Are Electric Vehicles Viable in Kathmandu? A Cost-Benefit Perspective

Submitted by

Saurav Dev Bhatta
and
Dilliraj Joshi

for

Integrated Development Society (IDS), Kathmandu

Submitted to

Kathmandu Electric Vehicle Alliance

Prepared for KEVA Secretariat under USAI/NEPAL
Cooperative Agreement NO: 367-A-00-02-00203-00 with PADCO, Inc;
Washington, DC

Table of Contents

Page Number

List of Tables

List of Boxes and Figures

Acknowledgement

We would like to express our gratitude to the Kathmandu Electrical Vehicle Alliance (KEVA) for inviting us to carry out this research. In particular, we want to thank Mr. Bibek Chapagain, KEVA – In country Coordinator, PADCO; Mr. Bikas Raj Pandey, Country Representative, Winrock International, Nepal; Mr. Suman Basnet, Director, REPSO, Winrock International, Nepal; and Dr. Bhola Chalise, Program Consultant, Winrock International, Nepal for their support.

It would have been impossible to complete this study without the inputs from various individuals who generously took time of their busy schedules to provide us with first-hand information relevant to the research. We would like to acknowledge the help received from the following individuals in this regard.

Mr. Adam Friedensohn, Himalayan Light Foundation
Mr. Ashok Raj Pandey, Nepal Electric Vehicle Industry (NEVI)
Mr. Balaram Timilsina, Trolley Bus Office
Mr. Bishow Ram Shrestha, Jana Utthan & Environment Electric Vehicle Pvt. Ltd.(JEEV)
Mr. Chiranjivi Gautam, Advisor, ESPS/DANIDA
Mr. Deepak Adhikari, Nepal Electricity Authority
Mr. Ek Raj Pokharel, Department of Transport Management
Mr. Lok Nath Subedi, former NEVI charging station employee
Mr. Megesh Tiwari, KEVA
Mr. Murari Sigdel, microbus owner
Mr. Pravakar Khadka, Electric Vehicle Association of Nepal (EVAN)
Mr. Rajon Lohani, Jana Utthan & Environment Electric Vehicle Pvt. Ltd. (JEEV)
Mr. Ram Kazi Maharjan, microbus owner
Mr. Ram Prasad Shedai, Department of Customs
Mr. Rajendra Brd. Karki, Kulayan Battery Industry
Mr. Rekh Brd. Thapa, Kulayan Battery Dealer
Mr. Taranath Phuyal, Nepal Electric Vehicle Industry (NEVI), Charging Station
Mr. Yadav Raj Gurung, Himalayan Light Foundation

Finally, we want thank our research assistant, Mr. Nirmal Sigdel, for his valuable help in gathering, compiling, and analyzing the relevant data.

Saurav Dev Bhatta
Principal Investigator
(Assistant Professor, University of Illnois at Chicago
Advisor, Integrated Development Society)

Dilliraj Joshi
Co-principal Investigator
(President,
Integrated Development Society)

Abbreviations

BPEV	Battery Powered Electric Vehicle
CEMAT	CEMAT Consultants
CEN	Clean Energy Nepal
CH_4	Methane
CO	Carbon monoxide
CO_2	Carbon Dioxide
DANIDA	Danish Agency for International Development
DoTM	Department of Transport Management
ENPHO	Environment and Public Health Organization
E-R	Exposure-Response
EV	Electric Vehicles
HC	Hydro Carbon
HMG/N	His Majesty's Government of Nepal
ICE	Internal Combustion Engine
ICEV	Internal Combustion Engine Vehicle
KEVA	Kathmandu Electric Vehicle Alliance
KV	Kilo Volt
LPG	Liquefied Petroleum Gas
MOF	Ministry of Finance
N_2O	Nitrous Oxide
NEA	National Electricity Authority
NESS	Nepal Environmental & Scientific Services
NMVOC	Non-methane Volatile Organic Compounds
NO_2	Nitrogen dioxide
NO_X	Oxides of Nitrogen
O_3	Greenhouse Gas Ozone
Pb	Lead
PCPI	Purchasing Power Parity Adjusted Per Capita Income
PM	Particulate Matter
PPP	Purchasing Power Parity
RSD	Respiratory Symptom Days
SO_2	Sulphur dioxide
TOD	Time of Day
VAT	Value Added Tax
VSL	Value of Statistical Life
WHO	World Health Organization

Executive Summary

A number of studies have shown that the poor air quality of Kathmandu is a matter of serious public health concern for Nepal. As the most important contributor to Kathmandu's air pollution is vehicular emissions, one way of tackling the pollution problem is through the promotion of zero emission electric vehicles (EVs) and other forms of clean transport. The biggest supporters of EVs in Kathmandu are, therefore, groups and individuals concerned about the deteriorating air quality of Kathmandu.

Environmentalists and other EV advocates generally focus on health and economic benefits when arguing for EV-friendly government policies. Recognizing these potential benefits of EVs, the government has already granted some tax and electricity tariff concessions to certain types of electric vehicles. But unless the degree of government support is increased, EVs will not be able to effectively compete with internal combustion engine vehicles (ICEVs) in the market. In order to increase government support to EVs, however, arguments based on the recognition of EV benefits alone will not be adequate. But if it can be shown that the *benefits* of electric vehicles to society outweigh the social *costs* associated with replacing their internal combustion engine (ICE) counterparts, then the government would be in a position to justify the enactment of new policy measures that will help increase the competitiveness of EVs.

This study performs a benefit-cost analysis of four types of electric vehicles that could potentially replace many of the existing ICEVs currently operating in Kathmandu, and identifies the cases where the government would be justified in further supporting EVs. It also briefly analyzes the impacts of potential EV-support measures on the cost-competitiveness of EVs in the market. The analysis is performed by comparing the benefits and costs of the following pairs of vehicles: (i) diesel-fueled microbuses and battery powered three wheelers (Safa Tempos), (ii) diesel-fueled microbuses and battery powered microbuses, (iii) diesel-fueled microbuses and trolley buses in the Tripureshwor to Suryabinayak route, and (iv) gasoline-fueled Maruti cars and battery operated REVA cars. It is expected that the results of the study will aid both the government and EV advocates in making informed decisions regarding the types of EVs that ought to be supported through government policies.

Social benefits and costs of EVs

As EVs are zero emission vehicles, the reduction in health damages arising from improved air quality is the most significant social benefit of replacing ICEVs with EVs. Among the pollutants emitted by ICEVs, particulate matter (PM_{10}) is the most potent in terms of impact on human health. Other pollutants that are damaging to health include sulphur dioxide (SO_2), nitrogen dioxide (NO_2), carbon monoxide (CO), and air toxics like benzene and formaldehyde. In addition, ICEVs also emit greenhouse gases that have an impact on the global environment.

A distinction must be made between existing or “old” ICEVs and future or “new” vehicles in terms of pollution potential. Older ICEVs emit higher levels of PM_{10}, SO_2, and NO_2 than new vehicles not only because of the difference in vehicle age but also because the latter have to meet the relatively stringent Euro 1 emission standards. Hence the health benefits of replacing old diesel vehicles by EVs are higher than the benefits of replacing new ones.

The social cost of an EV is the extra lifecycle cost associated with replacing an ICEV by an equivalent EV plus the health costs associated with the lead discharged from EV batteries. The lifecycle cost includes the extra production and operations cost as well as the cost of any additional infrastructure needed to operate the EV. Since the opportunity cost of old vehicles is zero, the extra cost of replacing old ICEVs by EVs is higher than the cost of replacing a new ICEV. Except in the case of trolley buses, the lifecycle costs of EVs are greater than the lifecycle costs of their ICEV counterparts, especially because of the high cost of EV batteries. Although the costs of battery lead discharge are not available in the literature, they are incorporated in this analysis by appropriately manipulating the benefit-cost equations. In this study, relatively conservative estimates of benefits and liberal estimates of costs are used in order to minimize the chance of falsely concluding that the benefits of EVs outweigh their costs.

Comparing EVs with ICEVs

The net social benefit of replacing a diesel microbus by an equivalent Safa Tempo is between Rs. 9642/year and Rs. 62181/year, if the cost of battery lead discharge is assumed to be zero. Because of lack of data on the impacts of battery lead discharge, the true cost of lead discharge cannot be incorporated in the net-benefit computation. But the analysis reveals that the net benefit would remain positive so long as the cost of lead discharge is not unrealistically high. Hence, it is clear that the government would be justified in giving further support to Safa Tempos.

The comparison of diesel microbuses and battery-powered electric buses shows that the costs of replacing the former by the latter are higher than the benefits even when the cost of battery lead discharge is not taken into account. Hence, unless technological improvements make BPEBs more cost-effective, it does not seem worthwhile for the government to support this category of EVs.

In the case of trolley buses, the net benefit of replacing old microbuses by equivalent trolley buses is between Rs. 7529/year and Rs. 45,136/year per vehicle. The net benefit of replacing a new microbus by trolley buses is negative if a low value is attached to the lives saved from pollution reduction. But since the benefits of replacing new microbuses outweighs the cost for reasonably high values for human life, there are sufficient grounds to argue for government support in reviving and expanding the trolley bus system.

Interestingly, however, the comparison of gasoline-fueled Maruti cars and battery-powered REVA cars shows a negative net benefit associated with replacing old Marutis with REVAs. The main reason for this is the substantially higher lifecycle cost of the REVA car. Hence, the replacement of existing Marutis by REVAs is not a desirable social objective. But the social benefit of replacing a *new* Maruti by an equivalent REVA is higher than the associated cost, with the net benefit ranging from Rs. 11,272/year to Rs. 12,224/year.

Making EVs competitive in the market

Currently the private lifecycle costs, i.e. the actual lifecycle costs seen by vehicle owners, of Safa Tempos and REVA cars are higher than the private costs of microbuses and Maruti cars, respectively. Trolley buses, on the other hand, have a lower lifecycle cost than new microbuses. But when compared with old microbuses, they too have a cost disadvantage. Hence, in general, these EVs cannot compete with their ICE counterparts in the market.

Making EVs competitive entails eliminating the private lifecycle cost gap between EVs and ICEVs. Given that EVs are so much more costly than old ICEVs, they cannot be made competitive with old ICEVs through changes in tax and tariff policies alone. If society is to enjoy the net benefits of replacing old ICEVs by EVs, then the government should consider banning the use of old microbuses in specific routes or enact regulations to gradually phase out the use of older ICEVs. In cases where it is desirable to replace new ICEVs by EVs, however, the government can enhance the competitiveness of the latter by manipulating policy variables such as the tax and tariff rates to either reduce the lifecycle cost of EVs or increase the lifecycle cost of ICEVs. The policy variables considered in this study include the average import tax + VAT rate for EVs, the interest rate for EV financing, the electricity tariff rate and a pollution tax on ICEVs.

Reducing the average tax rate or interest rate on EV financing cannot substantially lower the lifecycle costs of Safa Tempos. Allowing these EVs to purchase electricity directly at NEAs time of day (TOD) tariff rates will, however, give them a competitive edge over new microbuses. Similarly, raising the price of diesel to Rs. 49/liter via a pollution tax would also close the lifecycle cost gap in favor of Safa Tempos.

The lifecycle cost of a trolley bus is already less than the lifecycle cost of an equivalent new diesel microbus in spite of the large infrastructure cost needed to run the trolley buses. Hence, trolley buses should be able to compete effectively with microbuses once the Trolley Bus System is revived even if there is no additional government support. Enabling new REVA cars to compete with Marutis, on the other hand, would require the government to take concrete measures to reduce the purchase price of REVAs. For example, if the average import tax + VAT rate for electric cars were reduced from 160.4% to 70%, the lifecycle cost of the REVA would fall below the lifecycle cost of the Maruti 800. Although reducing the interest rate on EV financing could also achieve this result, the required rate reduction is too high to be implementable.

A quick exploration of the competitiveness of locally manufactured Kulayan flat-plate EV batteries revealed that substantial cuts in the average tax rate (from 29% to around 10%) are necessary to help them compete with imported TROZEN batteries. But Kulayan is currently in the process of switching to tubular lead-acid battery production. And it is not clear whether the new batteries would need any support from the government to gain a competitive edge over imports. Furthermore, before provide support to the battery industry, the government would also have to ask whether the economic benefits from supporting this industry justifies the extra pollution associated with the battery manufacturing process.

Recommendations

As maximizing social welfare is an overarching goal of the government, it should seriously consider providing additional support to EV in cases whether the social benefits of replacing ICEVs with EVs outweigh the social costs.

Based on the benefit-cost analyses performed in this study, the EVs deserving government support include Safa Tempos, trolley buses and REVA cars. Although one approach to supporting EVs is by banning the use of ICEVs along certain routes or gradually phasing out the use of EVs altogether, this study focuses on using tax breaks and other policy measures to give a competitive edge to EVs so that they can replace new ICEVs through the market mechanism. In particular it suggests using a combination of the following policy measures to support EVs: reducing the average import tax + VAT for EVs, reducing the electricity tariff rate, reducing the interest rate for EV financing, and imposing a pollution tax on fossil fuels.

In order to minimize the financial burden on the government of EV support measures, it recommends making the pollution tax an essential component of any policy combination. The extra revenue generated from the pollution tax will easily compensate for the losses the government would experience as a result of tax or tariff cuts. The study also strongly recommends that the NEA allow individual EV owners to charge batteries using NEA's TOD tariff rates. This step would significantly reduce the operating cost of EVs without requiring NEA to provide subsidized tariff rates.

1. Introduction

In recent years, scholars, policy-makers, and the general public in many parts of the world have become increasingly concerned over health and environmental damages associated with air pollution. As urban transport is among the most important contributors to urban air pollution, this concern has led to a heightened interest in Electric Vehicles (EVs) as well as other environmentally friendly alternative forms of transport (Riezenman 1998; Funk and Rabl 1999). Consequently, many industrialized countries have adopted policies aimed at encouraging the use of alternative-fuel vehicles. In the United States, for example, California, New York and a few other states have mandates that require 10% of all motor vehicles sold after 2003 to be zero-emissions vehicles or, in other words, EVs (Kazimi 1997; Lave et. al 1996). California, in particular, provides certain sales credits to encourage the purchase of EVs.

As elsewhere, people's interest in EVs in Kathmandu[1] too is intimately tied to the need for tackling increasing air pollution. Kathmandu is already one of the most polluted cities in the world, and most of this pollution comes from vehicular emissions (Devkota 1992; Shah and Nagpal, 1997; CEN 2003). Both the government and the general public have begun to recognize that the reductions in air pollution accompanying the use of EVs could yield important health and other benefits to the residents of Kathmandu. And highlighting these and other secondary benefits of EVs, environmentalists and EV advocates have been encouraging the government to support electric and battery operated vehicles through favorable policies.

Developing and enacting policy measures that actively support the proliferation of EVs, however, requires an understanding of not only the *benefits* but also the *costs* associated with promoting EVs. Given the necessity for allocating society's scarce resources among competing and often equally important development goals, it would be difficult for policymakers to justify EV support measures by only looking at the associated environmental and other benefits. Similarly, it would not be reasonable for the government to disregard EV support policies based on the cost burden alone without considering the benefits of EVs to society at large. More specifically, if the benefits of EVs to society outweigh the costs, then it can be argued that the government should seriously consider implementing policies aimed at encouraging the use of EVs.

A number of studies have analyzed the environmental implications of EVs in the US and a few other industrialized countries within a benefit-cost framework. Using technical specifications from EV prototypes, and comparing them to conventional internal combustion engine vehicles (ICEVs), these studies have generally concluded that the current costs of EVs exceed the benefits achieved from air pollution reduction (Delucchi and Lipman 2001; Johansson and Maertesson 2000; Funk and Rabl 1999). For example, Johansson and Maertesson (2000) find EVs unable to compete with ICEVs in Sweden even if the battery costs were substantially lowered. Similarly, the Funk and Rabl (1999) study shows that the net benefit to society of replacing a new gasoline or diesel car by an equivalent battery operated car is clearly negative in the case of the Paris region. More recently, Lave and MacLean (2002) have shown that the social value of emissions reductions in the US would

[1] Unless stated otherwise, Kathmandu refers to the Kathmandu Valley.

have to be many times larger than currently accepted values for commercial hybrid electric vehicles to be viable from the standpoint of society.

There are, however, no comparable studies that analyze the costs and benefits of EVs or other alternative-fuel vehicles within the context of developing countries, including Nepal. Do costs of EVs to society—that is the extra cost of EV production as well as cost to society arising from the damages caused by the negative impacts of EVs—exceed social benefits in Nepal as well? Or are these vehicles [socially] viable here even though EV technology is not yet viable in industrialized countries? As will be explained later, Nepal, like many other developing countries, actually possesses certain characteristics that could make EVs a natural option for her. And Kathmandu, as the Nepali city with the greatest population exposure to air pollution, has a particularly high potential for becoming a viable home for these types of vehicles.

1.2 Objectives of the study

This study explores the viability of battery powered electric vehicles (BPEVs) in Kathmandu within a benefit-cost framework. It also briefly analyzes the benefits and costs of electric trolley buses operating in the Tripureshwor to Suryabinayak route in the Valley. As indicated earlier, the basic question it asks is whether the social benefits of EVs exceed the social costs if these EVs were to replace comparable ICE vehicles. It argues that, from the perspective of maximizing social welfare, the government has adequate grounds for supporting EVs through appropriate policy measures for those vehicle categories where the benefits outweigh the costs. In the existing situation, one of the main reasons why ICEVs are more cost-competitive than EVs in the marketplace is that their owners and users do not have to bear the costs associated with the pollution they produce. In other words, the free market left to its own devices creates a mismatch between the costs seen by the ICEV users and the true social costs of ICEVs, thereby encouraging the over-use of these polluting vehicles. And one way of correcting this market failure is by implementing policies that favor EVs over ICEVs in cases where the social benefits of EVs outweigh the social costs. Hence, selective government support of EVs removes the “distortions” in the market and enables the market to function more efficiently.

While the primary aim of this report is to put forward arguments for selective government support of EVs based on social benefit-cost analyses, it also identifies policy measures that the government could potentially take to provide the required support, and presents policy simulation results that indicate the extent to which some of these measures might change the cost structure of EVs. It does not, however, present a benefit-cost analysis of these policies. The methods of support explored here basically try to reduce the gap between the "private" costs of EVs and ICEVs so that EVs can compete with ICEVs in the market[2]. The specific objectives of this study are as follows:

- Perform a benefit-cost analysis of electric vehicles in Kathmandu by comparing the benefits and costs of the following pairs of vehicles: (i) diesel-fueled microbuses and battery powered three wheelers, (ii) diesel-fueled microbuses and battery powered microbuses, (iii) diesel-fueled microbuses and trolley buses in the Tripureshwor to Suryabinayak route, and (iv) gasoline-fueled cars and battery operated cars.

[2] The difference between private cost and social cost is explained in section 2.2.

- Identify and prioritize policy measures that could help make EVs competitive in the marketplace and explore how much these measures can change the life-cycle costs of EVs.
- Briefly explore whether government support to local manufactures of lead acid deep-cycle batteries can be justified, and the degree of support required to make locally developed batteries competitive with their imported counterparts.

1.3 Significance of the study

Debates surrounding the promotion of EVs in Nepal have typically focused either on the benefits or on the costs, without looking at both benefits and costs within a single framework. It has, therefore, been difficult for EV advocates and policymakers to come to a common understanding on the relevance of EVs to Nepal. Although policies that might be implemented to support EVs in Kathmandu have been widely discussed in the past (e.g., see NESS 2003), there have been limited analytically rigorous discussions on the *justification* for such policies. This analysis, by presenting numerical evidence on the net social benefits of different categories of EVs, is expected to help both policymakers and EV advocates to better understand *when* and *why* EVs might be supported. Apart from clarifying why EVs should be supported, it is also expected to give policymakers a rough idea of how EV support policies might affect the competitiveness of EVs and the government budget.

