will influence the viability of each policy. The presence of these “enabling factors” can instill some confidence that the indicated policies can feasibly be implemented and will produce their desired effects.

2.2.1 **Policies to Meet Precondition #1: Near-Competitive Cost**

It is important to stress that near-competitive costs of FCBs is an ambient global precondition. As mentioned in the previous sections, the activities that are expected to buy down the difference in capital cost difference between a FCB and a conventional diesel bus will be primarily undertaken in the industrialized countries. However, insofar as developing countries can reinforce these international trends and in the process garner some competitive advantage for attracting limited investment funds, policies aimed at strengthening local R&D and implementation of demonstration projects could help facilitate technology learning in the global fuel cell industry. They can also facilitate the efficient and rapid transfer of FCB technologies into the domestic market as they approach cost competitiveness.

---

1 The policies discussed here have been chosen because they enhance the prospects for advanced transport technologies. They do not comprise a comprehensive set of policies for creating the investment preconditions described by the World Bank. A comprehensive set of policies would include policies extending far more broadly than advanced transport technologies. They might include policies pertaining to macroeconomic stability, intellectual property rights, governance, etc., which are beyond the scope of this study.
**Research & Development.** This policy buttresses technological development and breakthroughs through public funding and other types of public support and incentives. The challenge will be to instigate sufficient fuel cell R&D activities and expenditures in the developing countries to at least transfer and adapt fuel cell bus technologies to the local context. Programme countries that exemplify a significant level of R&D support are India, China, and Brazil, which are conducting research on a range of fuel cell technologies and hydrogen storage technologies at nearly twenty universities, national labs, and private sector development facilities. This key enabling factor that should be present in developing countries to facilitate such R&D-supporting policies includes:

- **An institutional capacity for conducting sophisticated scientific research.** This includes physical capital and human resources, as well as a well-developed education system for providing a continuing stream of technically trained professionals. Ideally, a country will already have in place some capacity for conducting fuel cell research (general electrochemistry, chemical engineering, process engineering, and other disciplines) linked to fuel cells and fuel processing, and sophisticated laboratory and field testing facilities. Characteristics of an R&D infrastructure that can translate technological advances into marketable products would include (a) R&D capacity within the private sector and linkages between public and private research efforts, (b) provisions and policies for establishing intellectual property rights, (c) an established program for lively interaction with fuel cell research activities both within and beyond national borders, (d) active efforts to take advantage of the potential for international commercial links (through foreign investment and private sector partnerships) to contribute to technology indigenization (through joint ventures, licensing agreements, etc).

**Demonstration Projects.** A policy that promotes demonstration projects serves to provide experience by which to better understand the technology, evaluate the performance, emissions, cost, procurement modalities, and operating characteristic of the buses, define infrastructure needs and plan for future scale-up. Perhaps most importantly, it helps a country acquire experience and familiarity with FCBs, enabling policy makers and stakeholders to make decisions about the desirability and appropriateness of FCBs in national transport planning.

Each of the five Programme countries has already engaged in demonstration projects aimed at showcasing advanced transport technologies, including alternative fuel buses, electric buses, and even a small but high-profile fuel cell bus demonstration (at the 2001 APEC summit). The enabling factor that should be present in developing countries to facilitate policies that support successful demonstrations that yield useful experience is:

- **An institutional infrastructure suitable for selecting, designing, implementing, monitoring, and transferring lessons from demonstration activities.** Characteristics of such an infrastructure would include (a) previous experience in conducting demonstration projects of advanced transport sector technologies, and (b) an entrenched monitoring and evaluation program that can serve as a high-quality basis for the validation of results, (c) institutional processes through which the lessons of demonstrations can be incorporated into the transport sector planning process, and (d) active agency participations and coordination of information exchange across relevant agencies and/or ministries.
2.2.2 Policies to Meet Precondition #2: Institutionalization of Demand Drivers

Policies that can promote the institutionalization of demand drivers seek to ensure that the local demand for FCBs is not a transitory phenomenon with questionable long-term prospects. Creating a robust demand entails embedding the underlying drivers for sustainable transport alternatives firmly in the market and planning process. One approach is to influence market decisions by implementing policies that internalize external costs, for instance by accounting through price mechanisms the degradation of environmental quality in urban areas. This could be done through the imposition of pollution taxes, the removal of subsidies that contribute to environmental harms. Policies can also be implemented to change markets, influencing the mix of products provided, for instance through the imposition of environmental standards affecting the which transport technologies and fuel options are present in the market. Finally, another approach is to provide a framework and information for society to move toward more sustainable alternatives in the transport sector, by influencing the decision making of planners, corporate entities, and private citizens. This could be done through the stakeholder and public education, and through the specification of procurement targets for advanced technologies.

Taxes and subsidies. Taxes are arguably the most efficient way to internalize externalities (e.g., social and environmental costs) in the market prices. Taxes can have direct and indirect effects on transit system as they act on both technology and broad travel behavior. Subsidies have a complementary effect, appearing in the form of direct grants, mandatory regulations, training assistance, price controls, guaranteed markets, provision of infrastructure and related services. Tariffs and duties can be employed in similar ways, insofar as they affect the competitiveness of imported capital (and fuels) versus domestic capital in transport applications. They can strongly influence the attractiveness of advanced technologies for which there is not yet an indigenous production capability.

The use of tax and/or subsidy policy in ways that influence transport markets is widespread. In several countries (including Egypt) diesel fuel is subsidized and therefore more attractive to consumers. In India, subsidies have been made available for compressed natural gas (CNG) and catalytic converter retrofits to make them affordable to vehicle and fleet owners. In the future, Egypt intends to implement a tax credit funded by bus manufacturers that will be earmarked for fuel cell development. For tax and subsidy policies, the enabling factor that should be present in developing countries to facilitate such policies is:

- A clear indication of government ability to impose fiscal measures, and a public willingness to pay for the resulting environmental quality gains. Characteristics of a political acceptability of taxes and the removal of subsidies for environmental quality gains include (a) broad awareness of the benefits involved through public education campaigns (see below), (b) faith in the government capacity to carry out economic and policy analysis and design appropriate fiscal measures, and (c) political authority and credibility to impose and enforce the appropriate levels of fiscal burden.

Environmental Standards and Technology Controls. Emission standards aim to restrict emissions of pollutants from point or mobile sources by limiting the emission rate for specified pollutants. Technology controls prescribe the specific technology to utilize to control emissions. Such environmental standards have been implemented in many developing countries, for instance through the phase-out of leaded gasoline, the mandating of catalytic converters, and the
imposition of sulfur limits on diesel fuel. The enabling factor that should be present in developing countries to facilitate such a policy is:

- **A demonstrated government commitment to improving urban air quality.** Characteristics of such a commitment would be a) measurable progress in addressing a poor urban air quality environments, b) past success with controlling emissions from stationary and vehicular sources, c) evolving sophistication of the regulatory framework for standards implementation and enforcement, and d) technological capacity of vendors and consumers to comply

**Procurement Requirements and Market Targets.** Procurement targets are mandates on future purchases of vehicles in public sector fleets, usually on a much larger scale than a demonstration project. Market targets are usually imposed on the broader transport sector. They are more flexibly defined, for example in terms of a sector-wide performance standard or renewable fuel percentage, and rely on the market to discover the most efficient way to meet the target. The enabling factor that should be present in developing countries to facilitate such a policy is:

- **Recognition that emissions from urban bus fleets seriously impact local air quality.** Characteristics of such recognition are the assessment of market-viable solutions with acceptable incremental costs, an awareness of consumers regarding these options, and realistic targets and time-tables.

**Public Education.** Public education policies can contribute greatly toward creating an environment of support for policies inspired by environmental concerns. Education initiatives can take the form of various types of outreach efforts, including: demonstration projects, educational programs in schools, public information sessions, and media campaigns. The common aim of such actions is to raise the level of awareness of a certain environmental issues and the existence of viable solutions, thereby providing justification for subsequent and sustained action. Several developing countries plan to undertaken such education efforts, such as fuel cell technology seminars at research centers, workshops at schools and the planning of radio campaigns. The enabling factor that should be present in developing countries to facilitate such a policy is:

- **A broad-based system for conveying environmental information to society.** Characteristics of such a system would be a) public service messages, b) environmental curriculum development, c) an achieved level of environmental awareness among the citizenry, and d) public education activities taken up by civil society organizations (i.e., NGOs)

2.2.3 **Policies to Meet Precondition #3: Indigenization of the Supply Chain**

Policies that can facilitate supply chain indigenization would be focused primarily on the removal of economic, policy, information, and other barriers to greater involvement of the private sector. Programme countries are already exploring roles for private sector entities in fuel cell development and commercialization, and are coordinating collaborations with the private sector. Two policies in particular: – promotion of public-private partnerships and stakeholder training – can play a role in bringing value added to existing local supply chains.

**Public-Private Partnerships.** This type of collaboration pools together the resources and expertise of the public and private sectors for providing FCBs, supplying fuel, and operating the system. Through such partnerships, the private sector can bring entrepreneurial resources and equity capital to carry out undertakings that are not normally within the domain of private
enterprise but which nonetheless offer commercial opportunities, thereby freeing public funds for other economic and social programs. The public sector brings institutional infrastructure and authority, and makes markets (e.g., urban mass transit customers) available to private enterprises under specified conditions. Policies can foster public-private partnerships by providing clear and transparent long-term arrangements for sharing of costs and benefits, establishing the conditions under which services are to be delivered, and creating a framework for oversight and review. Enabling factors that should be present in developing countries to facilitate such a policy are as follows:

- The private sector’s capacity and interest in playing roles in the transport sector, and the public sector’s ability to create a hospitable environment for partnerships, must be evident. Generally, there must be a favorable climate for private (both foreign and domestic) investment, implying a stable macroeconomic and policy environment, the characteristics of which have been discussed extensively elsewhere.

2.2.4 Policies to Meet Precondition #4: Sustainable O&M and Fueling Infrastructure

Establishing a sustainable O&M infrastructure depends on the existence of a FCB demonstration project in which local technicians and managers gain valuable operating experience. However, these gains can only be institutionalized, and thereby made sustainable, though complementary efforts that seek to codify this experience and ensure it constitutes a foundation upon which future efforts can build.

It is similarly necessary to ensure that the long-term hydrogen fueling options exist and are sustainable. In this regard, the GEF FCB projects must be seen as preliminary, as the fuel options employed in this initial stage will be constrained by local resource and infrastructure availability. These options can meet short-term needs, and can even contribute to technological learning regarding the longer-term sustainable options. But it is important to avoid “locking-in” inferior or less sustainable fuel infrastructures, such as hydrogen produced electrolytically from non-renewable sources or the on-board reforming of petroleum-based fuels. Countries therefore need to develop the capacity to analyze fuel resource and infrastructure options, and identify the best options based on their local development objectives.