The significance of this study from a research perspective lies in it's being the first study to compare ICE buses and cars with EVs in Nepal within a benefit-cost framework. Analyses of this type have rarely been performed for developing countries, and to the best of our knowledge there are no published papers comparing the benefits and costs of EVs in other South Asian countries. Hence this analysis could provide useful pointers to researchers interested in EVs in other South Asian countries as well. It should also be noted that Kathmandu is one of the few cities in the world with a functioning, privately operated fleet of BPEVs used for public transport. There are currently over 600 battery-powered three-wheeled auto rickshaws, locally known as Safa Tempos, operating along some of the major routes of the city. Hence, the portions of this study that deal with existing 3-wheeler EVs reflect a relatively more realistic analysis than those performed in many industrialized countries where the EV data are based on prototypes.

Finally, this analysis attempts to address an oft-quoted weakness of EV benefit-cost studies, namely the neglect of costs associated with the lead discharged from EV batteries. In the literature, the lead discharge costs have either been ignored, or have been presented in non-monetized form, thus making it infeasible to incorporate them in the benefit-cost analysis. As EV lead-acid batteries are much larger than those used in ICEVs, there is a tradeoff between EV benefits from reduced air pollution and the pollution from battery lead discharge. According to Lave et al. (1996), this tradeoff could be so severe that environmental damages associated with recycling and disposing the EV lead-acid batteries might actually swamp the EV air quality benefits. But their study only estimates the quantity of lead discharge and does not quantify or monetize the resulting impacts.[3] The current study uses an innovative graphical approach to capture the tradeoff between the cost of EV battery lead discharge and the benefits from air pollution reduction.

[3] In other words, it does no present a monetary estimate for the loss arising from lead discharge from EV batteries.

1.4 Limitation of the study

The main limitation of this study is data quality. The benefit-cost analyses presented here rely primarily on secondary data from other countries for estimating the benefits of electric vehicles. Since Nepal-specific data on vehicular emissions factors and pollution damage valuations are not available, this information was derived from figures based on studies done elsewhere. Similarly, the cost data were compiled by triangulating the information from the available literature with information collected from a brief survey of vehicle owners, manufacturers, operators and other relevant people. As this was a key-informant survey rather than a survey based on a random sample of informants, the information collected could be biased in a statistical sense.

1.5 Organization of the report

The rest of the report is organized as follows. Section 2 starts by highlighting some of the most widely discussed costs and benefits associated with EVs and proceeds to explain the reasons why these vehicles might be viable in developing countries like Nepal. Section 3 provides some background information on Kathmandu, including its air quality and experience with electric vehicles. Section 4 discusses the data and analytical framework used in this study. And the next section presents the results of the benefit-cost analyses. Section 6 discusses the impacts of policy measures aimed at supporting electric vehicles. Section 7 explores the ways for making locally manufactured deep-cycle lead acid batteries competitive with imported ones. And the final section presents the conclusions and recommendations.

2. Benefits and costs of EVs

2.1 Benefits

The bulk of the social benefits associated with EVs derive from environmental improvements, especially in localities that are heavily populated. As will be discussed in greater detail below, the reduction in health damages arising from improved air quality is, by far, the most significant benefit of EVs compared to ICEVs. There are, however, other benefits as well. For example, as EVs are relatively quiet by design, they contribute far less to noise pollution than comparable ICEVs. Similarly the ability of the EV electric powertrain to turn on and off instantly and their low maintenance requirements are features that are valued by consumers (Turrentine and Kurani, 1998). Another added benefit of EVs is their limited dependence on fossil fuels, an especially important advantage in countries that rely on imported fossil fuels.

As indicated above, the main advantage of EVs over ICEVs derives from their emission-free characteristic, which results in substantial health benefits from reduced air pollution.[4] It is also worth emphasizing that unlike ICEVs, which emit progressively more pollution with age, electric vehicles remain "green" their entire lives. Thus it can be argued that the air pollution benefits of EVs increase over time. Broadly speaking, typical ICEVs produce three types of air pollutants—primary pollutants that directly cause health and property damages locally, greenhouse gases that contribute to global warming, and air toxics that are harmful to health even in small amounts. These pollutants are discussed in detail below.

[4] Visibility improvement from the reduction in air pollution is another EV benefit which can be quite significant in areas where smog is a big problem.

2.1.1 Primary pollutants

Primary pollutants of relevance include particulate matter, carbon monoxide, sulphur dioxide, nitrogen dioxide and lead. The most significant negative impacts of these pollutants are health damages.

Particulate matter (PM): The most dangerous primary pollutant associated with internal combustion engines is particulate matter (PM) emitted by vehicles and refineries. While PM is emitted by both gasoline and diesel vehicles, the quantity emitted per kilometer of travel by the latter is much higher. There is strong evidence that particulate matters smaller than 10 microns in size (PM_{10}) are associated with a variety of respiratory and cardiovascular health problems that can even lead to premature death (World Bank 2003; WHO 1999; Bascom et al. 1996). Although the current study only looks at the damages caused by PM_{10}, it should be understood that smaller particulate matters have an even greater impact on health. For example, $PM_{2.5}$ (PM smaller than 2.5 microns in size) is considered to be between 2 and 10 times more potent than PM_{10} (McCubbin and Delucchi 1999). Considering that a large fraction of the particulate matter emitted by diesel engines is $PM_{2.5}$, the actual damages from particulate matter are probably much higher than the PM_{10} damage estimates used in this study.

Sulphur dioxide (SO_2): The inhalation of SO_2 also causes respiratory problems, though to a lesser extent than PM_{10}. People exposed to high concentrations of SO_2 have a greater chance of experiencing laryngo-tracheal and pulmonary oedema and asthma attacks. Like PM_{10}, this pollutant too is more prevalent in diesel exhausts than in gasoline exhausts.

Carbon monoxide (CO): Carbon monoxide emitted by ICE vehicles results from the incomplete combustion of hydrocarbon fuel. As the combustion process is more efficient in diesel vehicles than in gasoline ones, CO is primarily associated with gasoline exhausts. Inhaled CO gets absorbed into the bloodstream, binds with hemoglobin to reduce the oxygen-carrying capacity of the blood, and consequently affects all vital organs requiring a large supply of oxygen. There is some evidence linking CO exposure to increased mortality risk as well (WHO 2001; McCubbin and Delucchi 1999).

Nitrogen dioxide (NO_2): Although there is less certainty about direct health impacts of NO_2 (see Funk and Rabl 1999), studies show that prolonged exposure to high concentrations of this gas causes decreases in pulmonary function and increased incidence of cough, bronchitis and conjunctivitis (CEN 2003; WHO 1999). Like PM_{10} and SO_2, NO_2 is present in higher concentrations in diesel exhausts than in gasoline exhausts.

Lead (Pb): According to WHO (1999), there is a direct relationship between lead in the air and the level of lead in blood. The presence of lead in blood can cause a number of hematological and neurological problems in both adults and children. Lead emission from vehicles is not a major issue in most industrialized countries where the use of unleaded gasoline is now the norm. But since leaded gasoline is still used in many developing countries, reduction in the concentration of lead in the air is one of the benefits of EVs in these nations. In the case of Nepal, however, leaded gasoline is no longer a problem since it has already been phased out.

2.1.2 Greenhouse gases

The most important greenhouse gases emitted by conventional ICE vehicles are carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O). Oxides of nitrogen, including NO_2, and non-methane volatile organic compounds (NMVOC) emitted by these vehicles also contribute indirectly to greenhouse gas accumulation since they are precursors to the greenhouse gas ozone (O_3). As greenhouse gases contribute to global warming, reduction in the generation of these gases is actually a benefit that is shared by people beyond the geographical area under consideration. It should be noted, however, that since there are no established functional relationships between greenhouse gas emissions and global warming, determining the benefits associated with the reduction of greenhouse gases is a difficult task. Compared to diesel vehicles, gasoline vehicles typically emit more greenhouse gases per kilometer of travel.

2.1.3 Air toxics

Air toxics from vehicular emissions include carcinogenics such as Acetaldehyde, Benzene, Butadiene, and Formaldehyde. Benzene, in particular, is a known additive in the gasoline used in Nepal (CEN 2003). The health effects of benzene include lung cancer, leukemia, and damage to the central nervous system. Since vehicles emit these toxics in very small amounts, the damages associated with them are also relatively small.

2.2 Costs

Social cost refers to the cost incurred by society, as opposed to "private cost" which is the cost faced by individuals. From an economic perspective, society consists of producers, consumers and the government. And any transaction that only involves a transfer of funds from one segment of society to another is neither a cost nor a benefit within a benefit-cost framework. For example, government revenue lost through changes in tax laws is not a social cost even though it is a cost to the government. On the other hand, the pollution impacts of EV battery lead is a cost to society even though the EV user does not bear the cost of cleaning up the discharged lead. The social costs associated with EVs can be grouped into two categories—the costs of negative impacts of EV and their lifecycle cost. Each of these two costs is discussed below.

2.2.1 Costs of negative impacts

Although EVs are zero-emission vehicles, they are not necessarily non-polluting. For example, the negative impacts of air pollution from particles generated by the wearing out of tires and dust raised by vehicles on the road are equally problematic for both EVs and conventional ICE vehicles. In addition, there are certain “upstream activities” specifically associated with EVs that can produce significant amounts of air pollution. Upstream activities include all activities associated with the generation of electricity used to charge EV batteries. If electricity is generated using hydro, wind, thermal, or nuclear power, the associated damages are minimal. On the other hand, if electricity is generated through the burning of fossil fuels, the resulting air pollution can be substantial.

Another major cost associated with battery-powered EVs is the pollution from lead discharged from batteries. Because of their high costs and their inability to handle large distances, batteries are the Achilles heel of the EV industry (Hunt 1998; Delucchi and

Lipman 2001). The most popular batteries today are still the lead-acid type because they cost substantially less than other high-performance, environmentally friendlier batteries with longer lives and capacities such as Nickel-metal hydride and Lithium-polymer batteries. As they are the primary source of power in EVs, these batteries are understandably larger than those used in conventional ICEVs. Hence, mining, smelting and recycling lead-acid batteries results in larger amounts of lead discharge per vehicle in the case of EVs. The health impacts of lead have already been discussed earlier.

2.2.2 Lifecycle cost

The high EV lifecycle cost, i.e., the annualized initial vehicle cost plus operation and maintenance cost, is the main reason why these vehicles have not been able to compete with ICEVs. From the perspective of society, the initial cost of interest is the vehicle production cost before taxes. Compared to conventional vehicles, EVs generally require sturdier and better-built bodies, which raises the production cost of these vehicles. Similarly, the operation and maintenance cost for BPEVs is also higher because of high battery replacement costs. Hence, BPEVs are generally more costly to manufacture and operate than comparable ICEVs. According to Delucchi and Lipman (2001), the price of batteries would have to be much lower than the prevailing prices for BPEVs to compete with gasoline ICEVs.

2.3 Cost and benefits of EVs in developing countries

The EV costs and benefits discussed above are relevant regardless of whether these vehicles are operating in industrialized or developing countries. In the special case of developing countries, however, there are certain added benefits associated with EVs. One such benefit arises from the quality of vehicles and the fuel used to operate them. More specifically, developing countries typically have older and more polluting ICEVs, and a higher usage of leaded gasoline compared to industrialized countries. Furthermore, the pollution potential of fossil fuels in developing countries is often higher due to limited availability of quality-controlled, unadulterated fuel in the market. Evaporative emissions from refueling escape and the carburetor are also higher in developing countries because of the large number of older vehicles. Hence, we can infer that EV benefits accruing from emissions reductions are relatively larger in developing countries. Similarly, given that there are no dominant EV suppliers in the world market, different countries could actually produce their own EVs and benefit economically as well. As most developing countries do not have indigenous auto industries, their new EV industries would aid in the development of the local economy without displacing existing industries. Finally, it should be noted that owing to limited foreign exchange, the opportunity cost of purchasing oil from abroad to fuel ICE vehicles is relatively high in most developing countries; hence an added benefit of EVs would be a decrease in dependence on oil imports, particularly in cases where electricity is produced using hydropower.

At the same time, as vehicle performance requirements are much lower in developing countries, the costs of EVs would also be lower. More specifically, the typical driving distance and driving speed are much smaller in most third world cities. For example, the average driving speed in Kathmandu is around 7 km/hr and the average driving distance of 3-wheeler EVs in Kathmandu is less than 50 km per day (Baral et al. 2000), which is well within the range handled by low-end batteries.[5] The numbers are comparable for many Indian cities as well (Biswas and Biswas 1999). Hence, EV costs can be substantially lowered in developing countries by using the least expensive lead-acid batteries. These modest performance requirements, coupled with the acceptance by the population of a much lower vehicular comfort level, also means that the chassis of EVs—which constitutes a significant cost—can be much more rugged and utilitarian, and consequently far less expensive. Hence, there is a strong possibility that the social benefits from EVs could exceed their costs.

3. Background on Kathmandu

3.1 Advantages of EVs in Kathmandu

Even among developing countries, Nepal possesses certain unique characteristics that favor EV expansion, particularly in Kathmandu. The first is the combination of Nepal's immense potential for hydropower generation and limited power utilization capability during off-peak hours. Battery operated EVs, in particular, could take full advantage of this underutilized electricity and deliver substantial benefits to society at minimal additional cost. Furthermore, since most of the electricity is produced by hydropower, negative pollution impacts of upstream activities are negligible in Nepal. Second, Nepal imports 100% of the gasoline and diesel fuel it needs. Hence, the benefits from reducing its dependence on these fuels will be particularly important. Third, all the ICE vehicles used in Nepal are imported from abroad while EVs are largely assembled in Nepal. And some of the EV components—including the chassis—are manufactured in Nepal as well. Thus the EV industry not only provides direct employment and income, but it also contributes to the growth of sectors that supply it with inputs. And fourth, reductions in vehicular emissions in Kathmandu can have a substantial positive impact on the health of the local population since this city has a high population density and very poor ambient air quality.

These various factors, coupled with the fact that Nepal actually has a functioning EV transit system in Kathmandu, makes Nepal a uniquely appropriate place to study the viability of EVs in developing countries. The EVs currently in use in Nepal are 3-wheeled auto-rickshaws. Conventional ICE auto-rickshaws that seat 6 to 12 persons are hugely popular forms of public transport in South Asia. Hence, the Nepali experience with EV auto-rickshaws is of direct relevance to this region as a whole. Furthermore, the EV industry in Nepal is completely indigenous, with investments flowing almost entirely from local entrepreneurs and businessmen (Baral et al. 2000); thus it could also serve as an example for other developing countries that want to promote national industrial development using local resources.

3.2 The air quality of Kathmandu and causes of air pollution

As indicated earlier, it is primarily the benefits from air pollution reduction that have sustained the interest in EVs in Kathmandu. The ambient air quality of Kathmandu City is very poor, comparable to some of the most polluted cities in the world. In terms of PM_{10} pollution, for example, it outranks cities like Kolkata, Mumbai, and Mexico City.[6] Kathmandu City's average annual PM_{10} concentration of 198 $\mu g/m^3$ in 2003 is well above the

[5] Dellucchi and Lipman (2001) suggest that, for short driving distances, the lifecycle cost of BPEVs approaches that of ICEVs.

[6] The average annual PM_{10} concentration in Kathmandu City for 2003 was 198 $\mu g/m^3$. The figures for Kathmandu Valley, Kolkata, Mumbai, and Mexico City were 148, 143, 72 and 80, respectively (CEN 2003).

WHO guideline of 120 μg/m^3 (CEN 2003; WHO 2000). Although studies have found the concentrations of CO, NO_X, and SO_2 in the Kathmandu Valley to be below the WHO guidelines in general (CEN 2003; NESS 2001), these concentrations are not necessarily less than those for other polluted cities in the world.[7]

It is difficult to accurately estimate the air quality changes in Kathmandu because of the paucity of reliable historical data. There is, nevertheless, some evidence that the pollution level in Kathmandu has been increasing over time. In particular, data collected by the Environment and Public Health Organization (ENPHO) and the Ministry of Population and Environment (MOPE) in 1992 and 2002 in the Putali Sadak area indicate that there was a three-fold increase of PM_{10} concentration during this ten-year period (CEN 2003). Although it would be incorrect to assume a degradation of this magnitude in Kathmandu's overall air quality, it would be quite reasonable to suspect that the pollution level has probably increased over the years.

There are a number of factors that increase the vulnerability of Kathmandu to air pollution problems (CEN 2001; Shah and Nagpal 1997). One is the Valley's bowl-shaped topography. Since there are only a few air passes among the surrounding mountains, this shape results in inadequate air circulation and dispersion of air pollutants. Another factor is the phenomenon of temperature inversion in the Valley, which traps the cool air at night and early morning near the ground and exposes the population to high concentrations of pollutants, especially in winter months.

From the perspective of addressing Kathmandu's air pollution problem, however, the most important factor is the area's rapid population growth and accompanying increase in energy use. The consumption of fossil fuels to generate energy required for cooking, industrial production and transportation results in the emission of various types of air pollutants. Hence, population growth in general leads to higher levels of air pollution. Data from the population census show a 56 percent increase in the population of the Valley between 1991 and 2001. Studies have shown that among the different sources of pollution associated with human activity, industries and vehicles are the main contributors in Kathmandu. According to Shah and Nagpal (1997), for example, 45% of the PM_{10} emissions in 1993 came from the brick industry and the Himal Cement factory while 12% percent came from vehicle exhaust and 9% came from particle resuspension on the road. This study also estimates that the contribution of vehicle exhaust was around 28.5% of the winter average concentration of PM_{10} in Kathmandu. Similarly, Koirala (2002) indicates that emissions from the transportation sector constituted around 39% of the total emissions of CO, NO_2, SO_2, hydrocarbons, and total suspended particulates in the Valley in 1998.

Although contributions of the various pollution sources have not been estimated in recent years, there are good reasons to believe that vehicles have now become the biggest contributors to air quality degradation in Kathmandu. First, the number of brick kilns has decreased since 1993, and Himal Cement has ceased operations altogether. Second, many people have switched from biomass to higher quality kerosene and liquefied petroleum gas (LPG) for cooking purposes, thereby decreasing the contribution of emissions from domestic energy consumption (CEN 2003). Third, along with the increase in population, the number of

[7] Note that NO_2 and SO_2 concentrations at or above the WHO standards have been recorded in certain areas of the Valley. For example, measurements done by the Environmental Sector Program Support (ESPS) in 2003 showed that the NO_2 concentration in Putali Sadak exceeded the WHO standard (annual average) of 40 μg/m^3. Similarly, SO_2 concentration in Bhaktapur were found to be above the 50 μg/m^3 WHO guideline (CEN 2003).

vehicles in the valley has more than tripled since 1993 (CEN 2003). And fourth, the pollution level in Kathmandu has definitely not decreased since the Shah and Nagpal (1997) study; in the case of PM_{10}, there is strong evidence of pollution increase as explained earlier. Hence, it is highly likely that most of the increase in Kathmandu's air pollution can be attributed to vehicular emissions. The increasing problem of vehicular pollution points to the necessity of making vehicular emission reduction the focal point of the government's environmental improvement plans for Kathmandu.

The above discussion indicates that the air pollution in Kathmandu has *probably* increased during the past decade. It must be emphasized that the *impact* of air pollution, on the other hand, has *definitely* increased during this period. The main reason for the higher impact of pollution in recent years is the rapid population growth of the Valley. Since health damage is the most serious consequence of air pollution, the impact of pollution increases with the number of people exposed.[8] The population exposure has been increased further during this period by the growth in the fraction of the Valley population living in cities. The census data show that the percentage of the population living in the Valley's cities increased from 56 percent to 61 percent between 1991 and 2001 (CEN 2003). It must be added that the population of the Valley has been growing even more rapidly during the last three years because of increased in-migration from areas suffering from the ongoing political conflict. Population exposure to and the resulting damage from air pollution have, therefore, been continuously increasing in Kathmandu.