Licensing and Certification Requirements. Licensing and certification provide protocols that clarify the meaning of environmental and safety regulations and standards and harmonize their implementation across different manufacturers, technologies, and private operators. In doing so, they make it easier for companies and individuals to comply and authorities to enforce. As pertaining to FCBs, such policies can serve to create an institutional memory for practical O&M procedures and specifications. An example of a licensing/certification initiative as implemented in transport sector of one of the FCB Programme countries is the effort to acquire ISO compliance for Mexico’s four main bus manufacturers. An enabling factor that should be present in developing countries to facilitate such a policy is:

- A capacity to design and implement professional certification measures. Characteristics of such a capacity would be a) parallel measures in other sectors (e.g., power plan operator certification), b) evidence of efforts to instill a safety culture, c) competent local capacity for maintenance of conventional buses, and d) suitable continuing education programs in place for bus fleet technicians.
2.2.5 Cross-cutting policy: Stakeholders Training & Other Capacity Building Efforts

A cross-cutting policy that must underlie all the above preconditions is broad initiative aimed at strengthening local capacity for undertaking FCB projects and for generally enhancing transport planning capabilities. This involves the development and implementation of capacity building efforts across the various levels of FCB-related activities. Such a broad initiative would include enhancing basic and applied R&D capacity, training bus operators and technicians engaged in managing bus fleets, familiarizing fuel cell technology to prospective manufacturers, and creating skills and tools for financial analysis of transport programs.

An important capacity building avenue regards the assessment of fuel infrastructure options, benefits, and costs. Fuel infrastructure raises concerns that extend far beyond the management of urban bus fleets alone, touching upon national energy security issues, and energy planning with competing and intersecting demands across the electric power, industrial, and transport sectors.

A further critical element is to create transport planning processes that are equipped to investigate the range of available transport options for long-term planning, including technological alternatives as well as options that are not technology-based such as comprehensive land-use planning strategies that potentially hold much greater long-term potential.

The enabling factor for such capacity building measures is as follows.

- A skilled pool of local planners, researchers, and technicians who can be further trained in the relevant disciplines and issues. This entails (a) a large number of personnel with the appropriate advanced training in specialized areas pertinent to FCBs and transport planning, (b) educational facilities and other fora for capacity building, (c) mechanisms for transferring assessments and recommendations into the political planning process, (d) processes for identifying and engaging stakeholders for capacity building as well as informing policy.

3 Country Assessment Framework

This section addresses the underlying country contexts in each of the five countries (i.e., China, Brazil, Egypt, India, and Mexico) where the GEF FCB demonstration projects are to take place. The aim of this section is to begin to assess the extent to which the enabling factors discussed in the previous section exist in the five countries. The reader will recall that these enabling factors are key determinants for selecting an appropriate mix of policies to foster the attainment of the preconditions for future FCB investments in developing countries.
A tabulation of preconditions, policies, and enabling factors is presented in Table 2. The column to the far right of the Table represents our assessment of the ability to characterize enabling factors within the context of the current Scope of Work. For such cases, we recommend follow-up activities, including possibly country missions, to characterize the status of these enabling factors for each of the five program countries.

Given the summary in Table 2, the following enabling factors are described in this section:

- **Advanced infrastructure.** The sophistication of the research base varies significantly across the countries, as does the range of research activities and technical capacity that intersect with fuel cell technology and hydrogen supply infrastructure.

- **Local bus manufacturing capability.** This focuses on local experience with the production of conventional diesel buses and electric buses.

- **Recognition that emissions form urban bus fleets seriously impact local air quality.** This is reflected in the severity of urban air quality problems and extent of measures and regulations for limiting emissions.

<table>
<thead>
<tr>
<th>Precondition</th>
<th>Policy</th>
<th>Enabling Factor</th>
<th>Characterization</th>
</tr>
</thead>
<tbody>
<tr>
<td>Near-Competitiveness</td>
<td>R&amp;D</td>
<td>Advanced infrastructure</td>
<td>Yes</td>
</tr>
<tr>
<td></td>
<td>Demonstration projects</td>
<td>Multi-agency participation and coordination</td>
<td>Additional effort needed</td>
</tr>
<tr>
<td>Indigenization of the Supply Chain</td>
<td>Public-Private Partnerships</td>
<td>Favorable investment climate</td>
<td>Additional effort needed</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Local bus manufacturing capability</td>
<td>Yes</td>
</tr>
<tr>
<td>Institutionalization of Demand Drivers</td>
<td>Taxes, Subsidies, &amp; fares</td>
<td>Public willingness to pay for achieving environmental quality gains</td>
<td>Additional effort needed</td>
</tr>
<tr>
<td></td>
<td>Emission standards</td>
<td>Government commitment to improving urban air quality</td>
<td>Additional effort needed</td>
</tr>
<tr>
<td></td>
<td>Procurement targets</td>
<td>Recognition that emissions form urban bus fleets seriously impact local air quality.</td>
<td>Yes</td>
</tr>
<tr>
<td></td>
<td>Public Education</td>
<td>A broad-based system for conveying environmental information to society</td>
<td>Additional effort needed</td>
</tr>
<tr>
<td>Sustainable O&amp;M and Fuel Infrastructure</td>
<td>Licensing and Certification Requirements</td>
<td>Capacity to design and implement professional certification measures</td>
<td>Additional effort needed</td>
</tr>
<tr>
<td>Cross-cutting policy</td>
<td>Stakeholder training</td>
<td></td>
<td>Additional information needed</td>
</tr>
</tbody>
</table>
In addition, fuel supply and technology issues, whose current options differ significantly across the five countries, will be discussed. Fuel supply options differ with regard to the method chosen for the production of hydrogen (i.e., electrolysis with renewables, by reforming biomass/ethanol, natural gas, or methanol) in the demonstration projects, as well as long-term prospects.

The following sections provide an overview of the current state of the above factors for each of the five countries. In addition, a summary of the transit bus infrastructure, which offers a perspective of the potential market for FCBs, is provided in the Annex 1. A tabular summary of the characterization of enabling factors is provided in Annex 2.

3.1 China

The China demonstration project involves parallel projects in Beijing and Shanghai. Six hydrogen-fueled buses will be operated in each city over a period of 4 years. In both Beijing and Shanghai, the hydrogen will be produced by on-site, small-scale steam reforming of natural gas.

3.1.1 Technical Capacity and Infrastructure

In China, the needed technologies for developing FCBs, especially the technologies of hydrogen production and storage, are reported to be well developed (SSTC II, 1996). In fact, at low levels of FCB use, the current hydrogen production levels are considered to be sufficient. There are several cities (e.g., Shanghai, Nanjing, Dalian, Wuhan, Guangzhou, Suzhou) where technology has been developed based on water electrolysis or ammonia and methanol decomposition. However, there is little if any capability with on-board reforming from fossil fuels. The one exception is recent efforts to produce hydrogen from methanol steam reforming in a membrane reactor. China’s support of research and development activities is further demonstrated through a five-year project (2000-2005), which is assessing the fundamental of large-scale production, storage and transportation of hydrogen and related fuel cells (Mao, 2000). There are a number of collaborative initiatives in hydrogen research between academic institutions, the government and/or private companies that could provide impetus for advancing fuel cell technology in China, as shown in Table 3 (Canon, 2000).

<table>
<thead>
<tr>
<th>Organization</th>
<th>Fuel Cell Research focus</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tsinghua University and Karlsruhe Research Center (Germany)</td>
<td>Fuel cell technology and hydrogen storage system</td>
</tr>
<tr>
<td>Shanghai Institute for Organic Chemistry &amp; Shanghai Auto Industries Corporation</td>
<td>Fuel cell powered automobiles</td>
</tr>
<tr>
<td>Unirule Institute and Alton Jones Foundation</td>
<td>Hydrogen fuel cell buses in three cities (Jilin, Shanghai and Ningbao)</td>
</tr>
<tr>
<td>Shanghai Jiao Tong University and Japan Central Institute for Electricity</td>
<td>Molten carbonate fuel cell and Proton Exchange Membrane (PEM) fuel cell</td>
</tr>
<tr>
<td>The General Research Institute for Nonferrous Metals</td>
<td>Development of hydride materials for hydrogen storage</td>
</tr>
</tbody>
</table>
3.1.2 Indigenous development and manufacturing capability

There is a well-established bus manufacturing capability within China (SSTC-III, 1996). Sales volumes of medium buses are about 25,000 per year while sale volumes of large buses are around 5,000 per year. About 90% of these units are produced locally. However, while all of the non-engine components are produced within China, diesel engines are imported. As part of the capacity development assessment for fuel cell buses in China, a prefeasibility study for the development and manufacture of FCBs in China showed that existing production lines could be readily modified using a PEM power system. The estimated first-of-a-kind cost for local production was estimated to be US$1,340/kW, not including funds needed for research and development.

3.1.3 Urban Air Quality And Transport Policy Responses

A study of air pollution levels in cities by the World Health Organization (WHO) in 1992, ranked Beijing as the second most polluted mega-city in the world (MOST, 1999). In 1999 Beijing’s vehicle contribution to CO, HC and NOx, were 92%, 98%, and 85% respectively. Reports have documented the deleterious effects of air pollution on human health, subsequent effects of acid rain on ecosystem health and the adverse impacts of acid sedimentation on crops and forests. China has over 600 cities all of which are unable to meet the national standard of air quality and have similar air pollution trends to those of Beijing (Sperling and Zhou, 2001).

One government initiative launched in response to this serious environmental threat is the Clean Air Program starting in 2001 (also known as the “Air Purification Engineering Program”) which is aimed at reducing air pollution in cities from the two largest sources: motor vehicles and industrial coal boilers. The program targets vehicles in China through three main channels: expanding the use of liquid petroleum gas (LPG) and CNG vehicles; adopting electronic injection and tailpipe-emission reduction technologies; and developing and applying electric vehicles (including fuel-cell vehicles).

3.1.4 Fuel Supply and Technology

While the demonstration project uses small-scale steam reforming of natural gas, the preferred long-term option is the production of hydrogen from coal, with sequestration of separated carbon dioxide. From a cost standpoint, this is likely to be the most attractive low-cost, low-GHG emitting option for fuel in many parts of China (Williams, 2001). Coal resources are abundant throughout China. China has no major natural gas or oil supplies. Renewable resources such as wind are abundant in certain regions but currently only hydropower, which accounts for less than 1% of generating capability, is exploited.

3.2 Brazil

The Brazil demonstration project involves the Brazilian Government and the Empresa Metropolitana de Transportes Urbanos de Sao Paulo (EMTU/SP) operating 9-10 buses over 3-4 years. Hydrogen generated by electrolysis on-site (from off-peak hydroelectricity) in the bus garages is the preferred fuelling solution and Brazil expects to use an existing design of on-site electrolysis/storage and fuelling.
3.2.1 Technical Capacity and Infrastructure

In Brazil, fuel cell bus technology can build on the existing modern diesel bus and electric trolleybus-manufacturing infrastructure. The presence of over 10,000 CNG fuelled buses is also considered advantageous to further research and development efforts, as experience with CNG fuelling stations will be partially transferable to management of pressurized hydrogen fuelling station (MME, 1999). The technology of CNG fuelling stations and fuel storage in Sao Paulo is well developed as a result of the Mercedes-Benz CNG development center, which has invested over $100 million in engine development and testing facilities (MME, 2000).

3.2.2 Indigenous development and manufacturing capability

Brazil’s annual production of buses is comparable to that of all Western Europe countries combined (MME, 1999). Brazilian manufacturers have access to large-scale sources of major components within the region, because of their production of heavy truck engines, gearboxes and axles. As part of the feasibility assessment for fuel cells in Brazil, a preliminary study noted that the companies of the existing Brazilian bus producers have all the engineering capabilities necessary to adapt existing chassis designs to fuel cell buses and the drive part of the fuel cell driveline can be sourced from the same suppliers as for trolleybuses. The one exception to this merging of technologies is the fuel cell current generator itself. The estimated cost for a local production of a fuel cell bus in Brazil (excluding the fuel cell stack which is not expected to be locally produced in the demonstration phase) is approximately US$112,000 – this is 12% more than the cost of a locally manufactured trolleybus (MME, 2000).

3.2.3 Urban air quality and transport policy responses

The primary source of Sao Paolo’s air pollutants, namely, SOx, NOx, and particulates is the exhaust from the diesel engines used to power the vast majority of all heavy road vehicles. Moreover, diesel buses alone contribute over 50% of air-borne particulate matter in some bus corridors (Branco and Branco, 1999). Through the Proalcool Program, Brazil has experience with environmental regulation and establishing an extensive alternative fuel infrastructure, which provided cleaner transport and a extensively commercialized the use of domestic renewable energy resources in the transportation sector (MME, 2000).

3.2.4 Fuel Supply and Technology

Brazil plans to expand the electrolysis, storage and fuelling infrastructure employed in the demonstration project, to meet further hydrogen demand in the future. An advantage of electrolysis is that the electricity required could be generated from hydroelectric power, which currently provides 90% of Brazil’s electricity is generated from hydroelectric power, and is both a renewable and zero-emission source of energy (EIA, 2001). A study on the assessment of various fuels supply options for fuel cell vehicles suggests that Brazil could meet the long-term demand of thousands of fuel cell buses using its other abundant energy resources: either biomass (via ethanol, methanol, or hydrogen) or natural gas (via methanol or hydrogen). However, natural gas prices would have to be relatively high ($5-$6/GJ) in order for biomass to be competitive (Larson et al., 1998). Brazil deems that centrally generated hydrogen is not justified for the bus demonstration project alone and that on-board reforming of liquid fuels are impractical for urban buses (MME, 1999).
3.3 Egypt

The Egyptian Environmental Affairs Agency (EEAA), under the Ministry of the Environment, is the executing agency for the five-year demonstration project, which involves introducing eight fuel cell buses as substitutes to diesel buses in Cairo. For the demonstration project, a packaged electrolyzer unit, including high-pressure hydrogen gas storage cylinders, hydrogen compressors, and dispensers, will be purchased and installed at the host garage to meet the hydrogen requirement. The centralized reforming plant, hydrogen pipeline, and CO$_2$ sequestration facility are proven technologies and need not be demonstrated in this project.

3.3.1 Technical Capacity and Infrastructure

Egypt has extensive experience of operating refineries, petrochemical complexes, and fertilizer plants that provide a technical capacity basis for its future development and operation of hydrogen production facilities. As for the hydrogen distribution system, this could extend from knowledge and experience accrued in building Cairo’s natural gas distribution network (EEAA, 1999). An existing extensive education and research system can provide the pool of skilled labor needed for these technical developments.

3.3.2 Indigenous development and manufacturing capability

Egypt has an established bus manufacturing industry with an annual production of several thousand buses. The largest of the four main bus manufacturers in Egypt, state-owned NASCO, imports chassis, but manufactures the glider and assembles buses locally in Egypt and the three remaining companies are privately owned (Mercedes-Benz, MAN and Scania) and are also equipped with modern manufacturing and assembly facilities (EEAA, 1999). With the exception of the fuel cell stack, other fuel cell engine components, such as turbochargers, radiators, heat exchangers, electric motors, and inverters could be manufactured and serviced locally which could lower the cost differential between diesel bus and fuel cell buses. Including spare parts a diesel bus purchase price is US$120,000, which is less than half the cost of the estimated US$266,600 that it would cost to build a FCB (Bechtel, 2000).

3.3.3 Urban air quality and transport policy responses

Fumes from Cairo’s 1.2 million vehicles have contributed to serious air quality problems. Fossil fuel combustion in motor vehicles, power plants and large industries, as well as industrial process and solvent use are major sources of the pollutants (SO$_2$, NO$_x$, and VOC). Total particulate matter in Cairo is 5-10 times higher than WHO standards (EIA, 2000).

One of the long-term objectives of the Cairo Air Improvement Program (CAIP), initiated in 1995 is that a large-scale implementation of a vehicular testing program will bring 80% of vehicles on the streets of Cairo into compliance with government emission standards. The transportation sector is not a source of lead pollution in Cairo as leaded fuel has already been phased out, and the rest of the country is expected to follow suit by 2002 (EEAA, 1999).

In addition, CAIP is involved in the development of a fleet of buses fueled by CNG and the government has given itself five years to have all vehicles operating on natural gas, in line with the 1994 law on the environment. CAIP also attempts to tackle the air pollution problem at its source by setting up the country’s first station for treating exhaust systems on buses to improve emissions performance.
3.3.4 Fuel Supply and Technology

Although the demonstration project in Cairo is to be fueled by electrolytic hydrogen, the preferred long-term approach is centralized natural gas reforming plant with the product hydrogen delivered to the bus garages by a gas pipeline and CO\textsubscript{2} sequestered in a spent gas well. With an estimated reserve of 50 years and primary growth in Egypt’s energy sector, natural gas is Egypt’s most readily available source of energy for fuel cells (EEAA, 1999). Possible locations for a centralized hydrogen plant have been chosen, all with adequate natural gas supply and within proximity to Cairo in order to minimize the hydrogen transportation cost to the bus garages (Bechtel, 2000).

3.4 India

The India demonstration project entails a five-year program for eight FCBs for public transport in Delhi. A packaged electrolyzer unit, including high pressure hydrogen gas storage cylinders, hydrogen compressors, and dispensers, will be purchased and installed at the host garage to meet the hydrogen requirement. The long-term option is centralized reforming plant, and hydrogen pipeline, which are proven technologies that need not be demonstrated in this project.

3.4.1 Technical Capacity and Infrastructure

Indian technical capacity in fuel cell technology development extends into academic, non-governmental and private company entities, as shown in Table 4. (MINES and Bharat, 2000). India has a research infrastructure pertinent to fuel cell development, devoting considerable effort toward electric drive propulsion technology, such as fuel cells, batteries, and hybrid electric system. (Bose and Sperling, 2001). The Delhi Transport Corporation (a potentially major user of commercial FCBs) is looking to utilize their experience in CNG bus fuelling stations to facilitate conversion to FCBs, as is the case for Brazil mentioned above.

<table>
<thead>
<tr>
<th>Organization</th>
<th>Fuel Cell Research focus</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bharat Heavy Electrical Limited</td>
<td>PAFC systems</td>
</tr>
<tr>
<td>SPIC Science Foundation</td>
<td>PEMFC minibuses</td>
</tr>
<tr>
<td>TERI &amp; CECRI</td>
<td>MCFC systems</td>
</tr>
<tr>
<td>IISC, Bangolore</td>
<td>DMFC system</td>
</tr>
<tr>
<td>IISC &amp; CGCI</td>
<td>SOFC development</td>
</tr>
<tr>
<td>Banaras Hindu University</td>
<td>Metal hydride</td>
</tr>
</tbody>
</table>

3.4.2 Indigenous development and manufacturing capability

India has the benefit of a modern, well-equipped competitive bus industry that may be capable of embracing fuel cell technology. At the national scale, most buses are manufactured and assembled locally in India, with either self-made or imported diesel engines. A basic diesel bus can cost as little as $US 30,000 (MINES, 2000). Two major bus manufacturers TELCO and Ashok Leyland have an annual production capacity meeting the total bus demand of the country. Coupled with this local ability are the numerous bus-body building companies (Sutlej Motors, TVS and Autorola).

3.4.3 Urban air quality and transport policy responses

Of the 3 million premature deaths in the world that occur each year due to air pollution, the highest number has been estimated to occur in India (EIA, 2001). In Delhi, vehicles are estimated to account for about 70 percent of the city’s air pollutant emissions (CPCB, 1999).
The Ministry of Petroleum and Natural Gas has introduced low-sulfur diesel (0.25%) recently within the city limits, which is to be further extended. There have been accomplishments such as the phasing out of leaded gasoline; making mandatory the installation of catalytic converters for motor vehicles in 49 cities; and providing subsidies for CNG conversion and catalytic converters (MINES, 2000).

In recent years a series of regulatory reform to reduce air pollution have come from the Supreme Court. There are a host of Court-approved directives that will guide the management of Delhi’s surface transport system. At least two of directives which will have significant ramifications on the bus sector in Delhi; one demands the replacement of the diesel fleet in Delhi with CNG by April 2001 and another requires that all public sector buses older than 8 years, not running on CNG, must be scrapped by April 2001. The state-owned Diesel Transportation Corporation (the executing agency for the GEF FCB demonstration project) is pleading the Supreme Court for more time to comply, and requesting that the government ensure the delivery of sufficient CNG to meet the expected surge in demand in order to avoid major disruptions to service. (Dugger; Gopalakrishnan, 2001).

3.4.4 Fuel Supply and Technology

After a successful demonstration stage, India is expected to move from electrolysis to the reforming of natural gas for hydrogen production. India has the local operating and maintenance capability of hydrogen production facilities since it is currently operating many refineries, petrochemical complexes, fertilizer plants, and chlori-alkali plants which produce large quantities of hydrogen by either natural gas reforming or electrolysis processes. The government views ethanol as an unlikely fuel option because it is a seasonal commodity (MINES, 2000).