3.3 Kathmandu's experience with EVs

Kathmandu's experience with mass transit EVs began in 1977 with the introduction of the government-owned Trolley Bus system, consisting of a fleet of 22 buses operating along the thirteen-kilometer route between Tripureshwor and Suryabinayak (NESS 2003). Between 1977 and 1989, these buses were the mass transit mode of choice for the majority of the passengers traveling along this route (KEVA 2004). Over the years, however, the system began to lose efficiency for a host of reasons. The number of trolley buses in operation, the number of passengers, and the net revenue generated kept declining, leading to an accumulated loss of over Rs. 42 million between 1996/97 and 2001/2002 (KEVA 2004). Even the addition of ten new buses in 1997 was not enough to boost the efficiency of the system to acceptable levels. As a result, His Majesty's Government of Nepal (HMG/N) terminated the operation of the Trolley Bus system in December 2001. Subsequently, the Trolley Bus system was handed over to the local governments of Kathmandu, Bhaktapur and Lalitpur. While these governments are still in the process of deciding on an appropriate arrangement for the reactivation of the system, they have recently resumed trolley bus services in a limited section of the Tripureshwor-Suryabinayak route. The KEVA (2004) study concludes that, from a business perspective, there are bright prospects for reactivating the system through a public-private partnership venture.

More recently, Kathmandu has gained a lot of experience in the use of another type of EVs, namely battery-powered three-wheelers or Safa Tempos. Although trolley buses are a form of clean transport, the establishment of the trolley bus system was not necessarily motivated by environmental concerns. The introduction of Safa Tempos, on the other hand, has been directly related to the air pollution problem in Kathmandu. By the mid-1990s, the

[8] Population increase is accompanied by the construction of new housing units and other infrastructure. Hence the number of properties exposed to pollution also increases with population, resulting in additional property damage.

government and the residents of Kathmandu were becoming increasingly aware of the deteriorating air quality and the role of ICEVs in aggravating the problem. And as a concrete step towards addressing Kathmandu's pollution problem, the government banned the operation of all diesel auto-rickshaws in early 1999. Since these auto-rickshaws were serving some of the most important transit routes in the city, the ban resulted in a mismatch between supply and demand in the transportation sector and created opportunities for the introduction of new vehicles in the market. Although the Safa Tempo industry had been steadily expanding since its establishment in 1996, the ban had a dramatic impact on Safa Tempo production and sales. As the demand soared, the number of Safa Tempo increased from less than 200 in early 1999 to over 600 by September 2000 (Chautari 2000).

Unfortunately, the production of Safa Tempos came almost to a halt after 2000. A detailed discussion of the reasons for the decline of the EV industry can be found in NESS (2003). But one of the most important reasons was the government's decision to allow owners of the banned diesel auto-rickshaws to import diesel/petrol/LPG microbuses at reduced customs tariffs almost at par with the privileges extended to the EV industry. Although the Safa Tempos in Kathmandu are privately owned and operated, their commercial viability has been and continues to be tied to institutional support from the government. In particular, the government has assisted the industry in reducing the cost of production through tax breaks and reductions in import duty on components. It has also tried to bring down the cost of operation of EVs by providing electricity to charging stations at a subsidized rate. Hence, the special customs tariff rates extended to microbuses had a strong negative impact on the cost competitiveness of the Safa Tempos. The government's decision to promote microbuses in this manner appears to have been a politically motivated move and was not necessarily based on a rigorous analysis of the associated social costs and benefits. One of the objectives of this study is, therefore, to estimate the net benefits society would experience if microbuses were to be replaced by EVs.

Although Kathmandu's experience with BPEVs has been limited to Safa Tempos, the prospects for introducing four-wheeler BPEVs are also being explored by entrepreneurs and EV advocates. The Himalayan Light Foundation, for example, has been conducting research on the operations costs and technical performance of a battery-operated bus. It is expected that the results of this research will be valuable for prospective EV entrepreneurs. Similarly, there is a possibility that four-wheeler electric cars such as the Indian REVA car could be viable for Nepal from a social perspective. A private company did attempt to introduce REVA cars in Kathmandu recently. But the venture did not succeed as a result of the government's refusal to provide the usual EV special customs rates for these cars. So far, the government has not shown much interest in supporting battery-operated buses either. The current study should shed some light on whether or not it would be justifiable for the government to support battery-operated buses and cars.

4. Data and analytical framework

The benefit-cost analysis presented here compares the benefits [and costs] of EVs with those of diesel microbuses and small gasoline cars. In order to perform the analysis, all costs and benefits are expressed in terms of rupees per kilometer of travel. It is important to note that the levels of emissions are different for old or in-use ICEVs and new ICEVs. Similarly, the extra cost required to replace existing ICEVs by EVs is higher than the cost associated with choosing EVs over ICEVs in the future. Hence, separate benefit-cost analyses are performed for old and new ICEVs. It should also be pointed out that the approach used in the current analysis tends to underestimate the benefits and overestimate the costs of EVs in order to avoid presenting an "unrealistically rosy" picture in favor of EVs.

4.1 Positive impacts (benefits)

Recall that the primary benefits of EVs arise from reductions in air pollution-related health impacts. The first step in identifying these impacts involves compiling a vehicle emissions inventory that includes the amount of each pollutant generated by ICEVs per kilometer of travel (e.g., in grams per km). Since health and other damages from air pollution depend on the ambient concentration of pollutants, a comprehensive accounting of the environmental benefits and costs of EVs would also require a model that links vehicle emissions to changes in ambient concentrations of different pollutants in the air. Then, in the third step, exposure-response (E-R) functions relating the change in ambient concentration of pollutants to health and other impacts would have to be used to quantify the damages to health and property of the population under consideration. Finally, the various impacts would have to be valued in monetary terms in order to perform a benefit-cost analysis.

4.1.1 Vehicle emissions inventory

A comprehensive vehicle emissions inventory for Nepal is currently not available from any source. There are many factors that affect the quantity of emissions produced by ICEVs per kilometer of travel. These include vehicle characteristics such as engine type, vehicle age, maintenance level, and fuel quality; fuel characteristics such as fuel type; and operating characteristics such as altitude, temperature, humidity, speed, and loading. A comprehensive list of factors can be found in Faiz et al. (1996). Even in the absence of survey data, it should theoretically be possible to estimate vehicular emissions per kilometer for Kathmandu by properly scaling the emissions estimates from elsewhere to account for the variations in the factors mentioned above. In practice, however, the complexity of the non-linear relationships between these factors and vehicular emissions means that estimates for Kathmandu cannot be produced without the aid of sophisticated computer models. Hence, the approach taken in this study is to use vehicle emissions information from prior studies on Nepal where available, and to use values directly from elsewhere in other cases.[9] The poor quality of vehicles, the practice of overloading vehicles, frequent use of adulterated fuel, Kathmandu's high altitude, and congested driving conditions are some of the many reasons why the actual emissions per kilometer of travel for Kathmandu vehicles are probably higher than those for vehicles in most industrialized countries. So emissions estimates from industrialized countries will most likely underestimate the true emissions for Kathmandu vehicles.

The pollutants for which ICEV emissions information for Nepal is available are PM_{10}, NO_2, SO_2, and CO. Relevant numbers for these pollutants have been obtained from Shrestha and Malla (1996) and from a 1997 World Bank study of air quality in Kathmandu (Shah and Nagpal, 1997).[10] As there are no published studies that include data on greenhouse gas emissions from vehicles in developing countries, numbers from a 1999 study of EV benefits in France (Funk and Rabl 1999) are used. The assumption is that since ICE vehicles in developing countries are more polluting than those in France, the numbers used here will provide a *lower* bound for the benefits from EVs. Following Funk and Rabl (1999), this study

[9] The associated monetary damage estimates from other countries are, however, scaled *linearly* to account for the differences in living standard between Nepal and these countries.
[10] It should be noted that their figures too are based on values available in the literature.

groups the greenhouse gases CO_2, CH_4 and N_2O together as $CO_{2equivalent}$ and provides separate values only for NMVOC.

Data on the quantity of air toxics emissions and noise pollution from vehicles are not available in the published literature. But a study done by McCubbin and Delucchi (1999) provides estimates of toxics-related monetary damage estimates per kilometer for diesel and gasoline cars. Similarly, another study by Delucchi and Lipamn (2001) estimates the monetary damage per mile from noise pollution for gasoline cars. As in the case of greenhouse gases, these monetary values of damages from toxics and noise should also be considered lower bound estimates for Nepal. In other words, the current study is using very conservative estimates for the emissions of primary pollutants and greenhouse gases, as well as for damages from air toxics and noise pollution. Hence, it most likely underestimates the EV benefits from pollution and noise reduction.

The emissions data discussed above are for old or in-use vehicles. As all new ICEV imports are required to meet the Euro 1 standards, they will have lower emissions compared to older in-use vehicles. But given the unique driving conditions and driving practices in Kathmandu, it is doubtful that these new vehicles will continue to meet the Euro 1 emissions standards when they are actually in use. Furthermore, the Euro 1 standards for cars and light commercial vehicles are specified only for some of the pollutants (see ADB 2003). Hence, in order to derive the emissions estimates for Kathmandu, the Euro 1 standards have been appropriately scaled using information from other studies.

For example, the Euro 1 PM_{10} standard for minibuses (light commercial vehicles) is 0.14 g/km. Data from the Department of Transport Management (DoTM) show that although Euro 1 in-use vehicles have lower emissions than older vehicles, they are only around 50% cleaner in terms of smoke opacity (see CEN 2003, p. 29). Hence, rather than using 0.14 g/km as the emission factor for light duty commercial vehicles, it would be more reasonable to derive the factor by scaling down the PM_{10} emissions for old in-use vehicles by 50%. Emissions of CO, on the other hand, is set at the Euro 1 standard of 2.72 g/km itself since this value is similar to the value for old in-use vehicles. The SO_2 emissions level is derived from the CO data by multiplying it by the SO_2/CO ratio for Euro 2 in-use vehicles given in the study by Funk and Rabl (1999). The assumption is that this ratio is similar for the Euro 1 vehicles as well. The Euro 1 standards do not specify the emissions limits for NO_2 separately. Hence, the NO_2 emissions level is derived from Euro 1 standard of 0.97 g/km for HC+NO_X by utilizing the HC/NO_X ratio in the Funk and Rabl (1999) study. The emissions levels for the remaining pollutants are derived from the above estimates in a similar manner. Finally, the emissions per kilometer for microbuses are computed by scaling the minibus emissions using the fuel consumption ratio between microbuses and minibuses.

4.1.2 Impacts of emissions reductions

The environmental impact of emissions is dependent on the ambient concentrations of the various pollutants and the density of the population. If the concentration of pollutants in the air is not very high, emissions will be largely assimilated by the surrounding environment. Similarly, the total health impacts will be lower in an area with low population density compared to a densely populated area of equal size. As discussed earlier, Kathmandu is considered to be one of the most polluted cities in the world with concentrations of certain pollutants greatly exceeding WHO guidelines. And its population density of approximately 2700 persons/k.m^2 is comparable to some of the major cities in the industrialized world such as Los Angeles, New York and Paris.[11] Hence, this study uses impact estimates of emissions from studies of cities like Paris and Los Angeles as lower bound estimates for Kathmandu.

Ideally, of course, Kathmandu-specific models should be used to link emissions to ambient pollution concentrations and to their impact on the environment. Unfortunately, except for one study (Shah and Nagpal, 1997) linking PM_{10} emissions to increased mortality and morbidity, such models for Kathmandu are not available. The Shah and Nagpal (1997) study uses Kathmandu-specific dispersion models to estimate the change in population exposure to PM_{10} associated with an increase in PM_{10} emissions. Then utilizing results from dose-response research in the literature (Ostro 1994), it estimates excess deaths (mortality) and excess cases of illness (morbidity) from PM_{10} emissions. According to this study approximately 0.136 deaths and 2456 respiratory symptom days (RSD) are avoided per ton of vehicular PM_{10} emission reduction. It should be noted, however, that these mortality and morbidity figures are based on the assumption that the health impacts of PM_{10} are significant only above a certain threshold ambient PM_{10} concentration, namely 41 $\mu g/m^3$. Scientists now have evidence that PM_{10} is harmful to human health even in small concentrations and that there is no safe threshold for this pollutant (CEN 2003). The Shah and Nagpal (1997) impact figures also do not account for the relatively high $PM_{2.5}$/ PM_{10} ratio in vehicle emissions in Kathmandu. Furthermore, using these figures fails to account for today's higher population and PM_{10} ambient concentration. Hence, the present analysis most likely underestimates the benefits of PM_{10} reduction associated with the introduction of electric vehicles.

The current study draws from these results to estimate the decrease in the number of deaths and the number of RSDs per gram of reduction in PM_{10} emissions. Because of data limitations, it does not estimate the physical (health) impacts of reductions in the other pollutants. In other words, it does not estimate the decrease in morbidity or mortality associated with the reductions of different pollutants emitted by the ICEVs. Instead, it directly utilizes monetary damage figures (in rupees per gram of pollutant reduced) from the literature and uses them to perform the benefit-cost analysis.

4.2 Valuation of benefits

As mentioned above, all positive impacts of the reduction in emissions must be valued in monetary terms before they can be compared with EV costs. The Funk and Rabl (1999) study provides estimates of dollar benefits per gram reduction in each of the primary pollutants and greenhouse gases for Paris, France. Because of lower income levels, however, the average willingness of people in Nepal to pay for pollution reduction would be significantly less that that of Parisians. Hence, to estimate the damage estimates for Nepal, figures obtained from Funk and Rabl (1999) are adjusted downward by multiplying them by the purchasing power parity (PPP) adjusted per capita income ratio between Nepal and France.[12] Similarly, the damages (in rupees per kilometer) from toxic emissions and noise pollution for Kathmandu are estimated by adjusting figures from McCubbin and Delucchi (1999) and Delucchi and Lipman (2001), respectively, using the ratio between Nepal and the United States.

In the case of PM_{10} emissions, it is actually possible to obtain better damage estimates by utilizing the mortality and morbidity impacts derived by Shah and Nagpal (1999a).

[11] Computations based on data from International Urbanized Area Analysis and Data Product (2001).
[12] The PPP-adjusted per capita income figures are for 1998 and have been obtained from the Penn World Tables (2000). The computed per capita income ratio between Nepal and France is 0.068. Similarly, the ratio between Nepal and the United States is 0.048.

The monetary benefit associated with the reduction in morbidity can be estimated in a straightforward manner by multiplying the RSDs by lost wages.[13] As for valuing the mortality impacts of PM_{10}, one approach involves computing the present value of expected future wage income at the average age of the population and multiplying it by the number of lives saved due to the reduction in PM_{10} emissions (Shah and Nagpal 1997).[14] By looking only at forgone future wages, however, this approach places a very small value on each life saved. For example, assuming that the average age of the population in Nepal is 23 years and that the average number of working years is 37, the present value of expected future income for an individual using a wage rate of Rs.27,000/year[15] and a discount rate of 5% is only around Rs. 465,000.

The second, and more widely used approach, is to derive the value of statistical life (VSL) either by observing the tradeoffs people make between fatality risk and monetary return (for example, in the labor market)[16] or by asking people to state their fatality risk-return tradeoffs under some hypothetical market scenario.[17] The VSL obtained this way would obviously be higher and more realistic than the value obtained above. But since studies of this type have never been done for Nepal, the VSL for Nepal is estimated using results from studies done in the United States. The moderate range for VSL in the US is $2.5-$4 million (Boardman et al. 2000). The corresponding range for Nepal (Rs. 8.7—13.9 million) is obtained by multiplying the US VSL figures by the PPP-adjusted per capita income ratio between Nepal and the US. The current study uses these values for VLS in computing the benefits from PM_{10} reduction. It is worth noting that the final estimates of EV benefits depend largely on the value of statistical life used to derive the impacts of PM_{10}.

4.3 Costs and valuation of costs

4.3.1 Production and operations cost

Information on costs associated with EVs has also been obtained from multiple sources. Most of the ICEV and EV lifecycle cost data were assembled by triangulating information found in the literature with data gathered through personal communications with relevant people (see the Appendix F for the list of people consulted). The literature consulted to obtain cost information for Safa Tempos and diesel microbuses include Moulton and Cohen (1998), NESS (2003) and Devtech (2002). But since some of their data, for example production cost information, were outdated, more recent values were obtained by talking to vehicle owners, operators and sales people. Data for the trolley buses were based on KEVA (2004), CEMAT (2002) and direct communication with the trolley bus authorities. Similarly, information on

[13] Drawing from Shah and Nagpal (1997a) and accounting for the inflation between 1995 and 2004, this study uses Rs. 108 as the minimum wage lost due to one respiratory symptom day.

[14] Value of life = present value of expected future income = $\sum_{n=0}^{36} wage/(1+r)^n$, where r is the discount rate.

[15] Shah and Nagpal (1997a) use Rs. 20,000/year as the average annual wage for Nepal in 1997. In order to express this wage rate in 2004 rupees, it is multiplied by the GDP deflator for 1997 available from the Nepal Economic Survey (MOF 2003). The resulting value is around Rs. 27,000.

[16] The idea is that the salary in high-risk jobs varies according to the death-risk associated with the job. More specifically, the salary is higher in jobs where the risk of dying is greater and vice versa. So the value of statistical life can be estimated by appropriately analyzing the information on the pay scale and risk levels of jobs where there is a risk of getting killed.

[17] For example, people could be asked to specify the salary levels at which they would be willing to accept jobs that involved different levels of death-risk.

the REVA car and battery-operated buses were gathered through contacts at REVA and the Society of Indian Automobile Manufacturers.

When discussing costs of vehicles for benefit-cost computations, it is important to keep in mind that the relevant cost is the *additional* cost to society of producing and operating them. The production cost of an old ICEV is, therefore, zero from society's perspective. Another point to note is the meaning of EV cost. In this analysis, EV cost refers to the *extra cost* associated with producing and operating EVs compared to ICEVs. Hence EV cost is much higher when it is replacing an old ICEV than when it is replacing a new ICEV. The production and operations costs considered here are vehicle production cost, battery cost, maintenance repair cost, and fuel/energy cost. In the case of BPEVs, the cost of batteries can be considered a part of the operations cost since they represent a major running expense for EV owners.[18]

4.3.2 Cost of battery lead discharge

As discussed earlier, the cost associated with lead discharge from batteries is another major EV cost. Again, from a benefit-cost perspective, we are only interested in the *extra* lead discharged by EVs compared to their diesel counterparts. Estimates of lead discharge per ton of battery have been derived from DANIDA (1998) while the approximate battery weights for EVs and ICEVs have been obtained from Moulton and Cohen (1999), Chautari (2000), Devtech (2002) and personal communications with relevant people. According to DANIDA (1998), for every 100 tons of batteries consumed in Nepal, approximately 5 tons of lead are released in the environment during the collection and recycling process. Although there is limited battery manufacturing capability in Nepal, they estimate that another 0.15 tons of lead are released in the battery manufacturing stage as well. Hence, the amount of lead discharged from lead-acid batteries is approximately 5.15% of the total amount consumed. Using the above information along with data on battery life, the extra lead discharge per EV per year can be readily computed. The extra lead discharge per kilometer traveled by EVs is then computed from information on the distance traveled by EVs annually.

Converting the quantity of lead discharged by EVs to monetary figures requires information on health impacts per unit of lead discharge and the monetary value associated with these health impacts. Unfortunately, no published studies are available linking battery lead discharge to health impacts. Furthermore, health impacts of lead discharged into the environment depends on many factors including the degree of localization of the discharge, the medium into which the discharge takes place, and the pathways through which the discharge affects the population. All these factors differ widely between countries. In Nepal, for example, direct handling of lead on the part of battery collectors might be a more important pathway than seepage into groundwater. So even if cost figures for lead discharge were available from studies in other countries, it would be quite difficult to impute the corresponding costs for Nepal. Hence, instead of actually computing the cost of lead discharge, the following question is asked: what is the minimum value society must place on reducing each gram of lead discharge for the costs of EVs to exceed the associated benefits? If this minimum value is unreasonably high, it can be concluded that in reality, the costs of EVs must be lower than the benefits. In other words, it can be concluded that EVs are viable in Kathmandu.

[18] On the other hand, battery cost is not included in the production cost of EVs. In the final analysis, however, it does not matter whether battery cost is viewed as production cost or operations cost.

The above idea can be operationalized through a straight-line graph showing the tradeoff between the cost of lead discharge and value of statistical life. Recall that the major benefit from EVs derives from the reduction in PM_{10} emissions. And the monetary value of the benefit associated with PM_{10} reduction depends on the value of statistical life. Hence, in the graph, the value of statistical life represents the benefits associated with EVs. The cost of lead discharge, on the other hand, represents the costs associated with EVs. The derivation of the linear equation for the graph is presented in Box 1.

Box 1: Tradeoff between benefits from pollution reduction and costs of lead discharge

From the discussion above, we know that

$$B_{EV} = B_{PM_{10}} + B_{Other} \qquad (1)$$

where, B_{EV} is the total EV benefit, $B_{PM_{10}}$ is the benefit from PM_{10} reduction, and B_{Other} is the benefit from the reduction of other pollutants. But $B_{PM_{10}}$ itself is the sum of benefits from lives saved and benefits from reductions in morbidity. Hence, the total benefit from EVs can be written as:

$$\begin{aligned} B_{EV} &= [(Lives \times VSL) + B_{PM_{10}Other}] + B_{Other} \\ &= (Lives \times VSL) + B_{AllOther} \end{aligned} . \qquad (2)$$

In the above equation, $B_{AllOther}$ represents all the benefits other than those accruing from lives saved. Similarly, the total cost of EVs (C_{EV}) can be expressed as the sum of the cost of lead discharge and the total operation and production cost ($C_{P\&O}$). Defining Q_{Pb} as the quantity of lead discharge in grams and $Pb_{UnitCost}$ as the cost per gram of lead discharge, the total cost of EVs can, therefore, be written as:

$$C_{EV} = C_{P\&O} + (Q_{Pb} \times Pb_{UnitCost}) . \qquad (3)$$

Recall that in order for EVs to be socially viable, the costs of EVs must be lower than the benefits, i.e.,

$$\underbrace{C_{P\&O} + (Q_{Pb} \times Pb_{UnitCost})}_{C_{EV}} < \underbrace{(Lives \times VSL) + B_{AllOther}}_{B_{EV}} . \qquad (4)$$

Rearranging equation (4), the cases where EVs are socially viable can be captured by the following relationship between $Pb_{UnitCost}$ and VSL:

$$\begin{aligned} &Pb_{UnitCost} < \frac{(B_{AllOther} - C_{P\&O})}{Q_{Pb}} + \left(\frac{Lives}{Q_{Pb}}\right) VSL \\ &==> Pb_{UnitCost} < \alpha + \beta \times VSL \end{aligned} \qquad (5)$$

The graph represented by equation (5) says that, in order for EVs to be viable, the cost per gram of lead discharge should be less than $\alpha + \beta \times VSL$, where α and β can be computed from the available data. Thus it shows, for each VSL, the minimum cost per gram of lead discharge that will make EVs not viable.

4.4 Comparing ICEVs with equivalent EVs

As indicated earlier, the benefit-cost analysis for each type of ICEV is performed by estimating the additional benefits and costs associated with replacing the ICEV by EVs. It must be noted that for the comparison between an ICEV and an EV to be valid, the EV must deliver the same transportation benefits to travelers. Hence, when computing the costs of replacing a diesel microbus with an EV, for example, the microbus is compared with an equivalent *number* of Safa Tempos. The equivalent number is estimated as the ratio between the typical carrying capacity of a microbus (16 persons) and the carrying capacity of a Safa Tempo (12 persons). Hence, the cost of replacing a microbus by EVs is computed by comparing the cost of one microbus with that of 16/12 Safa Tempos. A similar approach is used for comparing other EVs and ICEVs as well.

4.5 Analyzing the impacts of policy changes

The goal of the benefit-cost analyses discussed above is to determine whether or not the different types of EVs are viable from a social perspective. The potential policy measures of interest, on the other hand, deal with ways to make EVs competitive in the marketplace in cases where they are socially viable. Hence, rather than looking at the social costs, they focus on the "private" lifecycle costs seen by existing and potential EV owners. The goal of the policy measures is to close the lifecycle cost gap between ICEVs and EVs. Accordingly, the policy analyses presented in this study focus on quantifying the impacts these measures have on the cost gap between ICEVs and EVs.

The most obvious EV support policy is to ban ICEVs altogether. But there are other less drastic policy measures that can potentially make EVs competitive in the marketplace by reducing their lifecycle costs. These measures can be grouped into three broad categories:

a) measures for lowering the purchase price of EVs,
b) measures for lowering the operating cost of EVs, and
c) measures for making ICEVs pay for the pollution they produce.

Category (a) includes reductions, beyond the current levels, in the customs tariff rates, the value added tax, and the interest rates on loans given for purchasing EVs. Reducing the electricity tariff rate is the main tool under category (b). Strictly speaking, reductions in annual fees and taxes is a separate category in itself. But since these are yearly expenses, they are also placed under category (b). Introducing a pollution tax on fossil fuels falls under the third category. The analysis involves simulating the changes in the lifecycle cost gap as a result of these policy measures.

Recall that one of the secondary objectives of this study is to briefly analyze the degree of government support required to make locally developed batteries competitive with their imported counterparts. This analysis is performed by looking at how the various cost components of locally developed batteries change when government support is made available. Again, the goal is to identify the scenario where the cost gap between imported batteries and locally assembled batteries is eliminated through government support.

5. Benefit-cost analyses of EVs

This section presents the results of the benefit-cost analyses performed on the following pairs of vehicles: (i) diesel-fueled microbuses and battery powered three wheelers, (ii) diesel-fueled microbuses and battery powered microbuses, (iii) diesel-fueled microbuses and trolley buses in the Tripureshwor to Suryabinayak route, and (iv) gasoline-fueled cars and battery operated cars. The goal is to identify the cases where the benefits of EVs outweigh the costs. Recall that while the costs associated with EVs include damages from battery lead discharge as well, it is very difficult to attach a monetary value to these damages. Hence, the benefit cost analyses presented here are performed in two stages. In the first stage, the cost of lead discharge is ignored when computing the cost of EVs. In the second stage, however, the graphical technique introduced in the previous section is used to identify circumstances where the net benefit of EVs is positive even when the cost of lead discharge in taken into account.

5.1 Diesel-fueled microbuses vs. battery powered three wheelers

5.1.1 Costs (excluding the cost of battery lead discharge)

The key figures used to compute the lifecycle costs of microbuses and Safa Tempos are presented in Table 5.1.1. The information in this table is first used to compute the annualized production and operations costs.[19] Since the vehicles and the batteries last for multiple years, an appropriate discount rate must be used to annualize the production cost and battery cost. A social discount rate of 5% (above inflation) is used for this purpose. Also note that, from the perspective of society, the production cost of microbuses is the market price minus the import tax ,VAT, and other miscellaneous taxes.[20]

Once the annualized costs have been computed, they are divided by the number of kilometers traveled annually to derive the costs per kilometer. Observe that the cost of diesel fuel in Table 5.1.1 is Rs. 37.31 while the current market price of diesel is only Rs. 31. The reason is that the market price does not represent the opportunity cost of diesel for Nepal. More specifically, since the market price of diesel in the bordering areas of India is higher (Rs. 37.31), some of the diesel meant for the Nepali market ends up across the border. Hence, the Indian price is a more reasonable estimate of the opportunity cost of diesel for Nepal than the government imposed market price.

---

[19] The annualized cost is computed using the following equation: $A = Y \div \left[\frac{1-\left(\frac{1}{1+r}\right)^{n+1}}{1-\left(\frac{1}{1+r}\right)} \right]$, where Y is the present value of the product, r is the discount rate and n is the lifetime of the product in years.

[20] In total, imported ICEVs pay 104.7 % in various taxes. See Appendix C for details.

Table 5.1.1: Key figures used for cost calculations (micros vs. Safa Tempos)

Key figures	Diesel microbus	3-Wheeler EV
Seating + standing passenger capacity (persons)	16	12
Vehicle lifetime (yrs)	20	10
Distance traveled per year per battery set (km/yr)	50400	18000
Social discount rate above inflation (%)	5.0	5.0
New vehicles, production cost without batteries (Rs/vehicle)	830638	360889
Old vehicles, production cost without batteries (Rs/vehicle)	0	0
Cost of battery set (Rs/bat)	2696	61386
Lifetime of battery set (yrs)	1.5	1.5
Cost of maintenance/repair (Rs/yr)	8000	18000
Cost of wear and tear of tires (Rs/yr)	6500	5100
Current fuel/energy cost (Rs/liter or Rs/kwh)	37.31	4.3
Energy consumption per battery charge (kwh/bat)	N/A	16
NEA TOD peak charge--6pm to 11pm (Rs/kwh)	N/A	4.80
NEA TOD normal charge--6am to 6pm (Rs/kwh)	N/A	4.25
NEA TOD off-peak charge--11pm to 6am (Rs/kwh)	N/A	3.00
Fuel/Energy consumption (liter/km or kwh/km)	0.1	0.267

Source: Field survey (2004), NEA (2003), NESS (2003)

Table 5.1.2 presents the costs (per kilometer) of a typical diesel microbus and an equivalent number[21] of Safa Tempos. As can be seen from the table, the EVs have an advantage over microbuses in terms of energy cost. But all the other cost items are higher for EVs. If EVs were to be purchased instead of a new microbus, the extra cost to society would be approximately Rs. 1.77 per kilometer. The cost burden to society would be even higher (Rs. 3.03/km) if an existing microbus were to be replaced by Safa Tempos since the social production cost of existing microbuses is zero.

[21] Since the passenger carrying capacity ratio between microbuses and Safa Tempos is 1.33 (=16/12), it is assumed that one microbus is equivalent to 1.33 Safa Tempos.

Table 5.1.2: Cost summary per vehicle using existing electricity tariffs (micros vs. Safa Tempos)

Cost item	Cost (Rs/km)				
	New diesel microbus	Old diesel microbus	Equivalent new EV	(Equiv. EV-new micro)	(Equiv. EV-old micro)
Production	1.259	0.000	1.649	0.389	1.649
Battery	0.036	0.036	3.068	3.032	3.032
Maintenance/Repair	0.159	0.159	0.667	0.508	0.508
Wear and tear of tires	0.129	0.129	0.189	0.060	0.060
Fuel/Energy	3.731	3.731	1.511	-2.220	-2.220
Total using existing electricity tariff	**5.314**	**4.055**	**7.083**	**1.769**	**3.029**

Source: Field survey (2004)

The total EV cost presented above is estimated using an electricity tariff rate of Rs. 4.25 as the per kilowatt-hour cost of electricity. This figure, however, leads to an over-estimate of the true social cost of electricity used for charging EV batteries. In order to obtain a better estimate of the social cost of electricity per kilometer of travel, it is necessary to use the opportunity cost of electricity instead of the existing tariff. This opportunity cost can be estimated from the time of day (TOD) tariff structure used by the National Electricity Authority (NEA) for 11 KV customers.

The NEA TOD tariff structure has different tariff rates for peak-hour usage, normal-hour usage and off-peak hour usage (see Table 5.1.1). As these rates are designed to cover NEA's electricity production and operations cost, the social opportunity cost of electricity per kWh definitely cannot exceed the TOD rates. Furthermore, there is a surplus of electricity in off-peak hours due to limited electricity consumption during the night and early morning. Hence the opportunity cost of providing electricity for charging EV batteries during off-peak hours is zero from the perspective of society. Although it can be argued that there is some surplus electricity during normal hours as well, it is better to remain conservative and assume that the TOD rate of Rs. 4.25/kwh represents the social cost of electricity during these hours. Hence, from a social perspective, the costs of electricity during the peak, normal and off-peak hours are Rs. 4.8/kwh, Rs. 4.25/kwh, and zero, respectively.

The time required to fully charge a typical deep-cycle lead-acid battery used in Safa Tempos is approximately 10 hours (NESS 2003). Hence it is not possible to complete the battery charging process during off-peak hours alone. Assuming that 70% of the charging (7 hours) takes place during off-peak hours and that the remaining process is split equally between peak and normal hours (15% each), the average social cost of electricity turns out to be Rs. 1.36/kwh.[22] The estimated EV costs based on this figure are presented in the Table 5.1.3. Observe that the EV energy cost per kilometer is now much lower than that in Table 5.1.2. As a result, the extra cost associated with replacing microbuses by EVs has been lowered by Rs.

[22] Average social cost of electricity = (0.7x0) + (0.15x4.25) + (0.15x4.8) = Rs. 1.36/kwh.

1.09/km for both old and new vehicles. The new total social cost of replacing a diesel microbus by Safa Tempos is Rs. 0.741/km and Rs. 2.00/km respectively for new and old microbuses

Table 5.1.3: Cost summary using TOD-based social costs of electricity (micros vs. Safa Tempos)

Cost item	Cost summary per vehicle (Rs/km)				
	New diesel microbus	Old diesel microbus	Equivalent new EV	(Equiv. EV-new micro)	(Equiv. EV-old micro)
Fuel/Energy cost using TOD-based social cost	3.731	3.731	0.483	-3.248	-3.248
Total cost using TOD-based social cost	**5.314**	**4.055**	**6.055**	**0.741**	**2.000**

Source: Field survey (2004)

5.1.2 Benefits

The benefits of replacing existing or "old" microbuses by Safa Tempos are given in Table 5.1.4. The procedure for computing the benefits should be clear from the columns in this table. The damages from microbus emissions in cents per gram have been imputed from studies in other countries and are shown in column 2.[23] Since the PM_{10} damage estimate depends heavily on the value of statistical life, separate PM_{10} damage estimates for low VSL ($2.5 mil.) and high VSL ($4.0 mil.) are presented. In order to use these damage estimates in the Nepali context, they have been multiplied by appropriate purchasing power parity adjusted per capita income (PPP-adjusted PCPI) ratios in column 3. These figures have been converted to Nepali rupees in column 4 by multiplying by the appropriate exchange rate (US$ 1 =NRs. 72). Columns 5 and 6 present the damage from each source in Rs./km and their relative contributions to total damage.

According to Table 5.1.4, the total benefit from replacing an old (in-use) microbus by Safa Tempos is Rs. 2.49/km when we assign a low value to reductions in mortality. The benefit is, of course, much higher (Rs. 3.23/km) for higher VSLs. Also observe that most of the damage from microbus emissions is related to PM_{10}. The second largest contributor is NO_2. Furthermore, the relative contribution of PM_{10} damage increases and that of NO_2 decreases with the value of statistical life since only PM_{10} has a direct impact on mortality.

[23] In the case of PM_{10}, however, the figures are based on mortality and morbidity impacts discussed in Shah and Nagpal (1997a). The valuations of PM_{10} mortality impacts in column 2 have been performed using VSL estimates for the United States. The VSL values in this column have not been adjusted to account for the per capita income differences between Nepal and the United States. Properly adjusted figures are presented in column 3.

Table 5.1.4: Benefits from reduction in damages from tailpipe emissions for old microbuses									
		(1)	(2)		(3)		(4)		
	Pollutant	Emission (g/km)	Unadjusted damage (cents/g)		Adjusted damage (cents/g)--multiply by PCPI ratio		Adjusted damage (Rs/g)		
			Low VSL	High VSL	Low VSL	High VSL	Low VSL	High VSL	
Primary pollutants	PM10	1.050	34.42111	54.87566	1.97524	2.96226	1.4507	2.1614	
	NO2	9.100	1.85600	1.85600	0.12604	0.12604	0.0907	0.0907	
	SO2	0.273	3.24800	3.24800	0.22057	0.22057	0.1588	0.1588	
	CO	1.904	0.00232	0.00232	0.00016	0.00016	0.00011	0.00011	
Greenhouse gases	CO2-equiv	541.5	0.00336	0.00336	0.00023	0.00023	0.00016	0.00016	
	NMVOC	0.675	0.10788	0.10788	0.00733	0.00733	0.00527	0.00527	
Others	Air toxics*								
	Noise*								
Total damage avoided									

Sources: Koirala (2003), Shrestha & Malla (1996), Faiz (1996), Funk & Rabl (1999), McCubbin & Delucchi (1999)
Note: Data on air toxics and noise are available in cents/km from Funk and Rabl (1999) and Delucchi and Lipman (2001). The emissions per kilometer and damage per gram are not available separately.

Table 5.1.4 (cont.): Benefits from reduction in damages from tailpipe emissions for old microbuses					
		(5)		(6)	
	Pollutant	Damage per km (Rs/km) = (1) x (4)		% damage from each pollutant	
		Low VSL	High VSL	Low VSL	High VSL
Primary pollutants	PM10	1.5233	2.2695	61.2304	70.1759
	NO2	0.8258	0.8258	33.1946	25.5355
	SO2	0.0434	0.0434	1.7427	1.3406
	CO	0.0002	0.0002	0.0087	0.0067
Greenhouse gases	CO2-equiv	0.0891	0.0891	3.5802	2.7541
	NMVOC	0.0036	0.0036	0.1431	0.1101
Others	Air toxics	0.0008	0.0008	0.0331	0.0255
	Noise	0.0017	0.0017	0.0672	0.0517
Total damage avoided		**2.4878**	**3.23**	**100.00**	**100.00**

The benefits from reduction in damages from tailpipe emissions for new microbuses are presented in Table 5.1.5. Since new microbuses are cleaner than older ones, the damages shown in this table are understandably lower than those in Table 5.1.4. Hence the total benefit from replacing a microbus by Safa Tempos is lower in the case of new microbuses.

Table 5.1.5: Benefits from reduction in damages from tailpipe emissions for new microbuses

		(1)	(2)		(3)		(4)	
	Pollutant	Emission (g/km)	Adjusted damage (Rs/g)		Damage per km (Rs/km) = (1) x (2)		% damage from each pollutant	
			Low VSL	High VSL	Low VSL	High VSL	Low VSL	High VSL
Primary pollutants	PM10	0.562	1.45074	2.16140	0.81569	1.21526	87.517	91.262
	NO2	0.496	0.09075	0.09075	0.04498	0.04498	4.826	3.378
	SO2	0.049	0.15881	0.15881	0.00780	0.00780	0.837	0.586
	CO	1.904	0.00011	0.00011	0.00022	0.00022	0.023	0.016
Greenhouse gases	CO2-equiv	365.6	0.00016	0.00016	0.06013	0.06013	6.451	4.516
	NMVOC	0.360	0.00527	0.00527	0.00190	0.00190	0.204	0.143
Others	Air toxics				0.00044	0.00044	0.047	0.033
	Noise				0.00089	0.00089	0.095	0.067
Total damage avoided					**0.932**	**1.332**	**100.00**	**100.00**

Sources: Koirala (2003), Shrestha & Malla (1996), Faiz (1996), Funk & Rabl (1999), McCubbin & Delucchi (1999)

5.1.3 Net benefits

The per kilometer costs, benefits and net benefits[24] of replacing old and new diesel microbuses by Safa Tempos are summarized in Table 5.1.6. Observe that the net benefit is positive for both old and new microbuses regardless of the VSL used. In other words, the benefits to society of replacing a microbus by EVs outweigh the costs for both categories of microbuses. Hence, from a social welfare perspective and from the perspective of correcting market failure, the government would be justified in concretely supporting EVs.

Table 5.1.6: Net benefit of replacing a microbus with Safa Tempos

	Cost (Rs/km)	Benefit (Rs/km)		Net Benefit (Rs/km)		Annual NB per vehicle (Rs/yr)	
		Low VSL	High VSL	Low VSL	High VSL	Low VSL	High VSL
Replacing old microbuses	2.000	2.488	3.23	0.488	1.234	24573	62181
Replacing new microbuses	0.741	0.932	1.332	0.191	0.591	9642	29781

The figures in Table 5.1.6 indicate that the net benefit of replacing a microbus by Safa Tempos is relatively higher in the case of old microbuses. The reason is that while the cost of replacing old microbuses is clearly higher than the cost of replacing new ones, the benefits associated with pollution reduction are also much higher for old microbuses.