3.5 Mexico

The demonstration project in Mexico seeks to implement twenty FCBs in Mexico City over a five-year period. The entire FCB fleet for the demonstration project is expected to be manufactured in Mexico using existing and newly developed technological capacities (SESTRAVI-STE, 1999). Natural gas reforming is the chosen process for hydrogen production.

3.5.1 Technical Capacity and Infrastructure

The Mexico City Government Secretary of Transport has bestowed the responsibility to research and develop FCB technology to the Electric Transport Service (STE) with the intent of transferring STE’s experience with electric-powered tramways, trolleybuses, and light trains to FCB technology (SETRAVI-STE, 1999).

3.5.2 Indigenous development and manufacturing capability

Mexico has already been introduced to FCBs, as its largest bus manufacturer, Mercedes Benz, showcased the Nebus (New Electric Bus) prototype to the environmental authorities of Mexico City. In the long term, Mexico City expects that FCBs, including the fuel cell stack, will be locally produced. Mexico City identifies the local bus manufactures, Mercedes Benz, Navistar, DINA and MASA, as future FCB manufactures so long as improvements in production planning, procurement, product quality and supporting services are achieved. As a promising first step, STE recently procured 200 locally-produced electric trolleybuses, the construction and assembly of which has helped established a relevant set of technological capabilities within local bus
manufactures. The cost of a FCB manufactured in Mexico has been estimated at $1,100,000 including the fuel cell engine – over a 10 fold increase in cost compared to a diesel bus (US$85,000) currently, but with considerable cost reductions expected over time (SETRAVI-STE, 1999).

3.5.3 Urban air quality and transport policy responses

Over 20% of the national population resides in Mexico City, the annual population growth of 1.4%, which intensifies the urgency to tackle the increasing levels of air pollution. The primary air quality problem is smog and the two main ingredients in smog that affect human health are ground-level ozone and fine airborne particles (Gilchrist, 1998). There are at least three initiatives taking place with implications on the bus sector and subsequently urban air quality: replacing the majority of urban buses which are high-emitting minibuses and microbuses with articulated diesel buses; investing in trolleybuses; and increase the use of diesel buses.

3.5.4 Fuel Supply and Technology

A prefeasibility study for the development and manufacture of fuel cell buses in Mexico (SETRAVI-STE, 19990) slated natural gas as the potential fuel supply to run the buses. Mexico is endowed with abundant proven natural gas reserves and has instituted policies to increase natural gas exploration to meet rising demand. Availability and infrastructure for natural gas for onsite natural gas reforming is not expected to be a constraint as the Mexican government is inviting private investment companies to develop additional networks of natural gas pipelines and the government operated gas industry is expanding production of natural gas. On-board reforming and electrolysis have not been developed as a result of this apparent long-term availability of natural gas.

4 Conclusions and Next Steps

In this paper, we have tried to meet a twofold purpose. First, we developed a policy framework to assess the country context favoring the continued support of multilateral institutions and other sources of investment in fuel cell buses. This framework consisted of identifying preconditions favorable to subsequent FCB investment, specifying FCB-supporting policies that can help to meet the particular preconditions, and identifying enabling factors in Programme countries that can make the FCB-supporting policies feasible. Secondly, we developed a country framework to begin to assess the extent to which to which the unique enabling factor context exists in each of the five Programme countries that would help to inform whether a particular policy would be suitable.

In our view, making definitive recommendations regarding the types of policies that should be considered by the UNDP-GEF FCB Programme countries is still premature. Additional effort is needed to better characterize the “enabling” situation in each country. While several country-specific factors have been characterized (based on the country reports and documents that have been generated for the fuel cell bus projects), others have not been. Assessing these other enabling factors would require access to information that is not available within the GEF FCB Programme documents, and would entail investigation and analysis at a level that could not be undertaken within the time and budget constraints of this project. Additional reconnaissance is therefore needed to understand these factors sufficiently to inform policy. Nevertheless, it is possible to make some preliminary recommendations regarding how one might assess these
policies in each of the five Programme countries, towards the aim of creating a climate favorable to future FCB investments.

The primary recommendation is that responsible entities (policy makers, civil society, etc.) in the Programme countries will need to identify national objectives regarding sustainable transportation, and investigate whether and how the implementation of any of the ten policies would help promote these objectives. Experts and stakeholders familiar with the national context should carefully assess the local relevance of the broader benefits of the ten policies (some of which are shown in Box 1). It is worth noting that these benefits are largely technology-independent. They would arise even if the policies were implemented in a technology-neutral manner that did not explicitly focus on fuel cells as the technological solution of choice. Such technology-neutral implementation could allow the most locally appropriate solutions to emerge, given the technical, institutional, and market context. (see the technology ladder in Bailie, et al, 2001). It would also generally make the public transport sector more hospitable to environmentally clean and technologically advanced solutions in the near-term, and may ultimately lead to advantage for fuel cell buses in the longer-term.

Table 5 below presents preliminary recommendations with respect to particular policies in each of the five Programme countries. We issue the strong caveat that they are based on a limited insight into specific country contexts, and a restricted understanding of the enabling factor situation in each country (see Table 2). Therefore, these recommendations are only intended to indicate a rough sense of policy viability, and promising areas for further investigation. The suitability of specific policies will depend upon the economic, institutional, technical, and resource context of a given country and should be carefully supported with country-specific assessments. A finding of “▲” indicates that this may be a promising policy to support; a finding of “▼” indicates that this policy may be unsuitable; and a finding of “—” indicates that it was not possible to assess -- even preliminarily -- whether the policy would be viable.

![Table 5: Preliminary recommendations for country-specific policy choices](image)

The key to making the right policy choices tomorrow -- and thus reaping the associated local and global environmental benefits -- will depend on a clear understanding of the range of country-specific factors that influence the suitability of particular policies. The policy assessment framework described in this paper attempts to identify some of the key issues (e.g., costs, risks, fit with local capacity, potential for market transformation) that can help guide potential investors before committing funds to future FCB projects. The preliminary recommendations...
presented in this paper point to promising policy directions that should be explored as experience is garnered from the FCB demonstration phase.

List of References


Ministry of Non-Conventional Energy Sources (MINES) and Delhi Transport Corporation (DTC), 2000. *Fuel Cell Bus Development in India.*


SETRAVI (Transport Secretary for the city of Mexico)-STE (Electric Service Transport), 1999. *Demonstration Project of Hydrogen Fuel Cell Buses and an Associated System for Hydrogen Supply in Mexico City.*


Annex 1: Existing Urban Bus Transit Infrastructure in the Five Programme Countries

China: China witnessed a 6.5% per year increase in the bus stock levels between 1990 and 1999 (Sperling and Zhou, 2001). Today, buses in China account for an estimate 75% of urban public transport passenger volume. Moreover, the demand for medium to large size (7 to 18 meters) buses in China is expected to grow at an average rate of 5% per year between 2000 and 2030, reaching about 7 million buses in 2030.

Beijing hosts a fleet of 8,850 buses with nearly 50% running on diesel fuel and about 30% on gasoline. Of the remaining buses, 1,600 operate using LPG and 300 use CNG. In addition, Beijing has 546 electric trolley buses. Shanghai is operating the largest bus system in the total national energy consumption (MOST, 1999).

Brazil: Brazil is ranked as the world’s third largest bus market after China and India. At the national level, Brazil operates 120,000 urban buses and requires 11,000 new units per year. Approximately 50% of Brazil’s bus fleet is in the 9 metropolitan regions of Brazil (prefeas.). Brazil has been increasing its development of Mass Rapid Transport (MRT) particularly busways, in many of it’s large cities. MRT has resulted in an estimated 10% of the metropolitan fleet and market is made up of buses operating in fully or partly reserved corridors, with improved road surfaces and high intensity of operation (STM, 2000). Another innovation in bus transit infrastructure is the integrated bus ways and city roads in Curitiba. This is likely the target market sector fuel cell buses.

The Sao Paulo Metropolitan Area (SPMA) is the largest urban region in Brazil and has a bus fleet of approximately 23,000 buses. The majority are diesel powered and the electric trolley fleet of 500 buses is one of the largest in the world. In addition, 13% of the Sao Paulo Trans bus fleet is comprised of CNG buses (MME, 1999).

Egypt: All buses in Cairo Transit Authority (CTA) and Greater Cairo Bus Company (GCBC), a wholly owned subsidiary of CTA, are diesel buses manufactured and assembled locally in Egypt. As a result of the Climate Change Action Plan, CTA and GCBC are currently introducing CNG buses through a demonstration project under the USAID funded Cairo Air Improvement Programs (CAIP). The number of buses in stock between both the CTA and GCBC are 3570 and of these 2550 are operating (Bechtel, 2000). The diesel fuel is subsidized and sold to users at a uniform price.

India: The national bus fleet comprises 600,000 vehicles out of which 130,000 are public buses. The stock in Delhi in the year 2000 was 18,000 and is predicted to more than double by 2010.

2 The transport planning in Curitiba uses 5 different types of bus operations (source: Birk and Zegra): (a) the express buses operate exclusively on the arteries’ dedicated busways; (b) ‘rapid’ buses (110 people) operate on both the arteries and on other main streets in city and their routes change depending on demand; (c) ‘bi-articulated’ rapid bus operating on the outside high-capacity lanes which can carry 270 people; (d) ‘inter district’ buses bring passengers between the city’s sectors lying between the arteries and link the routes of the express and the biarticulated buses. These buses also operate on ring road surrounding the CBD; and (e) ‘feeder’ buses mix with traffic on all other city streets and bring passengers to transfer station. The bus system, as a whole, covers 65% of the municipalities’ ground (World Bank, 2001).
Approximately 137 CNG buses are in operation (all publicly operated) and 1200 are on order (MINES, 2000). Thirteen diesel buses have been retrofitted with CNG. Only a few of the private charter buses (mainly school buses) have been retrofitted with CNG and 35 CNG refueling stations are open (Bose and Sperling, 2001).

Delhi has devoted 20% of its land to transport infrastructure but suffers from poor traffic management. The Mass Rapid Transport System (MRTS) has been launched and its first section should be completed by 2002. The first phase calls for 55 km of rail and busways by 2005 (MINES, 2000). The Plan includes 115 new ‘feeder’ bus routes on existing roads. The second phase should be completed by 2021 and carry 22 million pass per day.