The net benefits discussed so far have been expressed in terms of rupees per kilometer of travel. In order to make the net benefits more understandable, the last two columns in Table 5.6 show the *annual* net benefit associated with replacing one microbus by an equivalent number of Safa Tempos. These figures indicate that society would gain Rs. 24,573/year to Rs. 62,181/year per vehicle by replacing old microbuses with Safa Tempos. Although lower, the gains in the case of new microbuses are also quite substantial (Rs. 9642/year to Rs. 29781/year per vehicle).

[24] Net benefit = Benefit – Cost.

5.1.4 Accounting for the cost of battery lead discharge

Since the benefit-cost analysis presented above ignores the costs associated with the lead discharged from EV batteries,[25] it tends to overestimate the social net benefit associated with Safa Tempos. Hence the methodology proposed in section 4.3.2 will now be applied to account for cost of battery lead discharge.

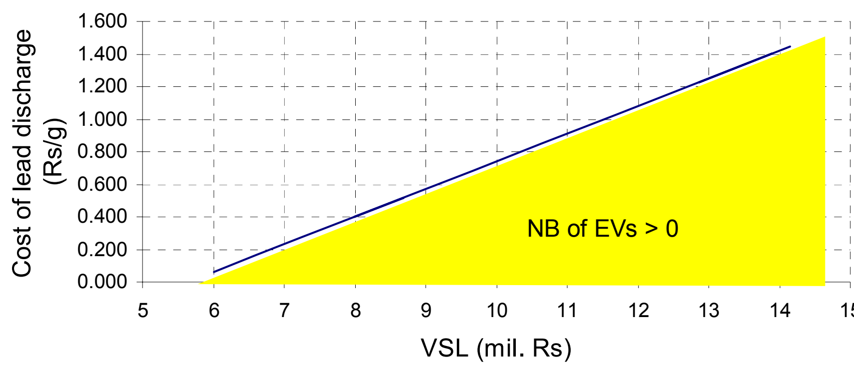
Recall that this methodology involves the construction of a straight-line graph that shows, for different values of VSL, the maximum unit cost of lead discharge below which the social net benefit remains positive. The graphs for old and new microbuses are shown in Figures 5.1.1 and 5.1.2, respectively. Equations (6) and (7) are the corresponding equations for these graphs.

$$\text{Old microbuses: } Pb_{UnitCost} = -0.896 + 1.696 \times 10^{-7} VSL \quad (6)$$

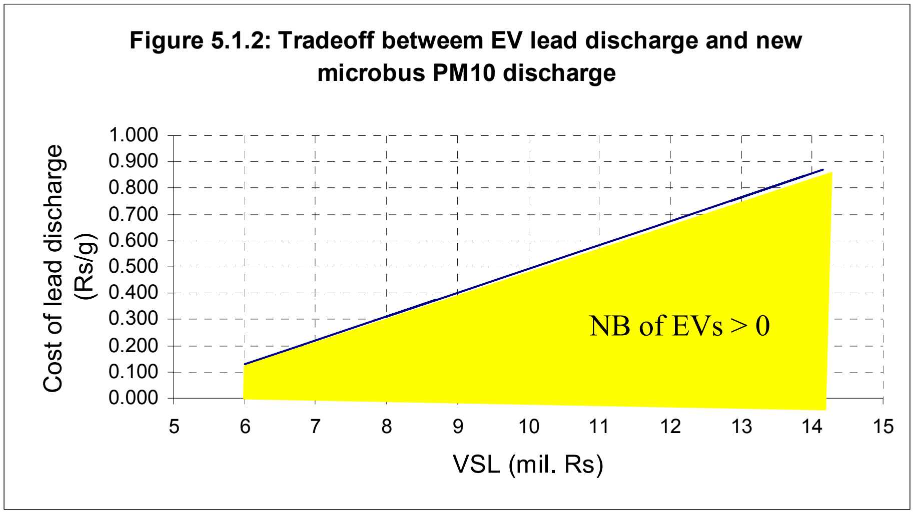
$$\text{New microbuses: } Pb_{UnitCost} = -0.408 + 9.081 \times 10^{-8} VSL \quad (7)$$

The shaded areas of the graphs show the cases where the benefits of EVs outweigh the costs. The following example illustrates the approach to extracting information from these graphs. Suppose the chosen value of VSL is Rs. 8.7 million. The graphs allow us to answer the following question: If the VSL is Rs. 8.7 million, how high must the per gram cost of lead discharge be for the costs of EVs to exceed the benefits? The graph in Figure 5.1.1 shows that the lead cost corresponding to a VSL value of Rs. 8.7 million is Rs. 0.58/g. Hence, the net benefit of EVs will remain positive so long as the true cost of lead discharge is less than Rs. 0.58/g. In other words, unless the cost of lead discharge is greater than Rs. 0.58/g, it would be worthwhile to replace old microbuses by Safa Tempos.

Figure 5.1.1: Tradeoff between EV lead discharge and old microbus PM10 discharge



[25] None of the journal publications reviewed have tried to account for the cost of battery lead discharge.



The next question is whether or not Rs. 0.58/g is a reasonable cost figure for lead discharge. To answer this question, compare this value with the cost per gram figures for SO_2 and NO_2, the two most damaging emissions after PM_{10}. Clearly, Rs. 0.58/g (the estimated cost of lead discharge) is many times higher than the costs of SO_2 and NO_2 given in Tables 5.1.4 and 5.1.5. And given the highly localized nature of battery lead discharge, there is no reason to believe that it will get dispersed into the human environment as easily as SO_2 and NO_2. Hence, Rs. 0.58/g can be considered an unreasonably high guess for the cost of lead discharge. In other words, the per gram cost of lead discharge is most likely much lower than Rs. 0.58/g, which means that the net benefit of EVs is positive even when battery lead discharge is taken into account. If higher values of VSL are used, the cost of lead discharge must also increase for the net benefit of EVs to become negative. It is, therefore, safe to conclude that, for the VSL range considered in this analysis, the benefits of EVs outweigh the costs even after accounting for the costs of battery lead discharge.

A similar analysis can be done for new microbuses using the graph in Figure 5.1.2. It shows that the lead cost corresponding to a VSL value of Rs. 8.7 million is Rs. 0.38/g. As this value too is much higher than the costs per gram of SO_2 and NO_2 given in Tables 5.1.4 and 5.1.5, it would be reasonable to conclude that the net benefit of Safa Tempos is positive even after taking the cost of battery lead discharge into account.

Table 5.1.7 presents net benefits of Safa Tempos using two different assumed values for the cost per gram of battery lead discharge. The net benefits in rows 1 and 3 are computed under the assumption that the cost per gram of battery lead discharge is relatively high—equal to that of SO_2 emissions. The assumed cost of lead in rows 2 and 4, on the other hand, is equal to the cost of NO_2 given in Table 5.1.5. As before, the net benefit is positive in all four cases. The annual net benefit to society of replacing an old microbus with Safa Tempos ranges from Rs. 12,355/year to Rs. 47,998/year. The annual net benefit in the case of new microbuses is lower but still substantial.

Table 5.1.7: Net benefit of replacing a microbus with Safa Tempos (accounting for lead discharge)

		Assumed cost of lead (Rs/g)		Net Benefit (Rs/km)		Annual net benefit per vehicle (Rs/yr)	
				Low VSL	High VSL	Low VSL	High VSL
Replacing old microbuses	(1)	0.1505	(same as for SO2)	0.2451	0.9523	12355	47998
	(2)	0.0860	(same as for NO2)	0.2996	1.0068	15100	50743
Replacing new microbuses	(3)	0.1505	(same as for SO2)	0.0234	0.4021	1178	20264
	(4)	0.0860	(same as for NO2)	0.0778	0.4565	3923	23009

5.2 Diesel-fueled microbuses vs. trolley buses

5.2.1 Costs

As the format of Tables 5.2.1, 5.2.2 and 5.2.3 follows the format of the tables in section 5.1.1, the cost figures presented in these tables should be self-explanatory. It is, however, worth pointing out an additional cost item in the tables in the current section. And that is the cost of infrastructure required to operate the trolley buses.[26] The KEVA (2004) study estimates the required annual infrastructure cost for running 22 buses along the Tripureshwor—Suryabinayak route. This information has been used to compute the infrastructure cost for one trolley bus per year as well as per kilometer of travel. Also note that neither the production cost of batteries nor the impact of battery lead discharge is relevant for the cost comparison between trolley buses and microbuses since both vehicles use the same type of batteries.

Table 5.2.1: Key figures used for trolley bus cost calculations

Key figures	Diesel microbus	Trolley bus
Seating + standing passenger capacity (persons)	16	60
Vehicle lifetime (yrs)	20	25
Distance traveled per year per battery set (km/yr)	50400	62400
Social discount rate above inflation (%)	0.05	0
Vehicle production cost without batteries (Rs/vehicle)	830638	3733333
Infrastructure maintenance and operation cost (Rs/yr)	N/A	662727
Cost of vehicle maintenance/repair (Rs/yr)	8000	140400
Cost of wear and tear of tires (Rs/yr)	6500	74880
Current fuel/energy cost (Rs/liter or Rs/kwh)	37.31	4.25
Fuel/Energy consumption (liter/km or kwh/km)	0.1	1.330

Source: Field survey (2004), CEMAT (2001), KEVA (2004)

[26] The cost of maintaining the roads is not included in this cost since this is not an infrastructure built specifically for the exclusive use of trolley buses.

Table 5.2.2: Cost summary per vehicle using existing electricity tariffs (micros vs. trolleys)

Cost item	Cost summary (Rs/km)				
	New diesel microbus	Old diesel microbus	Equivalent new Trolley	(Equiv. trolley-new micro)	(Equiv. trolley-old micro)
Production	1.259	0.000	1.078	-0.181	1.078
Infrastructure operations	0.000	0.000	2.832	2.832	2.832
Maintenance/Repair	0.159	0.159	0.600	0.441	0.441
Wear and tear of tires	0.129	0.129	0.320	0.191	0.191
Fuel/energy	3.731	3.731	1.507	-2.224	-2.224
Total using existing tariff (Rs/km)	5.278	4.019	6.338	1.059	2.319

The figures in Table 5.2.2 indicate that although the production cost and fuel/energy cost for trolley buses are lower than those for microbuses, they are overwhelmed by the infrastructure operating cost for trolley buses.

When analyzing the costs of Safa Tempos, it was argued that using NEA's existing electricity tariff rates would overestimate the opportunity cost of electricity used to charge batteries. In the case of trolley buses, on the other hand, the existing tariff rate of Rs. 4.25/kwh probably underestimates the opportunity cost of electricity usage. The reason is that unlike EV batteries that can store electricity from off-peak hours, trolley buses must use normal and peak-hour electricity. Given the high demand for public transportation right before and after office-hours and the relatively low demand at other times, it would be reasonable to assume that 90% of the trips made by trolley buses take place during the NEA-defined normal hours.[27] Assuming that the remaining 10% of the trips are made during peak-hours, the average cost of electricity using the TOD tariff structure would be Rs. 4.31/kwh. The cost comparisons based on this more appropriate estimate of electricity cost are given in Table 5.2.3. The social cost of replacing a diesel microbus by an equivalent trolley bus is, therefore, Rs. 1.08/km for new microbuses and Rs. 2.34/km for old ones.

Table 5.2.3: Cost summary using TOD-based social cost of electricity (micros vs. trolleys)

Cost item	Cost summary (Rs/km)				
	New diesel microbus	Old diesel microbus	Equivalent new EV	(Equiv. EV-new micro)	(Equiv. EV-old micro)
Fuel/Energy cost using TOD-based social cost	3.731	3.731	1.527	-2.204	-2.204
Total cost using TOD-based social cost	5.278	4.019	6.357	1.079	2.338

5.2.2 Net benefits

The benefits of replacing a diesel microbus by an equivalent zero emissions vehicle have already been presented in Tables 5.1.4 and 5.1.5. Comparing the figures in these tables with

[27] If trolley buses operate from say 6 am to 9 pm, then 3 of the 15 hours will fall under the peak-hour category. But the average number of trips per hour after 6 pm would be far fewer than the average during normal hours.

those in Table 5.2.3 gives the net benefits to society of replacing diesel microbuses by trolley buses.

Table 5.2.4: Net benefit of replacing microbus with trolley buses

	Cost (Rs/km)	Benefit (Rs/km)		Net Benefit (Rs/km)		Annual NB per vehicle (Rs/yr)	
		Low VSL	High VSL	Low VSL	High VSL	Low VSL	High VSL
Replacing old micros	2.338	2.488	3.23	0.149	0.896	7529	45136
Replacing new micros	1.079	0.932	1.332	-0.147	0.253	-7402	12736

It is clear from Table 5.2.4 that the net benefit of replacing an old microbus by an equivalent trolley bus is definitely positive. And although the net benefit of replacing new microbuses by trolley buses is negative when using a low value for VSL, it becomes positive as when values are attached to each life saved from pollution reduction. More specifically, the replacement of each new microbus by trolley buses could give society a yearly net benefit of up to Rs. 12,736. The number would, of course, be even higher when replacing an old microbus. Hence, there are sufficient grounds for arguing that the government should actively support the revival of the trolley bus system in Kathmandu. It is also interesting to note that the net benefits of replacing microbuses by Safa Tempos are higher than the net benefits obtained by replacing them with trolley buses.

5.3 Diesel-fueled microbuses vs. battery powered electric buses (BPEBs)

Unlike Safa Tempos and trolley buses, battery-operated buses have not yet been used in Nepal for mass transport. The analysis in this section is, therefore, partly based on information gathered on a prototype 16-seater battery powered microbus being currently tested by the Himalayan Light Foundation. But since the Himalayan Light Foundation has not finished estimating the operations costs and technical performance of the bus, the data provided by them was supplemented by information from the Society of Indian Automobile Manufacturers (SIAM) on battery-powered microbuses operating in India. Some key information is, nevertheless, missing. Since the analysis presented below often uses extrapolated data based on various assumptions derived from Kathmandu's Safa Tempo experience, the results should be viewed with caution. For example, in the absence of information on battery life, the electric bus battery has been assumed to last a bit longer than Safa Tempo batteries (2 years) under conditions of regular usage at around 100 km/day. Similarly, a BPEB is assumed to last the same number of years as diesel microbuses.

5.3.1 Costs

The relevant lifecycle cost figures for BPEBs and diesel microbuses are summarized in Tables 5.3.1 through 5.3.3. The extra costs associated with replacing a diesel microbus with a BPEB are very large when the existing electricity tariff rate is used to compute the energy cost of BPEBs. These costs go down if the opportunity cost of electricity based on the TOD rates is used in the cost computation as can be seen from the last row of Table 5.3.3. But they are still much higher than the comparable costs shown in Tables 5.1.3 and 5.2.3 for Safa Tempos and trolley buses, respectively.

Table 5.3.1: Key figures used in the cost calculations for battery-powered electric bus (BPEB)

Key figures	Diesel microbus	Battery-powered electric bus
Seating + standing passenger capacity (persons)	16	16
Vehicle lifetime (yrs)	20	20
Distance traveled per year per battery set (km/yr)	50400	30000
Social discount rate above inflation (%)	0.05	0.05
New: production cost without batteries (Rs/vehicle)	830638	681000
Old: production cost without batteries (Rs/vehicle)	0	0
Cost of battery set (Rs/bat)	2696	219000
Lifetime of battery set (yrs)	1.5	2
Cost of maintenance/repair (Rs/yr)	8000	9524
Cost of wear and tear of tires (Rs/yr)	6500	11607
Current fuel/energy cost (Rs/liter or Rs/kwh)	37.31	4.25
NEA TOD peak charge--6pm to 11pm (Rs/kwh)	N/A	4.80
NEA TOD normal charge--6am to 6pm (Rs/kwh)	N/A	4.25
NEA TOD off-peak charge--11pm to 6am (Rs/kwh)	N/A	3.00
Fuel/Energy consumption (liter/km or kwh/km)	0.0625	0.500

Source: Filed survey (2004), SIAM (2004), NEA (2003)

Table 5.3.2: Cost summary per vehicle using existing electricity tariffs

Cost item	Cost summary (Rs/km)				
	New diesel microbus	Old diesel microbus	BPEB	(BPEB-new micro)	(BPEB-old micro)
Production	1.259	0.000	1.735	0.475	1.735
Battery	0.036	0.036	3.739	3.703	3.703
Maintenance/Repair	0.159	0.159	0.159	0.000	0.000
Cost of wear and tear of tires	0.129	0.129	0.193	0.064	0.064
Fuel/Energy cost	2.332	2.332	2.125	-0.207	-0.207
Total cost using existing tariff (Rs./km)	3.915	2.656	7.951	4.036	5.295

Source: Field survey (2004), SIAM (2004)

Table 5.3.3: Cost summary using TOD-based social costs of electricity

Cost item	Cost summary (per vehicle)				
	New diesel microbus	Old diesel microbus	Equivalent new EV	(Equiv. EV-new micro)	(Equiv. EV-old micro)
Fuel/Energy cost (Rs./km)	2.332	2.332	0.679	-1.653	-1.653
Total cost using TOD-based social cost (Rs./km)	3.915	2.656	6.505	2.590	3.849

5.3.2 Net benefits

Comparing the benefits shown in Tables 5.1.4 and 5.1.5 with the costs summarized in Table 5.3.3, it is clear that the social costs of BPEVs outweigh the social benefits. The net benefits of replacing a diesel microbus by a BPEV are summarized in Table 5.3.4. If the costs of battery lead discharge were also added to the costs in the table, the net benefits would become even more negative. Hence, given the current level of technology, it does not seem worthwhile for the government to support battery-operated electric buses.

Table 5.3.4: Net benefit of replacing microbus with EV							
	Cost (Rs/km)	Benefit (Rs/km)		Net Benefit (Rs/km)		Annual NB per vehicle (Rs/yr)	
		Low VSL	High VSL	Low VSL	High VSL	Low VSL	High VSL
Replacing old micros	3.849	0.680	0.82	-3.169	-3.027	-159701	-152538
Replacing new micros	2.590	0.257	0.333	-2.333	-2.257	-117586	-113750

5.4 Gasoline-fueled passenger cars vs. battery operated passenger cars

In this subsection, the social benefits and costs of a typical gasoline-fueled passenger car, the Maruti 800, are compared with the benefits and cost of the REVA Standard electric car. Some of the relevant specifications of the two cars are given in Table 5.4.1.

Most of the specifications for the REVA were obtained from the company itself. Hence, they might not necessarily reflect the driving conditions and driving practices in Kathmandu. Also, note that a vehicle lifetime of 10 years is assumed for both types of cars even though this number might not match the claims of the manufacturers. This figure was chosen for the lifetimes since it is consistent with the lifetime used for passenger cars and comparable battery-operated cars in a study of EVs in the Paris region by Funk and Rabl (1999). Before proceeding with the analysis, it is worth pointing out that since the Maruti 800 is a gasoline-fueled car, it emits far less PM_{10} than comparable diesel-fueled cars. Hence, replacing the Maruti 800 by an equivalent REVA might not necessarily yield substantial health benefits to society.

5.4.1 Costs

Tables 5.4.1 and 5.4.2 present the key cost figures relevant to the analysis. Note that, as in the case of diesel, the price of gasoline is listed higher (Rs. 56.81/liter) than the prevailing market price (Rs. 54/liter) in Kathmandu. The reasoning is the same as before, namely that it is more appropriate to use the opportunity cost of gasoline rather than the market price in social benefit-cost computations. And a reasonable estimate of this opportunity cost is the gasoline price across the border in India.

Table 5.4.2 presents the summary of lifecycle cost components for the two vehicles. The electricity consumption cost in the table is computed under the assumption that, of the 6 hours required to fully charge a REVA battery, 4 hours of charging is done during off-peak hours at zero opportunity cost to society. Peak-hour electricity is used for the other two hours.[28]

[28] The assumption is that although the charging will be done at night, vehicle owners will not necessarily wait till 11 pm to start the charging process. In other words, the charging process will begin during peak hours (before 11 pm) and end during off-peak hours (after 11 pm).