**Mexico:** There are some 30,000 buses in service in the Mexico City Metropolitan Area, which is the largest urban concentration in the country and in the world. Approximately 75% of Mexico City’s buses are gasoline fueled and the remaining buses are diesel engine buses except for the 450 electric trolleybuses also in operation. All the gasoline buses are privately owned (SETRAVI-STE, 1999).
Annex 2: Summary Characterizations of Enabling Factors in the Five Programme Countries

<table>
<thead>
<tr>
<th>Country</th>
<th>Research &amp; Development Infrastructure</th>
<th>Local Bus Manufacturing Capability</th>
<th>Air Quality Policies</th>
<th>Fuel Availability</th>
<th>Near Term Option (Demonstration Phase)</th>
<th>Long Term Options</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>China</strong></td>
<td>Five year R&amp;D project (2000-2005) will assess fuel cell technology and large scale production, storage and transportation of hydrogen.</td>
<td>All non-engine components are produced in China (i.e., motors, power technology, electric components)</td>
<td>Clean Air Program starting in 2001 aims to reduce air pollution in cities from motor vehicles and industrial boilers.</td>
<td>Hydrogen produced by on-site, small-scale steam reforming of natural gas.</td>
<td>Production from coal with CO₂ sequestration.</td>
<td></td>
</tr>
<tr>
<td><strong>Brazil</strong></td>
<td>Indigenous electric trolleybus technology.</td>
<td>Major bus manufacturer; exporter</td>
<td>Regulating CNG in public transport sector</td>
<td>Hydrogen produced by on-site electrolysis.</td>
<td>On-site electrolysis or on-site steam reforming of natural gas.</td>
<td></td>
</tr>
<tr>
<td><strong>India</strong></td>
<td>Extensive ongoing FC technology R&amp;D initiatives</td>
<td>Most diesel buses manufactured in India</td>
<td>1998 Supreme Court directive to convert entire bus fleet to CNG by April 2001 in Delhi</td>
<td>Hydrogen produced by on-site electrolysis.</td>
<td>Centralized natural gas reforming plant.</td>
<td></td>
</tr>
<tr>
<td><strong>Egypt</strong></td>
<td>Extensive experience in natural gas processing and networks</td>
<td>Bus manufacturing industry could supply components except for fuel stack</td>
<td>Cairo Air Improvement Program</td>
<td>Hydrogen production by on-site electrolysis.</td>
<td>Centralized natural gas reforming plant.</td>
<td></td>
</tr>
<tr>
<td><strong>Mexico</strong></td>
<td>Indigenous electric trolleybus technology</td>
<td>The largest bus manufacturer in Mexico has showcased the Nebus, (New Electric Bus) prototype</td>
<td>Government investment in electric trolleybuses</td>
<td>Hydrogen production by on-site, small-scale reforming of natural gas.</td>
<td>Centralized reforming of natural gas.</td>
<td></td>
</tr>
</tbody>
</table>
Assessment of Policies to Support Fuel Cell Buses and the Transition to the Hydrogen Economy

Prepared for:
UNDP/GEF

Prepared by:
Alison Bailie
Steve Bernow
Bill Dougherty
Sivan Kartha
Chella Rajan

Stockholm Environment Institute – Boston Center
11 Arlington Street
Boston, MA 02116
USA

August 24, 2001
# Table of Contents

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Table of Contents</td>
<td>xxxiv</td>
</tr>
<tr>
<td>Executive Summary</td>
<td>xxxv</td>
</tr>
<tr>
<td>Introduction</td>
<td>1</td>
</tr>
<tr>
<td>Context</td>
<td>2</td>
</tr>
<tr>
<td>Fuel Cell Technology</td>
<td>2</td>
</tr>
<tr>
<td>Hydrogen Infrastructure</td>
<td>3</td>
</tr>
<tr>
<td>Challenges to Fuel Cell Commercialization</td>
<td>4</td>
</tr>
<tr>
<td>Challenges Common to New Technologies</td>
<td>4</td>
</tr>
<tr>
<td>Challenges Unique to Fuel Cells</td>
<td>4</td>
</tr>
<tr>
<td>Challenges Unique to Fuel Cell Buses</td>
<td>5</td>
</tr>
<tr>
<td>Policy Options for Action</td>
<td>5</td>
</tr>
<tr>
<td>Research, Development, and Demonstration</td>
<td>6</td>
</tr>
<tr>
<td>Government Mandates</td>
<td>8</td>
</tr>
<tr>
<td>Fiscal Incentives</td>
<td>11</td>
</tr>
<tr>
<td>Awareness Building</td>
<td>12</td>
</tr>
<tr>
<td>Applicability of Policies to IEA’s “Bus Technology Ladder” Concept</td>
<td>13</td>
</tr>
<tr>
<td>Conclusions</td>
<td>15</td>
</tr>
<tr>
<td>List of References</td>
<td>16</td>
</tr>
</tbody>
</table>
6 Executive Summary

Fuel cells are a promising clean and efficient energy conversion technology for urban bus fleets throughout the world. While there appears to be a broad consensus that the fuel cell market will develop first in bus fleets, numerous challenges and barriers exist that will need to first be overcome.

Barriers include those that arise for any new energy technology, such as an undervaluation of environmental and other societal benefits, continued availability of cheap fossil energy, limited global demand for clean technologies, and an inability to achieve economies of scale at current levels of production. In addition, there are other barriers that are unique to fuel cell technology, such as immature development of fuel cell design and manufacturing technology, inadequate hydrogen infrastructure, high initial costs, lack of adequate storage technology, an inadequate regulatory framework, and poor public perception. Finally, to commercially introduce fuel cell buses in most developing countries, the above challenges and barriers are even further exacerbated due to high costs, modest institutional capacity, and low levels of awareness.

A variety of policies can be put in place in both industrialized and developing countries with the aim of overcoming these barriers. Ten are offered in this report. Commercialization of fuel cell technology can be promoted through research, development, and demonstration (RD&D), which aims to foster breakthroughs in fuel cell technology and applications by making funding available from either the public sector or public-private partnerships. Government Mandates such as emission standards and technology controls can help to ensure that the fuel cell buses are considered as an option relative to conventional technologies. Another policy option are fiscal Incentives such as taxes and subsidies. Finally, an awareness building policy can help educate the public at large on the merits of transitioning to a hydrogen economy and the use of fuel cell technology.

The key to realizing a transition to a hydrogen economy for tomorrow -- and thus reaping the associated local and global environmental benefits -- will depend on making the right policy choices today. The policies described in this report summarize a set of policy prescriptions that can have an impact in near-term development while setting the stage for reinforcing the switch to a long-term sustainable energy system. There will be costs associated with the policies to enact this transition, but there will also be great rewards.
7 Introduction

Fuel cells are a promising clean and efficient energy conversion technology for urban bus fleets throughout the world. Transit systems are facing both local initiatives to improve air quality and international efforts to reduce greenhouse gas emissions, which are increasingly more difficult to meet with diesel technology. Cleaner and more efficient technologies such as fuel cells will become increasingly necessary as urban air quality problems grow more critical, as GHG constraints become more stringent and, eventually, as fossil resources become scarcer.

Fuel cells have experienced rapid development over the past several years, with industry and independent cost projections indicating that light duty fuel-cell vehicles will be cost-competitive by late in the this decade, once mass production is established. Daimler/Chrysler, Ford, Honda, Nissan, and Mazda have all produced prototype fuel-cell cars, and have formally announced plans to start mass production in the 2005-2007 timeframe. Though projections vary, industry analysts estimate that within the next twenty years, between 7 and 20 percent of new cars sold in the world will be powered by fuel cells.

The basic fuel-cell engine for buses would be similar to the fuel-cell engine in cars. Bus fleets are a particularly attractive commercial application for fuel cells because cost and volume constraints are less severe than with cars, and the supply of hydrogen is facilitated by the centralized refueling infrastructure that characterizes bus fleet operations.

To date, numerous fuel cell bus pilot projects using liquid or compressed hydrogen have been conducted in North American and European cities. Starting next year, a joint venture between Ballard Power Systems, Ford, and DaimlerChrysler aims to introduce 30 fuel cell buses across nine European cities. And, the Iceland Hydrogen initiative, unveiled in March 2001 and aiming to develop the world’s first hydrogen economy, begins with three hydrogen fuel cell buses in Reykjavik.

Indeed, many experts agree that the fuel cell market will develop first in bus fleets. However, while buses may present an easier near-term commercial target than cars, fuel-cell engine manufacturers are most aggressively pursuing the vastly larger automotive market. Policy options should be adopted to accelerate the commercialization of fuel cell technology for both applications.

This report surveys the policy options that could be implemented to accelerate commercialization of fuel-cell buses and, ultimately, transition to a hydrogen economy. A taxonomy is presented, which identifies and describes policies to advance clean bus technologies across a variety of development contexts. Some of these policies have already been adopted in certain places, and thereby provide an existing record of performance. The focus is primarily on the policy options available to national governments, although there are some measures that are applicable at the international level (e.g., harmonized standards).

---

3 For example, see F.R. Kalhammer, P.R. Prokopius, V.P. Roan, G.E. Voecks, 1998, Status and Prospects of Fuel Cells as Automobile Engines, a report of the Fuel Cell Technical Advisory Panel prepared for the California Air Resources Board, Sacramento, California, July.

4 For example, see American Methanol Institute, 2000, Beyond the Internal Combustion Engine: The Promise of Methanol Fuel Cell Vehicles.
In this paper, we first provide an overview of the context for a discussion of policies, namely the challenges and barriers to for widespread use of fuel-cell technology and a transition to a hydrogen economy. Following this discussion, we provide a survey of 10 specific policies that are available to policymakers in industrialized and developing countries to help promote a transition to the use of FCBs. This discussion focuses on a description of the policy its implementation feasibility, and a brief review of pertinent experience. Finally, the last section reviews the applicability of the policies to the rungs of IEA’s “bus technology ladder.”

8 Context

8.1 Fuel Cell Technology

As described in detail in other sections of this report, fuel-cell vehicles (FCVs) have the prospect for near zero tailpipe emissions of criteria pollutants (CO, NOx, HCs, etc.) and, depending on the fuel source, very low net lifecycle emissions of GHGs (including those associated with the production and delivery of the fuel for the fuel cell).

Fuel cells produce electricity through an electrochemical reaction between hydrogen (or hydrogen-containing fuels) and oxygen from air (see Box 1). There are six main types of fuel cells - each named according to the electrolyte used in its system - are phosphoric acid, molten carbonate, solid oxide, direct methanol, alkaline, and proton exchange membrane (PEM). Of these, the phosphoric acid fuel is the most commercially advanced, having been deployed in many applications around the world.

The hydrogen used in fuel cells can be obtained either by conversion of currently available primary sources such as oil, coal, natural gas, or biomass, or by electrolysis of water using electricity, including renewable sources such as solar, wind energy or hydro. Hydrogen can also be produced on-board by reforming a hydrogen-containing fuel such as conventional petroleum-derived fuels, ethanol, or methanol, which eliminates the need for a pure hydrogen supply, but necessitates a sophisticated on-board fuel processing subsystem.

Box 1: Fuel cell components. The key components are an anode, to which the fuel is supplied, a cathode, to which the oxidant (usually air) is supplied; and an electrolyte, which keeps the fuel separate from the oxidant. The fuel molecules are first separated into electrons and ions at the interface of the anode and electrolyte. The ions migrate through the electrolyte toward the cathode, while the electrons, which cannot move through the electrolyte, take an alternate route external to the fuel cell. The ions, oxidant, and electrons combine at the interface of the cathode and the electrolyte, producing water and/or carbon dioxide in amounts that depend on the type of fuel cell and type of fuel. The stream of electrons flowing through the external circuit is electricity.

Fuel cell buses (FCBs) have been identified by GEF as a promising future technology for GHG emissions reductions that are relevant to its Operational Programs OP7 and OP11. The chief roles for GEF are to fund the incremental costs associated with FCBs, collaborate with other multilaterals to serve as facilitator for commercializing the technology in developing countries, and serve as agent for information exchange. At present, GEF funding is being directed to support the introduction of FCBs for developing country markets, where bus markets are potentially large. The GEF strategy involves three phases, preparatory, demonstration, and commercialization. To date demonstration projects are at various stages of implementation in a few countries.

8.2 Hydrogen Infrastructure

It is difficult to build up demand for fuel cell vehicle technologies when a hydrogen infrastructure does not yet exist. Conversely it is difficult to motivate investment in a hydrogen infrastructure before there is significant demand from fuel cell vehicles. However, storage and infrastructure issues can potentially be overcome through two main strategies, namely:

- **On-board reforming.** Fuel cell vehicles could initially be commercialized based on systems with integrated fuel processing technology that allows liquid fuels to be “reformed” to hydrogen on board the vehicle. This could be developed for standard petroleum-derived hydrocarbon fuels, or alternative fuels such as ethanol and methanol, which are somewhat easier to reform than hydrocarbon fuels yet demand less significant infrastructure investments than hydrogen;

- **Creation of localized hydrogen distribution systems.** A hydrogen infrastructure could begin with localized mini-infrastructures created for specific dedicated markets such as a fleet of buses, delivery vans, etc.

For hydrogen to be a major energy carrier, as envisioned in the second bullet above, it must be able to be stored and transported economically. A range of technologies is under development to address this issue, as follows:

- **Compressed hydrogen:** this is the simplest and most cost-effective method for storing hydrogen on board vehicles, requiring only a compressor and pressure tank. Raising hydrogen’s low storage density pose economic as well as safety issues.

- **Liquefied hydrogen:** At a cost about five times as high as for compressed gas, hydrogen can be liquefied by compression and cooling to form a dense liquid. The resulting liquid hydrogen must then be stored a very low temperatures – below 250 Celsius.

- **Metal hydrides:** These are compounds that chemically bond the hydrogen at the molecular level in the metal through cooling and release hydrogen through heating. Some disadvantages exist related to the cost and weight of these systems.

- **Carbon-based systems:** These systems involve the development of materials that can store hydrogen at room temperature. Such systems are currently at an early stage of development.

Typically, hydrogen is transported in liquefied form using tanker trucks. However, compressed hydrogen can also be transported using pipelines, which are similar to those used to transport

---

natural gas. Both Europe and North America currently have hundreds of kilometers of operational hydrogen pipelines.

9 Challenges to Fuel Cell Commercialization

9.1 Challenges Common to New Technologies

There are a number of challenges commercialization barriers exist for widespread use of fuel cell technology. Some of these barriers are the same as for other new energy technologies, especially renewable energy technologies, namely:

- **Undervaluation of environmental and other societal benefits.** The public health impacts of air pollution are not factored into cost assessments, nor are environmental costs of resource extraction and depletion.

- **Continued availability of cheap fossil energy.** Highly efficient technologies such as fuel cells are disadvantaged when fuel prices are low. This is exacerbated by the fact that fuel prices in many countries are subsidized either directly (especially diesel for cargo and public transport) or indirectly (through import policies, military support, etc).

- **Limited global demand for clean technologies.** In face of other pressing development needs in many countries, scarce resources are available to meet clean development objectives.

- **Inability to achieve economies of mass production.** Even for technologies with good prospects for long-term competitiveness, low demand poses the classic “chicken and egg” problem, wherein conventional technologies are locked-in despite being inferior to new technologies that have not yet established markets.

9.2 Challenges Unique to Fuel Cells

Fuel cell technologies have their own unique set of challenges related to their relative technological newness and their need for hydrogen as a fuel. Some of the more prominent issues include:

- **Continuing development of fuel cell design and manufacturing technology.** Developers are still in the process of designing complete, integrated, optimized systems, with fully tested power electronics, electronic motor controller, thermal management, water management, air management, stack assemblies, fueling/fuel storage/fuel processing. Manufacturing processes are still under development, and significant cost reduction must still be realized in order to make large-scale commercialization feasible.

- **Inadequate hydrogen infrastructure.** The existing fuel supply infrastructure is oriented to the delivery of liquid fuels

- **Costs.** Continuing high production costs of hydrogen from both fossil and renewable energy sources

- **Storage.** Lack of attractive low-cost hydrogen storage technology

- **Regulatory framework.** There is currently a lack of widely accepted safety codes and performance standards for hydrogen infrastructure, handling, and storage
• **Perception.** In the public at large, there is a generally negative perception of hydrogen as a volatile and dangerous substance, and uncertainty about the performance of fuel-cell vehicles.

9.3 **Challenges Unique to Fuel Cell Buses**

For most developing countries, where there are not research and development activities in fuel-cell technology, the above challenges and barriers are even further exacerbated. The introduction of FCBs to urban fleets faces a number of specific barriers that dominate their consideration:

• **Costs.** Since FCBs have not achieved cost reductions that make them competitive with diesel buses, the conventional alternative in most countries;

• **Technical Capacity.** A small number of ongoing demonstration notwithstanding, there is little technical, institutional, and policy capacity related to the introduction, operation and maintenance of FCBs;

• **Awareness.** There is a lack of awareness and acceptance of FCB technology among policy makers, potential private sector investors, and the general public.

In the next section, a range of policy options are explored that address these barriers and challenges. Effective policy proscriptions to meet these assorted challenges and barriers will benefit from effective coordination between industrialized and developing nations. Such activities can facilitate adequate levels of information exchange, technology transfer, capacity building, and private/public partnerships.

10 **Policy Options for Action**

A wide range of policies can be applied to encourage the adoption of FCBs for transit fleets in industrialized and developing countries. In this section we identify and describe a set of 10 policies that can be categorized into the following strategy types:

• **Research, Development, and Demonstration.** This type of policy category aims to foster breakthroughs in fuel cell technology and applications. Specific policies include: 1) funding for research and development, 2) demonstration projects, and 3) public-private partnerships.

• **Government Mandates.** This policy category aims to exert control over technology performance through governmental regulatory actions to ensure that the fuel cell buses are considered an attractive option relative to conventional technologies. Specific policies include: 4) emissions standards and technology controls, 5) licensing and certification requirements, and 6) procurement targets.

• **Fiscal Incentives.** This type of policy category is designed to influence decisions by organizations and individuals through changes in prices or costs. Specific policies include 7) taxes, and 8) subsidies.

• **Awareness Building.** This category of policies focuses on a range of measures to educate the public at large on the merits of transitioning to a hydrogen economy and the use of fuel cell technology. Potential policies include 9) public education and 10) targeted training for key stakeholders.
Most of the above policy options types can be applied either as a singular intervention, or in combination with other policies. For example, a government mandate for a certain percentage of urban buses to be FCBs could be coupled with a fiscal incentive in which part of the incremental capital cost is offset through a subsidy. In the following subsections, we classify a potentially promising set of 10 specific policies that fall within the above broad categories that could help to promote an accelerated transition to FCBs. After providing a general description of the particular policy, we also indicate the relevance of the policy for promoting FCBs regarding the following criteria:

- **Implementation feasibility.** The relates to policy (i.e., can the policy be directly linked to emission reductions from buses), and its potential for accelerating commercialization of FCBs (i.e., can the policy lead to reductions in technology capital costs); and

- **Experience.** Where possible, we provide a summary of examples of where the policy has been implemented to promote FCBs;

It is important to note that for many policies there is little or no experience related to the application to FCBs. Where appropriate, we have identified those instances where relevant experience exists for other technologies on the “bus technology ladder.”

### 10.1 Research, Development, and Demonstration

Fuel cell research, development and demonstration (RD&D) activities require multidisciplinary activities involving a range of technological competencies, which are dispersed among universities, private industry, and public research laboratories. RD&D policies have demonstrated the potential to advance introduction dates for new technology, reducing the price, and enhancing performance.\(^6\) RD&D efforts include a strategic planning role to identify opportunities for collaboration with the private sector, and analysis of future scenarios, and coordination with RD&D programs internationally.

1. **Research and Development Activities.** Research and development policies aim to support technological development and breakthroughs through public funding and other types of public support and incentives. Most RD&D expenditures on fuel cell technologies is occurring in the industrialized countries, as funding levels required to achieve research objectives are large and typically beyond the reach of developing countries. Nevertheless, even in industrialized countries the challenges are large, leading to calls for a common European strategy to more closely match funding support for fuel cell research and development in Japan and the US.\(^7\)

- **Implementation feasibility.** The main constraint (other than availability of funds) to R&D initiatives is the technical capacity of a given country to absorb, interact with, and build upon existing research. Of the roughly $1 billion spent annually in worldwide R&D for fuel cells, 80 percent is directed at the development of fuel cells for transportation.

- **Experience.** Several publicly funded R&D initiatives have been launched in Europe, Asia, and North America. The first of these led to the deployment of fuel cells in high-tech

---


\(^7\) European Commission, DGXII-F, 1998. *A Fuel Cell Research, Development And Demonstration Strategy For Europe up to 2005*
aerospace applications, but the most recent of which have focused on commercial applications in vehicles and stationary power generation, and involve research on production, storage, utilization, and safety. As an example, a summary of the major research emphases in the US hydrogen research program is provided in Table 1.