Table 5.4.1: Key figures used in the cost calculations for the REVA car

Key figures	Maruti 800	REVA Standard
Seating capacity	5	4
Vehicle lifetime (yrs)	10	10
Distance traveled per year per battery set (km/yr)	12500	6250
Social discount rate above inflation (%)	0.05	0.05
New: production cost without batteries (Rs/vehicle)	282198	344000
Old: production cost without batteries (Rs/vehicle)	0	0
Cost of battery set (Rs/bat)	2003	56000
Lifetime of battery set (yrs)	2	4
Cost of maintenance/repair (Rs/yr)	15000	9000
Cost of wear and tear of tires (Rs/yr)	5000	5000
Current fuel/energy cost (Rs/liter or Rs/kwh)	56.81	9.9
NEA TOD peak charge--6pm to 11pm (Rs/kwh)	N/A	4.80
NEA TOD normal charge--6am to 6pm (Rs/kwh)	N/A	4.25
NEA TOD off-peak charge--11pm to 6am (Rs/kwh)	N/A	3.00
Fuel/Energy consumption (liter/km or kwh/km)	0.0625	0.113

Source: Field survey (2004), SIAM (2004), NEA (2003)

Table 5.4.2: Cost summary per vehicle using TOD-based social costs of electricity

Cost item	Cost summary (Rs/km)				
	New Maruti 800	Old Maruti 800	Equivalent REVA	(Equiv. REVA -new Maruti)	(Equiv. REVA-old Maruti)
Vehicle production	2.784	0.000	4.243	1.458	4.243
Battery	0.082	0.082	1.504	1.422	1.422
Maintenance/Repair	1.200	1.200	0.900	-0.300	-0.300
Wear and tear of tires	0.400	0.400	0.500	0.100	0.100
Fuel/Energy cost using TOD social cost	3.551	3.551	0.225	-3.326	-3.326
Total cost using TOD social cost	8.017	5.233	7.372	-0.645	2.139

As might be expected, the lifecycle cost of an old Maruti 800 is substantially less than that of an equivalent REVA. Although the REVA car has an advantage over its Maruti counterpart in terms of maintenance repair cost and fuel/energy cost, the high production cost and battery cost reduce its overall competitiveness. Interestingly however, the lifecycle cost gap is in REVA's favor when comparing it with a new Maruti. Hence if the cost of battery lead discharge is ignored, replacing a new Maruti with and equivalent REVA is worthwhile from the perspective of society.

5.4.2 Benefits

The benefits of replacing a Maruti with an equivalent REVA are summarized in Table 5.4.3. Observe that although the amount of PM_{10} emissions are less for gasoline-fueled cars compared to diesel-fueled vehicles, the benefits from PM_{10} reduction are still substantial, especially in the case of new Marutis. Also observe that benefits from reductions in greenhouse gases comprise a large percentage of the total benefits.

Table 5.4.3: Benefits from reduction in damages from tailpipe emissions for old and new Maruti 800 cars

		Replacing old Maruti 800 by REVA					Replacing new Maruti 800 by REVA				
	Pollutant	Emission (g/km)	Damage per km (Rs/km)		% damage from each pollutant		Emission (g/km)	Damage per km (Rs/km)		% damage from each pollutant	
			Low VSL	High VSL	Low VSL	High VSL		Low VSL	High VSL	Low VSL	High VSL
Primary pollutants	PM10	0.200	0.290	0.432	42.645	52.556	0.107	0.155	0.231	60.572	69.594
	NO2	2.700	0.245	0.245	36.012	29.789	0.490	0.044	0.044	17.336	13.369
	SO2	0.130	0.021	0.021	3.034	2.510	0.101	0.016	0.016	6.262	4.829
	CO	62.000	0.007	0.007	1.034	0.855	4.050	0.000	0.000	0.179	0.138
Greenhouse gases	CO2-equiv	616.0	0.101	0.101	14.892	12.318	224.0	0.037	0.037	14.364	11.077
	NMVOC	2.600	0.014	0.014	2.016	1.667	0.375	0.002	0.002	0.771	0.595
Others	Air toxics		0.001	0.001	0.121	0.100		0.000	0.000	0.170	0.131
	Noise		0.002	0.002	0.246	0.203		0.001	0.001	0.346	0.267
Total damage avoided			**0.6804**	**0.823**	**100.00**	**100.00**		**0.257**	**0.333**	**100.00**	**100.00**

Sources: Koirala (2003), Faiz (2000), Funk & Rabl (1999), McCubbin & Delucchi (1999), Shrestha & Malla (1996)

<u>5.4.3 Net benefits</u>

The information presented in Table 5.4.4 shows that while the net benefit of replacing an old Maruti by an equivalent REVA is negative, replacing a new Maruti yields a positive net benefit of Rs. 0.257/km to Rs. 0.333/km. These numbers translate to an annual net benefit of Rs. 11,272 to 12,224, depending on the value placed on each life saved from pollution reduction.

Table 5.4.4: Net benefit of replacing a Maruti 800 by an equivalent REVA

	Cost (Rs/km)	Benefit (Rs/km)		Net Benefit (Rs/km)		Annual NB per vehicle (Rs/yr)	
		Low VSL	High VSL	Low VSL	High VSL	Low VSL	High VSL
Replacing old Marutis	2.139	0.680	0.82	-1.459	-1.317	-18235	-16458
Replacing new Marutis	-0.645	0.257	0.333	0.902	0.978	11272	12224

The net benefits computed in Table 5.4.4 do not take into account the cost of the extra lead discharged from REVA batteries. When these costs are also taken into account, the net benefit of replacing new Marutis by REVAs gets reduced but still remains positive. Table 5.4.5 shows the net benefits of introducing a REVA car under the assumption that the per gram cost of battery lead discharge is comparable to those of SO_2 and NO_2. For example, the net benefit of a REVA car ranges from Rs. 0.79/km to Rs. 0.87/km when the assumed cost of lead discharge is Rs. 0.16/km. The corresponding annual net benefit to society ranges from Rs. 9933 to Rs. 10884.

Table 5.4.5: Net benefit of replacing a Maruti by an equivalent REVA (accounting for lead discharge)

	Assumed cost of lead (Rs/g)		Net Benefit (Rs/km)		Annual NB per vehicle (Rs/vehicle)	
			Low VSL	High VSL	Low VSL	High VSL
Replacing old micros	0.1588	(same as for SO2)	-1.5659	-1.4238	-19574	-17798
	0.0907	(same as for NO2)	-1.5200	-1.3779	-19000	-17224
Replacing new micros	0.1588	(same as for SO2)	0.7946	0.8707	9933	10884
	0.0907	(same as for NO2)	0.8406	0.9167	10507	11458

Sources: Koirala (2003), Faiz (2000), Funk & Rabl (1999), McCubbin & Delucchi (1999), Shrestha & Malla (1996)

Using the graphical technique introduced in section 4.3, it is also possible to estimate the minimum cost that needs to be attached to lead discharge for the net benefit of a REVA car to be negative. Results of the graphical analysis indicate that even if a low value (Rs. 8.7 million) is attached to each life saved, the cost of lead discharge must be over Rs. 1.37/g for the net benefit of a REVA car to become negative. Following the argument in section 5.1.4, it would be reasonable to state that Rs.1.37/g is an unrealistically high value for the cost per gram of lead discharge. In other words, the benefits of replacing a new Maruti 800 with a REVA car outweigh the costs even after accounting for the cost of lead discharge.

Although one policy implication of the above conclusion is that the government ought to support the proliferation of electric cars like the REVA Standard, the distributional consequences of providing tax breaks and other assistance to electric car owners cannot be ignored.[29] More specifically, giving tax breaks to import private electric cars means that although most Kathmandu citizens will benefit from reduced air pollution, the transportation benefits from these cars will be enjoyed only by the vehicle owners. In other words, the vehicle owners reap all the transportation benefits while the rest of the population subsidizes the purchase price of the vehicles. Note that the situation is different for EVs used for public transport since the transportation benefits of such vehicles are enjoyed by a large cross-section of the population.

6. Impacts of policies to support EVs

As discussed in section 4.5, the goal of the policy measures considered here is to eliminate the "private" lifecycle cost gap between ICEVs and EVs for those cases where the social benefits of EVs outweigh their costs. The idea is that once the gap is closed in favor of EVs, entrepreneurs will eventually recognize the cost advantages of EVs and reallocate their investments from ICEVs to EVs. Policy measures aimed at closing this gap can focus either on the EV costs or on the ICEV costs. The policy simulation results presented in this section show the impact of these policy measures on the private lifecycle costs of ICEVs and EVs.

The social benefit-cost analyses presented earlier used before-tax prices for the production cost of vehicles and the Indian price of diesel and gasoline for fossil-fuel cost. Similarly, it used information on NEA's TOD-based electricity tariff rates and the public's electricity consumption pattern to derive the social cost of electricity use. Since the analysis in this

[29] Although the net benefit to society as a whole is positive, the benefits are seldom distributed equally among the population. The benefit-cost framework does not take into account such distributional consequences.

section focuses on private rather than social costs, it uses after-tax market prices for the relevant cost components of vehicles in the lifecycle cost computations. For example, it uses the market price of vehicles for the vehicle purchase cost. Similarly it uses the prevailing market prices of diesel to compute the fuel cost for microbuses and the electricity tariff rates at charging stations to compute the energy cost for Safa Tempos.

Recall that the society suffers a net loss when *old* petrol cars are replaced by REVA cars and when diesel microbuses are replaced by BPEBs. Hence, policies to support these two categories of EVs will not be considered here.

6.1: Helping Safa Tempos to compete with diesel microbuses

The policy variables considered in this study and their baseline values are given in Table 6.1.1. The impacts of policy measures are simulated by manipulating these variables. The baseline values for the costs relevant to the current analysis are presented in Table 6.1.2. Observe that the most important cost components of EVs are the energy cost, vehicle purchase cost and battery cost. Energy and vehicle purchase cost, in particular, can be readily manipulated through appropriate policy changes.

Table 6.1.1: Policy variables and their baseline values (microbus vs. Safa Tempo)

EV average import tax & VAT rate (%)	Interest rate for EV financing (%)	EV annual taxes and fees (Rs)	Electricity tariff rate for charging batteries (Rs/kwh)	Diesel price (Rs/liter)
12.5	13	1440	9	31

Source: Field survey (2004), personal communication with relevant government officials

Table 6.1.2: Summary of private costs per vehicle (microbus vs. Safa Tempo)

Cost item	Cost summary (Rs/km)					% of total cost		
	New diesel microbus	Old diesel microbus	Equivalent new EV	(Equiv. EV-new micro)	(Equiv. EV-old micro)	New diesel microbus	Old diesel microbus	EV
Vehicle purchase[30]	4.240	0.000	2.452	-1.788	2.452	53.5%	0.0%	25.2%
Battery	0.048	0.048	3.154	3.107	3.107	0.6%	1.3%	32.5%
Maintenance/Repair	0.159	0.159	0.667	0.508	0.508	2.0%	4.3%	6.9%
Wear and tear of tires	0.129	0.129	0.189	0.060	0.060	1.6%	3.5%	1.9%
Fuel/Energy	3.100	3.100	3.200	0.100	0.100	39.1%	84.1%	32.9%
Annual taxes and fees	0.250	0.250	0.053	-0.197	-0.197	3.2%	6.8%	0.5%
Total	7.926	3.686	9.716	1.789	6.030	100%	100%	100%

Source: Field survey (2004), personal communication with relevant government officials

<u>6.1.1 Measures for lowering the purchase price of EVs</u>

From a policy perspective, there are two key approaches to lowering the purchase price of EVs: (i) reducing import-related taxes and VAT and (ii) reducing the interest rate for EV financing.

The existing average tax rate (including import and value added taxes) for EVs is approximately 12.5%.[31] Table 6.1.3 shows how the cost of Safa Tempos varies with changes

[30] The after tax market price of a diesel microbus is around Rs. 1.7 million.

in this average tax rate. The last two columns present the difference in the total cost between EVs and microbuses. It is clear from the table that tax breaks are not enough to make EVs competitive with microbuses. For example, the lifecycle cost of Safa Tempos would remain higher than that of both old and new diesel microbuses even if the average tax rate were to be lowered to 1%.

Table 6.1.3: Changing the average import-related taxes and VAT (microbus vs. Safa Tempo)

	EV average import tax & VAT rate (%)	EV vehicle purchase cost (Rs/km)	ICEV vehicle purchase cost (Rs/km)	EV Total cost (Rs/km)	ICEV Total cost (Rs/km)	Total cost difference (EV - ICEV) (Rs/km)	Total cost difference (EV - ICEV) (Rs/yr)
	12.5	2.45	0.00	9.72	3.69	6.03	303908
	5	2.29	0.00	9.55	3.69	5.87	295668
Old microbus	1	2.20	0.00	9.46	3.69	5.78	291274
	12.5	2.45	4.24	9.72	7.93	1.79	90189
	5	2.29	4.24	9.55	7.93	1.63	81949
New microbus	1	2.20	4.24	9.46	7.93	1.54	77554

The impacts of changes in the interest rate on loans for EV purchase are presented in Table 6.1.4. Although the lifecycle cost gap does decrease with the lowering of the interest rate, this policy measure too is inadequate for making Safa Tempos competitive with microbuses. Also observe that since the lifecycle cost gap between Safa Tempos and old microbuses is much larger than that between Safa Tempos and new microbuses to begin with, it is highly unlikely that anything short of banning old microbuses or giving cash subsidies to EVs will lead Safa Tempos to replace microbuses.

Table 6.1.4: Changing the interest rate for EV financing (microbus vs. Safa Tempo)

	Interest rate on loans (%)	EV vehicle purchase cost (Rs/km)	ICEV vehicle purchase cost (Rs/km)	EV Total cost (Rs/km)	ICEV Total cost (Rs/km)	Total cost difference (EV - ICEV) (Rs/km)	Total cost difference (EV - ICEV) (Rs/yr)
	13	2.45	0.00	9.72	3.69	6.03	303908
	7	2.00	0.00	9.22	3.69	5.54	279084
Old microbus	1	1.57	0.00	8.75	3.69	5.06	255254
	13	2.45	4.24	9.72	7.93	1.79	90189
	7	2.00	4.24	9.22	7.93	1.30	65365
New microbus	1	1.57	4.24	8.75	7.93	0.82	41534

6.1.2. Lowering the operating cost of EVs

The most effective way to lower the operating cost of Safa Tempos is by decreasing the electricity tariff for charging batteries. Given the existing NEA tariff structure, all Safa Tempos charge their batteries at charging stations. NEA currently provides electricity to EV

[31] See Appendix C for a complete list of vehicle taxes.

battery charging stations at the rate of Rs. 4.3/kwh (NEA 2003). After adding an overhead cost of Rs. 4.7/kwh to cover fixed and operating costs plus profits, the stations charge EVs a tariff rate of Rs. 9/kwh (NESS 2003; Devtech 2002). Table 6.1.5 shows how the lifecycle cost gap between Safa Tempos and microbuses changes with decreases in the tariff rate seen by EVs.

Table 6.1.5: Changing the electricity tariff rates for battery charging (microbus vs. Safa Tempo)

	Electricity tariff for battery charging (Rs/kwh)	EV energy cost (Rs/km)	Micro fuel cost (Rs/km)	EV Total cost (Rs/km)	ICEV Total cost (Rs/km)	Total cost difference (EV - ICEV) (Rs/km)	Total cost difference (EV - ICEV) (Rs/yr)
	9	3.20	3.10	9.72	3.69	6.03	303908
	8.4	2.99	3.10	9.50	3.69	5.82	293156
	7	2.49	3.10	9.00	3.69	5.32	268068
	5	1.78	3.10	8.29	3.69	4.61	232228
Old microbus	3.9	1.39	3.10	7.90	3.69	4.22	212516
	9	3.20	3.10	9.72	7.93	1.79	90189
	8.4	2.99	3.10	9.50	7.93	1.58	79437
	7	2.00	3.10	9.22	7.93	1.30	65365
	5	1.78	3.10	8.29	7.93	0.37	18509
New microbus	3.9	1.39	3.10	7.90	7.93	-0.02	-1203

Observe that manipulating the tariff rates alone will not make Safa Tempos competitive with old microbuses. On the other hand, the lifecycle cost of Safa Tempos can be brought below that of *new* microbuses if there is a substantial reduction in the tariff rate. More specifically, if the tariff rate is lowered to Rs. 3.9/kwh, Safa Tempos will gain a competitive edge over new microbuses. This basically means that NEA would have to reduce the existing tariff rate by Rs. 5.1/kwh, an impossible task in the existing setup considering that NEA currently charges only Rs. 4.3/kwh to charging stations. If, however, NEA allowed individual EV owners to directly charge their batteries using the TOD tariff rates, then the average tariff rate seen by EVs would actually be only Rs. 3.46.[32] In other words, EVs could compete with microbuses if NEA changed its restrictive policies regarding time of day metering and allowed EVs to charge their batteries using the TOD rates.

It was mentioned earlier that another approach to lowering the operations cost of EVs is by reducing the various annual fees and taxes imposed on motor vehicles. As the government has already exempted Safa Tempos from many of these fees and taxes, they only pay around Rs. 1440/yr—a very small amount compared to the Rs. 12,610 paid yearly by microbuses. Hence, even if these fees and taxes on Safa Tempos were to be eliminated altogether, the impact on the lifecycle cost gap would be minimal.[33]

6.1.3 Making ICEVs pay for the pollution they produce

[32] Average tariff rate seen by EVs under the TOD rate structure = 0.7x3.0 + 0.15x4.8 + 0.15x4.25 = 3.46.
[33] The total lifecycle cost of Safa Tempos would go down by a mere .05%.

One way to make ICEVs pay for the pollution they create is by imposing a pollution tax on fossil fuels. This is an appealing policy option from three perspectives. First, it is consistent with the widely popular polluter-pays principle, which states that parties that pollute the environment should pay for the pollution they create. Second, since a pollution tax can be a source of revenue for the government, the concerned officials have reasons to view it in a positive light. Furthermore, the government can also use the generated revenue to support electric and other non-polluting vehicles. And third, the imposition of a tax on fuel directly increases the operating cost of ICEVs, thereby reducing the lifecycle cost gap between EVs and ICEVs.

Table 6.1.6 shows the impacts of pollution taxes on the lifecycle cost gap between Safa Tempos and microbuses. The increases in the market prices of diesel shown in the table are equal to the taxes imposed. Again note that the cost gap between Safa Tempos and old microbuses is too large for the diesel price increase to have a substantial impact. But it is clear that increasing diesel price to Rs. 49/liter will make Safa Tempos more competitive than new diesel microbuses.

The current diesel price of Rs. 31/liter is Rs. 2.58 less than what it costs Nepal Oil Corporation (NOC) to supply this fuel in Kathmandu.[34] Hence, removing this subsidy would raise the price of diesel to Rs. 33.58. The impacts of this change in price are shown in rows 2 and 8 of Table 6.5. Similarly the Table also shows the impacts of equalizing the price of diesel in Nepal with that of bordering areas of India where the price is Rs. 37.31. Although this is a significant price increase compared to the baseline price of Rs. 31/liter, it is not enough to make Safa Tempos competitive with microbuses. As indicated above, the price has to be raised by Rs. 18/liter (58%) in order to have the desired impact. The feasibility of implementing such a price hike is, of course, questionable.

Table 6.1.6: Making microbuses pay for the pollution they produce

	Diesel market price (Rs/liter)	EV energy cost (Rs/km)	ICEV fuel cost (Rs/km)	EV Total cost (Rs/km)	ICEV Total cost (Rs/km)	Total cost difference (EV - ICEV) (Rs/km)	Total cost difference (EV - ICEV) (Rs/yr)
	31	3.20	3.10	9.72	3.69	6.03	303908
	33.58	3.20	3.36	9.72	3.94	5.77	290905
	37.31	3.20	3.73	9.72	4.32	5.40	272106
	40	3.20	4.00	9.72	4.59	5.13	258548
	45	3.20	4.50	9.72	5.09	4.63	233348
Old microbus	49	3.20	4.90	9.72	5.49	4.23	213188
	31	3.20	3.10	9.72	7.93	1.79	90189
	33.58	3.20	3.36	9.72	8.18	1.53	77185
	37.31	3.20	3.73	9.72	8.56	1.16	58386
	40	3.20	4.00	9.72	8.83	0.89	44829
	45	3.20	4.50	9.72	9.33	0.39	19629
New microbus	49	3.20	4.90	9.72	9.73	-0.01	-531

Source: Field survey (2004

[34] This information was obtained through personal communication with officials at the Nepal Oil Corporation. The fossil fuel prices are for April 16, 2004.

Although it was mentioned above that a pollution tax on diesel would generate extra revenue for the government, this is not necessarily true all the time. In particular, since the increase in price leads to a decrease in the demand for diesel, the price increase is accompanied by a decrease in the quantity of diesel purchased by consumers. Hence, although the buyers of diesel pay a higher price for the diesel they consume, they no longer consume as much as before. If the decrease in consumption is very large, then the total revenue can actually decline as a result of the price increase.

Whether or not revenue increases with an increase in price depends on the price elasticity of demand for diesel. Using data from the literature, Koirala (2002) estimates that the price elasticity of diesel for Nepal is around 0.34. In other words, although every percent increase in the price of diesel is accompanied by a decrease in the quantity of diesel consumed, the decrease is relatively small (only 0.34%). Hence, the increase in diesel price as a result of the pollution tax leads to an increase in revenue for the government. Also note that if the price of diesel is increased to Rs. 49/liter, microbus owners cannot necessarily pass on the tax burden to microbus passengers through a fare hike since such a move would lead passengers to switch to Safa Tempos. Hence, a pollution tax on diesel will not necessarily hurt the users of mass transport.

6.2 Helping trolley buses to compete with diesel microbuses

The baseline values for the relevant policy variables are given in Table 6.2.1. The trolley buses considered here are locally assembled buses that cost around Rs. 4.2 million. And it is assumed that this price reflects the average import tax + VAT rate (12.5%) used in the analysis for Safa Tempos. Yet another assumption is that trolley buses are required to pay the same amount of annual taxes (Rs.12430) as microbuses even though it seems like the trolley buses currently in operation are not paying these fees.

According to the information in Table 6.2.3, trolley buses have a significant cost advantage over microbuses in terms of vehicle purchase cost and fuel/energy consumption. Hence, even though the trolley infrastructure operating cost is quite large, the total cost per kilometer for trolley buses is lower than that for new microbuses. The last row of Table 6.2.3 shows that replacing a new microbus with an equivalent trolley bus results in a cost saving of approximately Rs. 200,060/year. In other words, there is no need for subsidy support from the government to make trolley buses competitive. This finding is consistent with the findings of KEVA (2004).

Table 6.2.1: Policy variables and their baseline values (microbus vs. trolley bus)

Trolley average import tax & VAT rate (%)	EV annual taxes and fees (Rs)	Electricity tariff rate	Diesel price (Rs/liter)	Interest rate for trolley financing (%)
12.5	12430	4.25	31	13

Note: information based on personnel communication with relevant government officials

Table 6.2.2: Summary of private costs per vehicle (microbus vs. trolley bus)

	Cost summary (Rs/km)					% of total cost		
Cost item	New diesel microbus	Old diesel microbus	Equivalent new trolley	(Equiv. trolley-new micro)	(Equiv. trolley-old micro)	New diesel microbus	Old diesel microbus	Trolley
Vehicle purchase	4.240	0.000	2.167	-2.074	2.167	53.8%	0.0%	29.0%
Infrastructure	0.000	0.000	2.832	2.832	2.832	0.0%	0.0%	37.9%
Maintenance/Repair	0.159	0.159	0.600	0.441	0.441	2.0%	4.4%	8.0%
Wear and tear of tires	0.129	0.129	0.320	0.191	0.191	1.6%	3.5%	4.3%
Fuel/Energy	3.100	3.100	1.507	-1.593	-1.593	39.3%	85.2%	20.2%
Annual taxes and fees	0.250	0.250	0.054	-0.196	-0.196	3.2%	6.9%	0.7%
Total	7.878	3.638	7.480	-0.398	3.842	100%	100%	100%

Source: Field survey (2004)

The large infrastructure cost and the vehicle purchase cost are the main disadvantages trolley buses have over old microbuses. Tables 6.2.3 and 6.2.4 summarize the impacts of different policy measures on the lifecycle cost gap between old microbuses and trolley buses. While changing the tax rates, electricity tariff rate and the interest rate for EV financing are helpful, these changes cannot bridge the lifecycle cost gap on their own. A pollution tax on diesel fuel can make trolleys cost-competitive with old microbuses if a tax of around Rs. 39 is imposed on each liter of diesel purchased. Such a high tax rate is most likely not feasible in practice.

Table 6.2.3: Changing the average import-related taxes and VAT

	EV average import tax & VAT rate (%)	EV vehicle purchase cost (Rs/km)	ICEV vehicle purchase cost (Rs/km)	EV Total cost (Rs/km)	ICEV Total cost (Rs/km)	Total cost difference (EV - ICEV) (Rs/km)	Total cost difference (EV - ICEV) (Rs/yr)
	12.5	2.17	0.00	7.48	3.64	3.84	193660
	5	2.02	0.00	7.34	3.64	3.70	186379
Old microbuses	1	1.95	0.00	7.26	3.64	3.62	182496
New microbus	12.5	2.17	4.24	7.48	7.88	-0.40	-20060

Table 6.2.4: Impact of policy measures on the lifecycle cost gap between old microbuses and trolley buses

Policy measure	Interest rate on loans (%)	Electricity tariff for battery charging (Rs/kwh)	Diesel price (Rs/liter)	EV Total cost (Rs/km)	ICEV Total cost (Rs/km)	Total cost difference (EV - ICEV) (Rs/km)	Total cost difference (EV - ICEV) (Rs/yr)
Status quo	13	4.25	31	7.48	3.64	3.84	193660
	7	4.25	31	6.75	3.64	3.11	156992
Changing interest rate	1	4.25	31	6.12	3.64	2.48	125114
Changing tariff rate	13	1	31	6.33	3.64	2.69	135565
	13	4.25	37.31	7.48	4.27	3.21	161857
Implementing pollution tax on	13	4.25	50	7.48	5.54	1.94	97900
diesel	13	4.25	70	7.48	7.54	-0.06	-2900

6.3 Helping REVAs to compete with Maruti 800s

The baseline values of the relevant policy variables and the lifecycle cost gap between a Maruti 800 and an equivalent REVA are presented in Tables 6.3.1 and 6.3.2, respectively. Note that the tariff rate for charging batteries Rs. 9.9/kwh, a higher rate than the one used in the Safa Tempo analysis. This high tariff rate is used in the analysis since REVA owners will most likely charge their batteries at home and will, therefore, be subjected to the electricity tariff rate for domestic consumers (Rs 9.9/kwh). It is also assumed that REVA cars have to pay the same amount of annual taxes and fees as the Maruti 800.

Note that since REVAs are subject to the same import tax + VAT rate (NESS 2003) as ICE cars, the vehicle purchase cost is a far more important cost component of REVA cars than that of Safa Tempos. Hence, it would be difficult to make REVAs cost-competitive without lowering the import tax + VAT rate. Recall that the social cost of replacing an old Maruti by an equivalent REVA is higher than the resulting social benefit. Hence, it is not worthwhile for the government to support the displacement of old Marutis by REVA. The policy measures discussed below are relevant only for new Marutis and REVAs.

Table 6.3.1: Policy variables and their baseline values (Maruti vs. REVA)

EV average import tax & VAT rate (%)	EV annual taxes and fees (Rs)	Electricity tariff rate for charging batteries (Rs/kwh)	Gasoline price (Rs/liter)	Interest rate for EV financing (%)
160.4	4660	9.9	31	13

Table 6.3.2: Summary of private costs per vehicle (Maruti vs. REVA)

Cost item	Cost summary (Rs/km)					% of total cost		
	New Maruti	Old Maruti	Equivalent REVA	(Equiv. REVA-new Maruti)	(Equiv. REVA-old Maruti)	New Maruti	Old Maruti	Equivalent REVA
Vehicle purchase	9.655	0.000	14.608	4.953	14.608	63.9%	0.0%	72.9%
Battery	0.110	0.110	2.163	2.052	2.052	0.7%	2.0%	10.8%
Repair/Repair	1.200	1.200	0.900	-0.300	-0.300	7.9%	22.0%	4.5%
Wear and tear of tires	0.400	0.400	0.500	0.100	0.100	2.6%	7.3%	2.5%
Fuel/Energy	3.375	3.375	1.392	-1.983	-1.983	22.3%	61.8%	7.0%
Annual taxes and fees	0.373	0.373	0.466	0.093	0.093	2.5%	6.8%	2.3%
Total	15.113	5.458	20.029	4.916	14.570	100%	100%	100%

Source: Field survey (2004)

Table 6.3.3 summarizes the impacts of different policy measures on the private lifecycle cost gap between new Marutis and REVAs. As indicated above, the most effective way to make REVAs cost competitive is by reducing the average import tax + VAT rate for REVAs. If the rate is brought down to 70% from 160.4%, replacing a new Maruti by an equivalent REVA will result in a cost saving of Rs. 1935/yr. Observe although this is a large tax break, the new tax rate of 70% will still give the government a substantial amount of revenue.

It is also possible to reduce the effective purchase price of REVAs by lowering the interest rate for EV financing. But it would not be possible to make REVAs competitive with the Maruti 800 using this approach unless the interest rate were lowered to around 2%. Also observe that it is not possible to eliminate the cost difference between Marutis and REVAs by manipulating electricity tariffs alone.

The final policy measure considered here is the imposition of a pollution tax on gasoline. Since fuel cost comprises only 22% of the total cost of the Maruti 800, raising the fuel price via a pollution tax has a relatively moderate impact on the cost difference between Marutis and REVAs. For example, if the gasoline price in Kathmandu is set equal to the price in India (Rs.56.8), the cost difference decreases only slightly from Rs. 4.92/km to 4.74/km. So unless the pollution tax is extremely high (Rs. 79/liter), the cost advantage of the Maruti 800 cannot be eliminated.

Table 6.3.3 Impacts of policy changes on lifecycle cost gap between new Marutis and REVAs

Policy measure	EV average import tax & VAT rate (%)	**Interest rate on loans (%)**	**Electricity tariff (Rs/kwh)**	**Gasoline price (Rs/liter)**	**REVA Total cost (Rs/km)**	**New Maruti total cost (Rs/km)**	**Total cost difference (EV - ICEV) (Rs/km)**	**Total cost difference (EV - ICEV) (Rs/yr)**
Status quo	160.4	13	9.9	54	20.03	15.11	4.92	61446
Changing import tax + VAT rate	100	13	9.9	54	16.64	15.11	1.53	19103
	70	13	9.9	54	14.96	15.11	-0.15	-1935
Changing interest rate on loans	160.4	7	9.9	54	17.18	15.11	2.07	25866
	160.4	2	9.9	54	14.91	15.11	-0.21	-2590
Changing electricity tariff rate	160.4	13	3.6	54	19.14	15.11	4.03	50372
	160.4	13	1	54	18.78	15.11	3.66	45801
Implementing pollution tax on gasoline	160.4	13	9.9	56.8	20.03	15.29	4.74	59251
	160.4	13	9.9	70	20.03	15.80	4.23	52852
	160.4	13	9.9	133	20.03	20.05	-0.02	-273

7. The competitiveness of locally manufactured batteries

The Biratnagar-based Kulayan Battery Industry is the only deep-cycle lead-acid battery manufacturer in Nepal. Kulayan is currently in the process of switching from traditional flat-plate lead-acid battery production to the production of more advanced tubular batteries. As the Kulayan tubular batteries are not yet available in the market, the industry's representative was able to provide cost information only for the older flat-plate batteries. Hence, the following discussion on the competitiveness of locally manufactured batteries is based on a comparison between imported batteries and the Kulayan flat-plate batteries.

The closest competitors of the Kulayan batteries are the US made TROZEN deep-cycle lead acid batteries. At a market price of Rs. 48,000 per battery set, the Kulayan batteries are less expensive than the TROZEN batteries, which cost around Rs. 62000 per set. But while a TROZEN battery set lasts around 18 months, the average lifetime of a Kulayan battery set is less than 12 months (NESS 2003). Hence, although the latter has a lower market price, it cannot compete with TROZEN batteries when the annualized costs are compared. More specifically, the Kulayan battery market price is around 14% higher than the annualized cost of a TROZEN battery set (Rs. 41835/year at a 5% discount rate).

7.1 Government tax on components of local batteries

Table 7.1.1 summarizes the cost components of a typical Kulayan battery. The information in this table indicates that the battery manufacturing process in Nepal is actually a battery assembling process that relies primarily on imported components; the value added component of the process is very small. The high market price of the battery can be attributed mainly to the 29% tax (customs duty, local development tax and VAT) the government levies on all imported components.

Table 7.1.1: Cost and taxes on components of local batteries

Component	Quantity per cell	Cost Before Tax	Custom %	Local Dev. Tax %	VAT %	Cost After Tax
Casing (Box)	1 piece	387.60	15	4	10	500
Electrolyte (Acid)	6.5 liter	387.60	15	4	10	500
Separator	42 pieces	390.70	15	4	10	504
Plate	45 pieces	1604.65	15	4	10	2070
Labor cost		200.00				200
Total cost of components per cell						3774
Cost of one battery set (12 cells)						45288
Other costs + profit margin (6%)						2712
Market price of one battery set						**48000**

7.2 Policy changes for raising the competitiveness of local batteries

It is clear from Table 7.1.1 that the most straightforward way of closing the price gap between these locally manufactured batteries and imported batteries is by manipulating the tax rates. But before proceeding to analyze the impacts of changes in the tax rates, it is important to briefly discuss the justification for supporting local battery manufacturers. The most compelling argument in support of local battery production is that it brings economic benefits though increased employment opportunities and production-consumption linkages with other industries. The benefits from better alternative use of the foreign currency saved from reduced battery imports can be considered another advantage of local production.

But it must be pointed out that the battery manufacturing industry is fundamentally a polluting industry. The extra pollution generated in the process of manufacturing and recycling lead-acid batteries locally is definitely more than the lead discharged from the handling and transporting of imported batteries. Furthermore, any tax concession to local battery manufacturers will increase the local production, at subsidized tax rates, of not only EV batteries but other vehicle batteries as well. Hence, arguments in support of local battery manufacturing would not be entirely consistent with the basic argument made in favor of EVs, namely that EVs should be supported for the substantial environmental benefits they deliver.

If the government were nevertheless in favor of supporting the local battery manufacturing industry, it could either lower the various taxes on imported battery components or it could increase the taxes on imported batteries. Table 7.1.2 summarizes the impacts of changes in the tax rates on imported components. The last column shows the difference between the price of a local battery set and the annualized price of a TROZEN battery set.

Table 7.1.2 Tax breaks and costs of various battery components

Tax rate	Cost of casing after tax (Rs/cell)	Cost of electrolyte after tax (Rs/cell)	Cost of separators after tax (Rs/cell)	Cost of plates after tax (Rs/cell)	Labor cost (Rs/cell)	Total cost after tax (Rs/cell)	Price of 1 local battery set (12 cells)	Price difference (local – imported)
0.29	500	500	504	2070	200	3774	48000	6155
0.24	481	481	484	1989	200	3635	46229	4394
0.19	461	461	465	1909	200	3496	44467	2632
0.15	446	446	449	1845	200	3385	43058	1223
0.05	407	407	410	1684	200	3108	39535	-2300
0.01	391	391	395	1620	200	2998	38126	-3709

The table shows only the aggregate tax rate on the various components. For example, an aggregate tax rate of 19% can be implemented by using any appropriate combination of rates for the customs tax, the local development tax and VAT (say 5 % customs, 4% local development and 10% VAT). The impact on battery cost, however, is the same regardless of the tax rate combination used.

Observe that the aggregate tax rate must be decreased to somewhere between 15% and 5% (i.e., around 10%) for the market price of local batteries to drop below that of TROZEN batteries. Although this looks like a significant reduction in the tax rate, a 10% tax rate is still much higher than the 1% tax rate applicable to imported deep-cycle lead-acid batteries used in Safa Tempos. If the tax rate on battery components were lowered to 1%, then the market price of local batteries could be lowered as much as Rs. 38126 per battery, making them substantially less expensive than TROZEN batteries.

As mentioned earlier, the annualized cost gap between local and imported batteries can also be closed by increasing the taxes on the latter. If the government stops giving tax breaks to imported batteries and subjects them to a 29 percent tax rate (same as the tax rate on battery components), then the cost of imported battery shoots up to Rs 79188. The annualized cost of imported batteries would then be equal to Rs. 53,433. This would enable the government to assist the local battery industry without experiencing any loss of revenue. Also note that the reduction in battery imports would result in foreign exchange savings that can eventually be used for importing battery components.

8. Conclusions and recommendations

8.1 Conclusions

This study has analyzed the viability of four different types of electric vehicles in Kathmandu within a social benefit-cost framework. The analysis has been performed by comparing the benefits and costs of these electric vehicles with those of ICEVs currently operating in Kathmandu. Since old ICEVs and new ICEVs are distinctly different in terms of both the lifecycle costs and vehicular emissions, separate analyses have been performed for old and new ICEVs. In addition to the social benefit-cost analyses, the study has also explored policy measures for making EVs competitive in the market by eliminating the private lifecycle cost gap between EVs and ICEVs. It has also briefly analyzed the possibility of raising the competitiveness of locally manufactured EV batteries through changes in the tax rates. The conclusions drawn from the study are summarized below:

- The social benefits of replacing a diesel microbus with an equivalent Safa Tempo clearly outweigh the social costs when the cost of battery lead discharge is ignored. And unless it is assumed that the cost per gram of lead discharge is unrealistically high, the net benefits of Safa Tempos remain positive. Hence, there are sufficient grounds to argue that the government should actively support the proliferation of Safa Tempos in Kathmandu.
- Since old microbuses emit more pollutants than new one, the net benefits of replacing the former by Safa Tempos are substantially greater than the net benefits of replacing newer microbuses. The government should, therefore, give more emphasis to replacing old microbuses by EVs.
- The net benefits of replacing diesel microbuses by battery-powered electric buses are negative even when the cost of battery lead discharge is not taken into account. Hence, unless technological improvements make BPEBs more cost-effective, it does not seem worthwhile for the government to support these buses.
- The social benefit of replacing an old microbus by an equivalent trolley bus is clearly greater than the associated social cost. And if a reasonably high value is attached to each life saved from pollution reduction, the net benefit of replacing a new microbus by trolley buses is also positive.
- Because of the high production cost of the REVA Standard, the net benefit of replacing an old Maruti 800 by an equivalent REVA is negative. But the social benefit of replacing a new Maruti by an equivalent REVA is greater than the cost even when battery lead discharge is taken into account. Hence the government might want to consider supporting the replacement of new Marutis with REVAs. It is, however, clearly not worthwhile for the government to support the replacement of old Marutis.
- The benefit-cost analysis results discussed above are based on relatively conservative estimates of EV benefits and relatively liberal estimates of EV costs. The EV benefits used in the analysis underestimate the true benefits for the following reasons:
  - the benefits to the tourism industry of vehicular emissions reductions have not been included,
  - the benefits from the jobs created by local EV manufactures, and the multiplier impact of the EV industry on the rest of the economy have not been included,
  - the benefits arising from the best alternative use of the foreign exchange saved as a result of reduced oil imports have not been included, and
  - the benefits from PM_{10} reduction have been computed using figures based on the assumption that PM_{10} is harmful only above a certain threshold concentration even though researchers now believe that there is no minimum threshold for this pollutant.
- If the excluded benefits listed above are also accounted for, then the net benefits of EVs will be even higher than the current estimates. Safa Tempos, trolley buses and electric cars are, therefore, socially viable EVs for Nepal.