Table 1: Fuel Cell Research and Development Activities in the USA

<table>
<thead>
<tr>
<th>Department of Energy (DOE)</th>
<th>On-board and off-board systems, building applications</th>
</tr>
</thead>
<tbody>
<tr>
<td>National Aeronautic and Space Agency (NASA)</td>
<td>Hydrogen leak detection, liquefied hydrogen storage</td>
</tr>
<tr>
<td>Defense Advanced Research Projects Agency (DARPA)</td>
<td>Direct methanol fuel cells, logistic-fueled fuel cell power plants</td>
</tr>
<tr>
<td>Department of Transportation (DOT)</td>
<td>Fuel cell buses</td>
</tr>
<tr>
<td>Department of Defense (DOD)</td>
<td>Hydrogen production and storage</td>
</tr>
</tbody>
</table>


2. Fuel Cell Demonstration Projects. Demonstration projects are an important component of RD&D activities. Because fuel cell buses are not commercially available, prototype fuel cell bus demonstration projects provide experience by which to better understand the technology, evaluate the performance, emissions, cost, and operating characteristics of the buses, define infrastructure needs, and plan for future evaluations. They provide information on real-world operating conditions about the durability of the fuel cell system under transit duty cycle, its compatibility with transit operating and maintenance practices, and potential life cycle costs. Safety issues, as well as the range of feedstock fuels, can be evaluated from both a vehicle and infrastructure perspective.

- **Implementation feasibility.** The effectiveness and difficulty depends greatly on the ambition of the demonstration program. Simple, limited demonstration programs that aim to operate a bus for a short period of time, relying on outside expertise, could be relatively straightforward to implement. More extensive demonstration programs that aim to create and expand a long-term fuel cell bus operation, build local capacity, contribute to infrastructure development, establish local manufacturing ability, create outreach to the broader community, etc., can be much more challenging to successfully carry out, but ultimately will be much more effective at building markets for fuel cell buses.

- **Experience.** A large number of demonstration projects have been implemented or are in planning. (See Table 2) Note that all of the demonstration programs for which buses have already been operated have occurred in major urban centers in the industrialized countries. The GEF fuel cell bus project is the first that targets cities in developing countries.

3. Public-Private Partnerships: In general, the aim of such partnerships is to bring together the strengths of both the public and private sectors to facilitate infrastructure development and technological innovation. They have become increasingly common in fuel cell demonstration projects. Indeed, almost all of the fuel cell research activities and demonstration projects described above are being conducted in the context of a partnership between public and private institutions – motivated by reasons of investment, technology expertise, or distribution channels.
In addition to improving efficiency, public-private partnerships can provide capital to finance government programs and projects of a commercial nature, thereby freeing public funds for other economic and social programs.

<table>
<thead>
<tr>
<th>Program</th>
<th>Cities</th>
<th>Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>XCELLSIS/Ballard</td>
<td>Vancouver, Chicago</td>
<td>3 buses per city</td>
</tr>
<tr>
<td>Phase 3 Fuel Cell Bus Program.</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Generation I, II, II fuel cell bus project</td>
<td>Georgetown</td>
</tr>
<tr>
<td></td>
<td>Bavarian hydrogen initiative</td>
<td>Erlangen, Germany</td>
</tr>
<tr>
<td></td>
<td>THERMIE Programme of EC</td>
<td>Berlin, Copenhagen, Lisbon</td>
</tr>
<tr>
<td></td>
<td>GEF fuel cell bus Initiative</td>
<td>Brazil, Mexico, Egypt, India and China</td>
</tr>
</tbody>
</table>

• **Implementation feasibility.** The implementation of public-private partnerships for fuel cell technology development has the advantage of a good track record. Such partnerships have led the development of fuel cells at least since the days when International Fuel Cells first worked with the US National Aeronautic Space Agency (NASA) to supply electricity to the manned space missions. Collaborative research at national laboratories, universities, and private companies have produced significant recent breakthroughs in technologies, such as large reductions in platinum requirements of PEM cells. Key to the formation of public-private partnerships is the realization that such partnerships are cost-effective and can yield greater benefits than individual efforts.

• **Experience.** There are many examples of public-private partnerships. The California Fuel Cell Partnership - formerly begun in 1999 between auto manufacturers, oil companies, a fuel cell company, and the State of California - aims to advance fuel cell vehicle technologies and addressing fuel infrastructure issues, as well as launching an estimated 70 demonstration fuel cell passenger cars and fuel cell buses between 2000 and 2003. Other public-private partnerships include the Northeast Advanced Vehicle Consortium (NAVC), Hawaii’s proposed Hydrogen Private-Public Partnership, and Canada’s National Fuel Cell Research and Innovation Initiative

### 10.2 Government Mandates

Government mandates can encourage adoption of fuel cell technology by requiring a particular action required on the part of the private and public sectors. Mandates are typically regarded as a “command and control,” as opposed to market-oriented, option because they are a regulatory-based mechanism with enforcement provisions. Examples include mandatory emissions standards, licensing and certification requirements, vehicle procurement targets, and emission controls. Enforcement mechanisms typically resort to financial or legal sanctions applicable to manufacturers, vehicle owners, and operators.
4. Emissions Standards and Technology Controls: Emission standards refer to limits in the emissions of pollutants from individual sources by specifying a maximum emission rate for each pollutant (from example in units of grams per kilometre travelled). One advantage of an emission standard is that they can mitigate excessive geographic concentrations of pollutants, especially in densely populated areas, which could occur through some of the transferable emission rights policies. A disadvantage of performance standards is that since they specify emission rates, the total emissions of pollutants may increase over time as the bus fleet size increases in order to meet increasing demand. Technology controls specify the particular technology that must be utilized to control emissions. They differ from standards in that they do not constrain emission rates but rather impose a certain control technology.

- Implementation feasibility. The link of emission standards and technology controls to policy objectives is high, but these policies are generally unpopular with entities that are required to comply. If the policy dictates a specific technology or standard, it may be inappropriate in different locations or for different companies. Flexible regulations coupled with fiscal and other incentives for early adopters of advanced technologies can provide impetus for rapid implementation. Internationally harmonized regulations can help ensure that developing countries do not become the target of obsolete technologies.

- Experience. There are many examples of government mandates to improve performance in the transport sector. India has had recent experience regarding technology controls. Indian transit entities must comply with a government mandate requiring that over 7,000 transit buses and 2,000 school buses in New Delhi operate on natural gas by March 2001. This program has faced serious initial implementation hurdles and is far from operational. In Brazil, the introduction of more stringent emission standards have led Sao Paulo officials to take action and mandate that all buses be powered by natural gas by 2005. In the USA, the South Coast Air Quality Management District in California requires “all new transit vehicle or urban bus purchases or leases must be alternative-fuel heavy-duty vehicles when adding or replacing buses to their vehicle fleet.”

5. Licensing And Certification Requirements: Licensing and certification procedures specify protocols for companies and individuals to comply with regulations. They also ensure that government agencies set realistic standards and regulatory requirements, with proper testing facilities (to measure loaded-mode bus emissions, for instance) and standardized procedures. They also help harmonize implementation of rules across different manufacturers, technologies, and private operators. Licensing and certification requirements include inspection and maintenance (I&M) programs that require existing vehicles to be tested for emissions and be repaired if failing to meet the operative emission standard. At present there are no licensing and certification requirements for fuel cell buses. However, such standardization is necessary to move from demonstration programs to large-scale implementation.

- Implementation feasibility. Government agencies must have proper training and capacity to set up licensing and certification procedures. They must also ensure that administrative procedures are carefully designed to absorb the cost of licensing, and yet contain disincentives for corruption. Due to the fact that fuel cell buses are a relatively new

---

technology, certification and licensing procedures for fuel-celled buses are likely to face challenges unless simple standards are developed and adopted at first. Many programs are oriented toward private vehicles but can be expanded to include buses as well.

- **Experience.** There is ample experience in industrialized and developing countries with developing licensing and inspection requirements for vehicles. Some programs are fairly stringent such as California’s program for new vehicle certification to meet emissions standards, in effect for light-duty vehicles and heavy-duty engines of different sizes and technology types. However, some technical barriers (e.g., design and implementation of heavy-duty chassis dynamometers) have made it difficult to set up adequate certification procedures for stringent tail-pipe emission standards from trucks and buses.

6. **Procurement Targets:** The public sector (e.g., federal, provincial, state, and municipal agencies) can choose to adopt certain vehicle purchasing criteria. This would involve specifying that a certain percentage of new bus purchases be of fuel cell buses. Given the commercial availability of the technology and depending on the procurement target itself, the overall bus fleet can be transformed. Compared to demonstration projects, this type of action is of a much larger scale and more likely to have a greater effect on reducing capital costs through promoting economies of scale in their production. Additional economies might be achieved with national or even international purchasing consortia. Due to high capital costs, setting procurement targets for fuel cell buses will be influenced by cost considerations, unless adequate fiscal incentives are available.

- **Implementation feasibility.** Transit agencies throughout the world have developed broad levels of competence in conventional vehicle procurement. Incorporating a fuel cell bus component could ideally fit well within the procurement framework already established. However, meeting procurement targets on a forward looking basis will likely require the development of specific fuel cell bus procurement guidelines as a starting point for a transit agency assembling a solicitation of offers and to guide cost-effective procurement. Although such guidelines could operationalize procurement of fuel cell buses, there may be reluctance on the part of fleet managers to make major changes to their operations if the new technology has not been well demonstrated and accepted.

- **Experience.** At present, there are no jurisdictions that have set a procurement target for FCBs. However, there is growing experience related to “green vehicle procurement” of high efficiency and alternative-fuelled vehicles. For example, the New York City's Metropolitan Transportation Authority has approved an order for 200 hybrid electric transit buses worth $77 million. This order is the largest order of its kind in North America. Other North American examples include operations for Logan Airport in Boston, Massachusetts that purchased 32 CNG buses. Since 1998, the bus fleet has procured no new diesel buses.

---

9 Based, for example, along the lines of Denver’s Green Fleets Program
10 Source: [http://www.massport.com/planning/logan_commu.html](http://www.massport.com/planning/logan_commu.html)
addition the record of alternative fueled bus performance in many European cities has been in the whole quite positive relative to diesel alternatives.\textsuperscript{12}

### 10.3 Fiscal Incentives

Fiscal incentive policies are designed to influence decisions by organizations and individuals through changes in prices or costs. Typically, they include taxes and subsidies on production factors (for example, carbon tax, fuel tax), taxes on products and other outputs (for example emission taxes, conventional bus equipment taxes, financial inducements (for example tax credits, subsidies) and transferable emission rights (for example, tradable emission reductions, tradable credits). The choice of policy option would depend on the particular objectives to be met. National governments could pursue action in most of these policy areas. International organizations could facilitate exchanges of information regarding implementation issues and economy-wide effects.

7. Taxes: Taxes represent a versatile policy measure, as they are able to address many of the different social costs related to conventional transit buses at once. These instruments involve imposing charges on goods that are deemed less desirable by virtue of their environmental impacts or other external costs. Taxes can have either direct or indirect effects on transit systems as they act on both technology and broad travel behavior. For example, fuel taxes could be based on carbon content of fuels to encourage the use of low carbon emitting fuels and discourage the use of fuels with high carbon emissions. Targeted vehicle taxes could encourage purchase of fuel cell buses while discouraging purchase of conventional diesel buses. Typically, a large share of tax revenues has been devoted to road construction and maintenance. Revenues generated from additional taxes could be devoted to funding FCB programs. They could also be returned entirely or in part to citizens, through reductions in other taxes or in direct payments to households.

- **Implementation feasibility.** Since there is widespread experience with motor fuel taxes, it would be straightforward from a strictly mechanical perspective to implement additional taxes. Mechanisms for collecting taxes are already in place. As to their disbursement, revenue recycling to fund FCB programs may require a restructuring of the tax system. Tax shifting approaches could be considered which would integrate subsidies on desirable goods with charges on undesirable goods. For example, vehicle feebates apply a purchase tax to vehicles with high emissions and a subsidy to vehicles with low emissions. The levels of the subsidies are designed to counter each other so the programs are approximately revenue neutral. The acceptance and direct change of these policies each lie between those for subsidies and for financial instruments. While such policies, where implemented, are designed to affect consumer-purchasing behavior of light duty vehicles, systems could be designed to incentivize the purchasing decisions of bus fleet managers and authorities. An important consideration in tax/fiscal policies is their distributional and equity impacts.

- **Experience.** Substantial fuel tax levels have had the effect of making the cost of operating a vehicle reflect a larger share of its social costs. In Europe, it has been politically acceptable to tax and use the national treasury for subsidizing transportation initiatives. In the major cities

\textsuperscript{12} Watt, G. 2000, *Natural Gas Vehicle Transit Bus Fleets: The Current International Experience*
of Italy, France, Germany, Sweden, Netherlands and Belgium, subsidies for public transportation are quite high by U.S. standards, and fares are between only fifteen and forty percent of operating costs. In the U.S., fares cover thirty to seventy percent of operating costs. In Europe, fuel taxes represent around 70% to 80% of the price of petrol -- in the USA, about 33%. High fuel taxes have provided incentive for Europeans to switch from private cars to other forms of transport, which have lower social costs.

8. Subsidies: Broadly speaking, subsidies are measures that keep prices beneath market level and that give financial support directly or indirectly to producers or consumers. Governments in both developing and developed countries intervene heavily in subsidizing transportation in many ways: from direct grants to mandatory regulations; from training assistance to price controls and guaranteed markets; and in providing infrastructure and related services. Many have argued that the inherent subsidies to the oil industry are a major obstacle to a transition to a hydrogen fuel economy. However, subsidies could be used to improve the financial returns for entities that take actions to improve the environment or achieve some public benefit. Grants, loans, tax credits and other such instruments could be applied directly to new technologies and practices. Moreover, import tariffs can be revised for environmentally desirable technologies that are produced outside of the country. While many types of current subsidies tend to aggravate problems by subsidizing current forms of energy consumption, subsidies can nevertheless be implemented to creating conditions favorable to commercialization of FCBs.

10.4 Awareness Building

Awareness building policies concern providing information that explains factors relevant to FCBs (e.g., identifying specific benefits of FCB, describing problems with status quo operations), justifies particular aspects of complementary policies (e.g., level of standards or taxes, amount of funding for research), helps those applying the policy to avoid problems in reaching objectives, and facilitates improvement in future projects. At the national level, this policy strategy is integral to supporting any of the other policies but can also be considered as an independent policy strategy.

At the international level, awareness-building policies can be designed to enhance technology transfer and institutional capacity. For example, an essential complementary policy is the information flow at the multilateral level. Effective information and technology transfer will need the awareness and support of multilaterals involved with energy, environment and trade issues. Policies include a) using existing program structures to facilitate transfer of information and technology b) providing the policy objectives and specific design to agencies that might be aware of barriers to its effectiveness and alternative designs.

9. Public Education: These policies mostly focus on disseminating information to individuals that may not have a direct stake in the process but whose acceptance and support will aid in positively affecting perceptions of FCB technology. Options include a) providing information about health, noise reduction and other co-benefits of FCBs – both theoretical and based on emerging results pilot programs, b) demonstration projects, as described in an earlier section,

directly include individuals in the project and c) educational programs at schools to engage students at more in-depth levels.

- **Implementation feasibility.** The effectiveness of these policies corresponds to how closely they are tied to other policies that individuals can see or participate in. Providing information on FCB operations and benefits in conjunction with a demonstration project will improve both policies’ abilities to encourage adoption on the technology.

10. **Training for Stakeholders:** The support and relevant knowledge of policy stakeholders (transit districts, bus company owners, maintenance technicians, and bus drivers) will greatly affect the success of any policy and long-term goals of FCB diffusion. In addition to the information aimed at the general public (as described in the previous subsection), options include: a) providing information about longer term financial and maintenance advantages of FCBs to influence purchases by private companies; b) providing training for companies interested in FCBs, preferably at a company with significant experience – this training should comprise any fleet management issues along with specific programs for drivers and technicians; c) providing training and technical materials to FCB (or component) manufacturers; and d) designing policies such that learning can be effectively passed along to the different stages of the policy, to subsequent policies (RDD leading to appropriate standards) and to policies in other countries.

- **Implementation feasibility.** These policies will be most effective when tied with policies that have direct links to technology diffusion. International agreements will likely be needed to promote exchange of the most recent experiences – this will call for efforts by national governments and multilateral organizations.

- **Experience.** Vancouver, B.C. and Chicago, Illinois had similar FCB demonstration policies that were able to benefit from the other’s experience. Other efforts are focused on alternatively fueled buses due to the more limited history of FCB policies. Specific examples include 2 efforts by Clean Cities International, a program of the US Department of Energy – (1) reports that “Efforts are also underway in Monterrey, Mexico, through an agreement with Clean Cities consultants at Gladstein and Associates, to conduct a reverse trade mission, provide outreach materials, and build a Clean Cities initiative.” The USDOE has asked international organizations, such as the U.S. Agency for International Development, to fund efforts such as training programs for technicians and drivers operating natural gas buses.

11 **Applicability of Policies to IEA’s “Bus Technology Ladder” Concept**

Much of the discussion to this point has been highly focused on policies that can promote the penetration of FCBs in transit bus systems. In many contexts, these policies could also have a significant impact in promoting a transition to the use of other types cleaner and more efficient. For example, a standard requiring that air pollutant emissions be below a certain threshold could

mean the purchase of buses having certain emission control technologies, and could be monitored through a fleet inspection and maintenance program.

The International Energy Association has developed a ladder for cleaner bus technologies consisting of the following six rungs:

- **Better Bus Maintenance.** This corresponds to regulations for addressing inspection and maintenance operations of transit bus fleets.

- **Diesel Water Emulsions** - A low-emission diesel fuel/water blends to produce a stable fuel emulsion that can be safely stored and used in existing diesel technology. The emulsion reduces two of the most critical emissions from compression ignition engines -- nitrogen oxides (NOx) and particulates (PM). The fuel can be used in older and newer diesel engines and requires no modification to fuel systems or engine hardware.

- **Low sulfur diesel with Catalytic Filter** This involves using low sulfur diesel to reduce SOx emissions combined with a catalytic filter, an emission control technology that combines the functions of catalytic converter and particulate soot trap to reduce particulates and NOx. These technologies can be applied to existing diesel buses.

- **Alternative fuels** – Compressed natural gas (CNG), di-methyl ether (DME) and liquefied petroleum gas (LPG) can be used to fuel transit buses and result in lower particulate and NOx emissions than standard gasoline or diesel buses. Existing engines can be converted to use one of these fuels or new buses can be built with engines designed specifically for the alternative fuel. These technologies are commercialized with one in four buses on order in the US using alternative fuel.  

- **Hybrid Electric** This technology combines a combustion engine with a battery, or similar device, for storing energy. This lowers emissions through increased fuel economy (resulting from using efficient electric motor to drive wheels and storing energy otherwise lost when braking). These vehicles are in the early stage of commercialization.

- **Fuel Cell Buses.** FCBs represent a vanguard technology holding promise for attaining emission reductions at or greater than that achieved in the previous rungs.

- **Hydrogen Infrastructure.** The last step in the ladder could be development of sufficient scale in FCB use to warrant a more extensive infrastructure for producing, storing and delivering hydrogen fuel.

Several polices could promote action at all levels of the ladder, depending on the design and level of the policy and the conditions of the host country. For example, increased fuel taxes on diesel would increase the financial benefits of technology or practices at any of the rungs. Information or Research Development and Demonstration are vital components of any policy design for technologies and practices that are not considered standard in the host country. However, such policies are particularly important for technologies and practices with few current applications.

---

Since the policies have been described in some detail previously, we use the following table to summarize ideas on the close matches between policies and rungs of the technology ladder. We classify each of the policies described in the previous section relative to their appropriateness for each rung in the technology ladder as “good”, “fair”, “poor.” Policies that are not applicable to the particular rung are indicated with “NA” for not applicable.

12 Conclusions

This previous discussion has reviewed fuel cell technology, barriers, and policies. In addition, a broad assessment has been offered regarding the suitably of certain policies relative to the bus technology ladder. It is important to again stress that while there appears to be a broad consensus that the fuel cell market will develop first in bus fleets, a host of built-in challenges and barriers will need to first be overcome. Apart from research and development, the 10 policies are appropriate for consideration in both industrialized and developing countries. The key next step will be to undertake some form of market assessment at either a national or regional level to assess the right mix of policies relative to a country’s unique circumstances. Certainly, there will be costs associated with an enactment of some subset of these policies, but there will also be ample benefits from the transition to a more sustainable energy system.
13 List of References

<table>
<thead>
<tr>
<th>Table 3: Qualitative assessment of policies for the bus technology ladder</th>
</tr>
</thead>
<tbody>
<tr>
<td>Better Bus Maintenance</td>
</tr>
<tr>
<td>RD&amp;D</td>
</tr>
<tr>
<td>Research &amp; Development</td>
</tr>
<tr>
<td>Demonstration</td>
</tr>
<tr>
<td>Government Mandates</td>
</tr>
<tr>
<td>Emissions Standards and Technology Controls</td>
</tr>
<tr>
<td>Licensing And Certification Requirements</td>
</tr>
<tr>
<td>Procurement Targets</td>
</tr>
<tr>
<td>Fiscal Incentives</td>
</tr>
<tr>
<td>Taxes</td>
</tr>
<tr>
<td>Subsidies</td>
</tr>
<tr>
<td>Awareness Building</td>
</tr>
<tr>
<td>Public Education</td>
</tr>
<tr>
<td>Training</td>
</tr>
</tbody>
</table>


17