- Making these EVs competitive in the marketplace basically involves implementing policy measures to close the private lifecycle cost gap between the EVs and ICEVs.
- There are certain economic benefits associated with local production of EV batteries. But since some battery lead and other pollutants are released into the environment in the production process, local production is disadvantageous from an environmental perspective. Any government support for local production of EV batteries should, therefore, consider this tradeoff as well.
- Tax breaks are the primary tools available to the government for raising the competitiveness of local batteries.

8.2 Recommendations

- This study recommends that, from a social welfare perspective, the government should consider providing support to EVs in cases where the social benefits of replacing an ICEV by an equivalent EV outweigh the associated social costs. Based on this criterion, it identifies Safa Tempos, trolley buses, and electric cars as the EV categories deserving support.
- From an efficiency perspective, the specific courses of action for providing the required support should try to utilize the market mechanism whenever possible. Hence, compared to a ban on ICEVs, it is better to implement measures that bridge the private lifecycle cost gap between EV and ICEVs and let the market run its course after that. The advantage of this approach is twofold. First, such a move would probably be considered less radical than banning ICEVs and would, therefore, be politically more acceptable to policymakers. Second, and more importantly, allowing ICEVs to continue operating in Kathmandu would put continuous pressure on EVs to keep improving their technical efficiency. A ban of ICEVs, on the other hand, would give EVs a monopoly in the mass transportation sector and reduce the incentive to innovate.
- The study shows that the net benefit to society of replacing old microbuses by Safa Tempos or trolley buses is much greater than the net benefit from replacing new microbuses. In general, however, EVs cannot be made cost-competitive with old ICEVs through realistic changes in tax and tariff policies. Hence, the best way for society to reap these benefits is by banning the use of old microbuses in specific routes or by changing regulations to gradually phase out the use of older ICEVs.
- In order to enable the market mechanism to replace new ICEVs by EVs, the study recommends using combinations of the following policy measures: reducing the average import tax + VAT for EVs, reducing the electricity tariff rate, reducing the interest rate for EV financing, and imposing a pollution tax on fossil fuels. Examples of recommended policy combination for the different types of EVs are presented in Table 8.2.1. Note that each recommended combination includes a pollution tax on fossil fuels so that the government revenue generated from this tax can compensate for the losses experienced by the government as a result of tax breaks and subsidized tariffs for EVs. Similarly the recommended electricity tariff rate in all the combinations is the NEA TOD rate.

Table 8.2.1: Examples of policy combinations for supporting EVs							
		EV average import tax & VAT rate (%)	Electricity tariff rate for charging batteries (Rs/kwh)	Diesel or gasoline price (Rs/liter)	Interest rate for EV financing (%)	EV cost – new ICEV cost (Rs/yr)
Safa Tempo	Status quo	12.5	9	31	13	90189
	Policy change	12.5	**TOD rate**	**33.58**	13	-22136
Trolley	Status quo	12.5	4.25	31	13	-20060
	Policy change	12.5	**TOD rate**	**33.58**	13	-32080
REVA	Status quo	160.4	9.9	31	13	61446
	Policy change	**130**	**TOD rate**	**56.81**	**7**	-4785

- Since the estimated private lifecycle costs of trolley buses are already less than the costs of new microbuses, the government does not necessarily have to support trolley buses financially though subsidies or tax breaks. But the government should explore the possibility of supporting the expansion of the trolley bus system through a public-private partnership venture as recommended by KEVA (2004).
- Since the benefits of replacing passenger cars by electric cars outweigh the costs, the government might want to consider restricting future purchases of cars for government offices to electric cars. Approximately 65 new government vehicles are registered in Bagmati zone each year. [35] Assuming that 20% of these vehicles are cars, a total of 13 cars are purchased each year by the government for use in Kathmandu. So if the next batch of purchases included only REVAs, for example, the net benefit to society would range from Rs.130,000/year to Rs. 142,000/year. [36]
- Motorcycles comprise a significant and growing portion of the vehicle fleet in Kathmandu, and their average annual growth rate is around 21.6% (see CEN 2003). Policymakers should, therefore, also explore the viability of replacing gasoline-fueled motorcycles with electric motorcycles.

[35] This estimate is based on data from DoTM.
[36] Recall that the net benefit of replacing one Maruti by an equivalent REVA is between Rs. 9933/year to Rs. 10885/year.

References

Baral, A., Parajuli, R. and B. Aryal (2000). Institutional responses to electric vehicle promotion in Nepal. *Studies in Nepali History and Society* 5(1): 89-125.

Bascom, R., Bromberg, P. L., Costa, D. L., Devlin, R., Dockery, D. W., Frampton, M. W. Lambert, W. J., Samet, M. F., Speizer, E., and Utell, M. (1996). Health effects of outdoor pollution. *American Journal of Respiratory Critical Care Medicine*, 153, 3-50 (Part 1) and 477-498 (Part 2).

Biswas, T. K. and N. M. Biswas (1999). Electric vehicle: a natural option for India? *IETE Technical Review*, 16(3&4), 367-373.

Boardman AE, Greenberg DH, Vining AR, Weimer DL (2000) *Cost-benefit analysis: concepts and practice*. Prentice-Hall, Upper Saddle River, NJ

Chautari, M. (2000). *Bottlenecks in the proliferation of electric vehicles in Nepal*. Discussion paper (unpublished) by Martin Chautari, Nepal.

CEMAT (2002). *Revival of Kathmandu–Suryabinayak trolley bus system*. Report submitted to Kathmandu Electric Vehicle Alliance (KEVA), Nepal.

CEN (2003).*Health impacts of Kathmandu's air pollution*. Report submitted to Kathmandu Electric Vehicle Alliance (KEVA), Nepal.

DANIDA (1998). *Study on environmental impacts of rechargeable batteries in relation to DANIDA financed projects on electric vehicles and solar energy in Nepal*. Kathmandu: Danish Agency for Development Assistance and Ministry of Foreign Affairs..

Devkota, S. R. (1992). *Energy utilization and air pollution in Kathmandu valley, Nepal.* Bangkok: MS thesis (unpublished), Environmental Engineering Division, Asian Institute of Technology.

Devtech (2002). *Current status survey of three wheeler electric vehicles (Safa Tempo) of Kathmandu valley and appraisal study of operating the electric vehicles of some sub-metropolitan cities of Nepal*. Report submitted to ESPS/DANIDA, Nepal.

Faiz, A., Weaver, C. S. and M. P. Walsh (1996). *Air pollution from motor vehicles standards and technologies for controlling emissions*, Washington DC: The World Bank.

Funk, K. and A. Rabl (1999). Electric versus conventional vehicles: social costs and benefits in France. *Transportation Research, Part D*, 4(6), 397-411.

Hunt , G. L. (1998). The great battery search. *IEEE Spectrum*, 35(11), 21-28.

International Urbanized Area Analysis and Data Product (2001). Retrieved from http://www.demographia.com/db-intluadens-rank.htm (*10/04/2004*).

Johansson, B. and A. Maertensson (2000). Energy and environmental costs for electric vehicles using CO_2-neutral electricity in Sweden. *Energy*, 25(8), 777-792.

Kazimi, C. (1997). Evaluating the environmental impact of alternative-fuel vehicles. *Journal of Environmental Economics and Management*, 33(2),163-185.

KEVA (2004) *Business plan of Tripureshwor Suryabinayak trolley bus system*. Nepal: Kathmandu Electric Vehicle Alliance (KEVA).

Koirala (2002) *Are economic instruments preferable to command and control instruments in controlling vehicular air pollution in the Kathmandu valley?* Australia: MS thesis (unpublished), National Center for Development Studies, The Australian University..

Lave, L B. and H. L. MacLean (2002). An environmental economic evaluation of hybrid electric vehicles: Toyota's Prius vs. its conventional internal combustion engine Corolla," *Transportation Research, Part D,*7, 155-162.

Lave, L. B., Russell , A. G., Hendrickson , C. T. and F. C. McMichael (1996). Battery-powered vehicles: ozone reduction versus lead discharges. *Environmental Science & Technology*, 30(9), 402A-407A.

McCubbin, D. R. and M. A. Delucchi (1999). The health costs of motor-vehicle-related air pollution. *Journal of Transport Economics and Policy*, 33(3), 253-86.

MOF (2003). *Economic survey 2003*. Kathmandu: Ministry of Finance, His Majesty's Government of Nepal.

Moulton, P. and M. Cohen (1998). *Promoting electric vehicles in the developing world*. A paper presented at the International Electric Vehicles Conference, San Jose, Costa Rica.

NEA (2003). *A year in review*. Kathmandu: Nepal Electricity Authority.

NESS (2001). *Final report on WHO/PoA No. NEP PHE 001, Result No. 8.* Kathmandu: Nepal Health Research Council.

NESS (2003).*Analysis of HMG policies and regulations affecting electrical vehicles*. Report submitted to Kathmandu Electric Vehicle Alliance (KEVA), Nepal.

Ostro (1994). *Estimating the health effects of air pollution: a method with an application to Jakarta*, Policies Research Working Paper 1301, Washington DC: The World Bank,.

Penn World Tables (2000) . *The Penn World Table*. Philadelphia: University of Pennsylvania.

Riezenman, M. J. (1998).The EV future. *IEEE Spectrum*, 35(11), 19-20.

Shah, J. J. and T. Nagpal (1997). Urban air quality management strategy in Asia: Kathmandu Valley report. *World Bank Technical Paper No. 378*.

WHO (1999). World Health Organization environmental health information: Air quality guidelines. Retrieved from http://www.who.int/environmental_information/Air/Guidelines/Chapter3.htm#3 (01/30/2003)

WHO (2000). Guidelines for Air Quality. Geneva: World Health Organization. Retrieved from http://www.who.int/environmental_information/Air/Guidelines/Chapter3.htm#3 (01/30/ 2003)

WHO (2001). *WHO strategy on air quality and health, occupational and environmental health, protection of human environment*. Geneva: World health Organization.

World Bank (2003). The science of health impacts of particulate matter. *South Asia Urban Air Quality Management Briefing Paper No. 13*. New Delhi: Energy Sector Management Assistance Program, World Bank.

Appendix A: Scope of Work

1. Review the reports titled "Analysis of HMG Policies and Regulations Affecting Electrical Vehicles" by Nepal Environmental & Scientific Services (NESS) and "Health Impacts of Kathmandu's Air Pollution" by Clean Energy Nepal (CEN) and Environment and Public Health Organization (ENPHO).

2. Provide an economic and financial cost-benefit analysis of these scenarios*:

   - A comparison of an expansion and growth of battery operated three wheelers in urban settings with the expansion of diesel-fueled microbuses.
   - A comparison of an introduction and growth of battery operated microbuses (with similar seating capacity as the current microbuses with the expansion of diesel microbuses.
   - A comparison of a revival of the existing trolley bus services with the status quo of diesel mini and microbuses plying in the Tripureshwor to Bhaktapur route.
   - A comparison of promoting electric cars with the growing fossil fuel based cars in Nepal. Based on the comparison what subsidies (custom tariff, registration, annual taxes, parking) if any, is justified to be extended to individuals and organizations owning electric four wheelers.
   - Policies to use electric vehicles (wherever possible) by HMG/N offices vs. the status quo.
   - A comparison of promoting the use of locally developed Lead Acid deep cycle battery with imported deep cycle lead acid batteries. Based on the comparison what subsidies (custom tariff, annual taxes etc.) if any, is justified to be extended to local manufacturer/s of deep cycle lead acid batteries?
   - Policies for EVs to access special electricity tariff set aside for the transportation sector and through Time of Day metering.

* The numerical analysis will focus primarily on EV benefits arising from reduced health damages (morbidity and mortality). Other factors that could be included in the qualitative discussion include: a) use of the country's natural resources b) using the off peak hydroelectricity, c) less reliance on imported fossil fuel, which reduces the spending of foreign reserve, and d) the negative effect on the tourism industry.

3. Identify the highest priority policy changes for HMG/N to consider based on the analysis of regulations, possible changes and their impacts and the cost-benefit analysis. The study should also provide suggested changes on custom duties if the current duties are not sustainable by the nation or by the EV industry.

4. It is expected that the study will take around 60 professional working days to complete. The consultant will provide a draft of the report for KEVA review after about 50 working days. KEVA comments will be provided within 15 days, then the consultant will have another 10 days to complete a final report. KEVA would like to have the final report completed by June 15, 2004.

Appendix B: Nepal Vehicle Mass Emission Standard, 2056

A. Vehicles fuelled with gasoline (positive ignition engines)

1 For passenger cars with up to six seats and gross vehicle weight (GVW) less than 2.5 tons

1.1 Type 1 Test - Verifying exhaust emissions after a cold start.

	Grams per kilometer	
	Carbon monoxide (CO)	Hydrocarbons plus oxides of nitrogen (HC + NOx)
Type Approval*	2.72	0.97
Conformity of Production*	3.16	1.13

Note: The test shall be as per the Driving Cycle adopted by different countries, with cold start on Chassis Dynamometer.

1.2 Type II Test - Carbon monoxide emission at idling speed.

This test applies to vehicles fuelled with leaded gasoline only.

The carbon monoxide content by volume of the exhaust gases emitted with engines idling must not exceed 3.5% at the settings used for the Type I test.

1.3 Type III Test - Verifying emissions of crankcase gases.

The crankcase ventilation system must not permit the emission of any of the crankcase gases into the atmosphere.

1.4 Type IV Test - Determination of evaporative emission

This test applies to all vehicles fueled with leaded and unleaded gasoline.

Evaporative emissions shall be less than 2 g/test.

1.5 Type V Test - Durability of pollution control devices.

This test applies to vehicles fuelled with unleaded gasoline only.

The test represents an endurance test of 80,000 kilometer driven on the road or on a chassis dynamometer.

2 For light-duty commercial vehicles with gross vehicle weight (GVW) less than or equal to 3.5 tons

2.1 Type 1 Test - Verifying exhaust emissions after a cold start.

Reference Mass (kg)		Grams per kilometer	
		Carbon monoxide (CO)	hydrocarbons plus oxides of nitrogen (HC + NOx)
RM < 1250	Type Approval	2.72	0.97
	Conformity of production	3.16	1.13
1250<RM<1700	Type Approval	5.17	1.4
	Conformity of production	6	1.6
RM>1700	Type Approval	6.9	1.7
	Conformity of Production	8	2

Note: 1. The test shall be as per the Driving Cycle adopted by different countries, with cold start on Chassis Dynamometer.

2. Reference mass means the "unladen mass" (mass of the vehicle in running order without crew, passengers or load, but with the fuel tank full and the usual set of tools and spare wheel on board, when applicable) of the vehicle increased by a uniform figure of 100 kg.

3. Includes passenger vehicles with seating capacity more than six persons or reference mass more than 2,500 kg.

2.2 Type II Test - Carbon monoxide emission at idling speed.

This test applies to vehicles fuelled with leaded gasoline only.

The carbon monoxide content by volume of the exhaust gases emitted with engines idling must not exceed 3.5% at the settings used for the Type I test.

2.3 Type III Test - verifying emissions of crankcase gases.

The crankcase ventilation system must not permit the emission of any of the crankcase gases into the atmosphere.

2.4 Type IV Test - determination of evaporative emission.

This test applies to all vehicles fuelled with leaded and unleaded gasoline.

Evaporative emissions shall be less than 2 g/test.

2.5 Type V Test -durability of pollution control devices.

This test applies to vehicles fuelled with both leaded and unleaded gasoline.

The test represents an endurance test of 80,000 kilometer driven on the road or on a chassis dynamometer.

3 For two wheelers and three wheelers

3.1 Type I Test - Verifying exhaust emissions after a cold start.

	CO (grams per kilometer)		**HC + NOx (grams per kilometer**	
	2- wheeler	3- wheeler	2-wheeler	3-wheeler
Type Approval	2	4	2	2
Conformity of Production	2.4	4.8	2.4	2.4

Note: The test shall be as per the Driving Cycle adopted by different countries, with cold start on Chassis Dynamometer.

3.2 Type II Test - Carbon monoxide emission at idling speed.

This test applies to vehicles fuelled with leaded gasoline only.

The carbon monoxide content by volume of the exhaust gases emitted with engines idling must not exceed 3.5% at the settings used for the Type I test.

3.3 Type III Test - verifying emissions of crankcase gases.

The crankcase ventilation system must not permit the emission of any of the crankcase gases into the atmosphere.

Not applicable for two wheelers.

3.4 Type IV Test -Determination of evaporative emission.

This test applies to vehicles fuelled with leaded and unleaded gasoline.

Evaporative emissions shall be less than 2 g/test.

Not applicable for two wheelers.

3.5 Type V Test - Durability of pollution control devices.

This test applies to vehicles fuelled with unleaded gasoline only.

The test represents an endurance test of 80,000 kilometre driven on the road or on a chassis dynamometer.

B. Vehicles Fueled with Diesel (Compression ignition engines)

1 For passenger cars with upto six seats and gross vehicle weight (GVW) less than 2.5 tons

1.1 Type 1 Test - Verifying exhaust emissions after a cold start.

	Grams per kilometer		
	CO	**HC + NOx**	PM(particulate matter)
Type Approval	2.72	0.97	0.14
Conformity of Production	3.16	1.13	0.18

Note: The test shall be as per the Driving Cycle adopted by different countries, with cold start on Chassis Dynamometer.

1.2 Type II Test - Carbon monoxide emission at idling speed.

Not applicable

1.3 Type III Test - verifying emissions of crankcase gases.

Not applicable.

1.4 Type IV Test - determination of evaporative emission.

Not applicable

1.5 Type V Test - durability of pollution control devices.

The test represents an endurance test of 80,000 kilometer driven on the road or on a chassis dynamometer.

2 For light-duty commercial vehicles with gross vehicle weight (GVW) less than or equal to 3.5 tons.

2.1 Type 1 Test - Verifying exhaust emissions after a cold start.

Reference Mass (kg)		grams per kilometer		
		CO	HC +NOX	PM
RM < 1250	Type Approval	2.72	0.97	0.14
	Conformity of production	3.16	1.13	0.18
1250<RM<1700	Type Approval	5.17	1.14	0.19
	Conformity of production	6.0	1.16	0.22
RM>1700	Type Approval	6.9	1.7	0.25
	Conformity of Production	8.0	2.0	0.29

Note: The test shall be as per the Driving Cycle adopted by different countries, with cold start on Chassis Dynamometer.

Reference mass means the "unladen mass" (mass of the vehicle in running order without crew, passengers or load, but with the fuel tank full and the usual set of tools and spare wheel on board, when applicable) of the vehicle increased by a uniform figure of 100 kg.

Includes passenger vehicles with seating capacity more than six persons or reference mass more than 2500 kg.

2.2 Type II Test - Carbon monoxide emission at idling speed.

Not applicable

2.3 Type III Test - verifying emissions of crankcase gases.

Not applicable

2.4 Type IV Test - determination of evaporative emission

Not applicable

2.5 Type V Test - durability of pollution control devices.

The test represents an endurance test of 80,000 kilometer driven on the road or on a chassis dynamometer.

3 For heavy-duty vehicles and vehicles with gross vehicle weight (GVW) more than 3.5 tons

3.1 Type I Test -Verifying exhaust emissions after a cold start.

Pollutants	Type Approval	Conformity of Production
CO (grams per kilo-watt hour)	4.5	4.9
HC (grams per kilo-watt hour)	1.1	1.23
NOx (grams per kilo-watt hour)	8	9
PM (grams per kilo-watt hour) for engines with power less than 85 KW	0.61	0.68
PM (grams per kilo-watt hour) for engines with power more than 85 KW	0.36	0.4

Note: The test shall be as per the Test Driving Cycle adopted by different countries with 13 Mode Emissions Engines Dynamometer Test.

3.2 Type II Test - Carbon monoxide emission at idling speed.

Not applicable

3.3 Type III Test - Verifying emissions of crankcase gases.

Not applicable

3.4 Type IV Test - Determination of evaporative emission.

Not applicable

Type V Test - Durability of pollution control devices.

Not applicable.

Explanatory Notes

Type Approval

Most countries require some form of certification or type approval by vehicle manufacturer to demonstrate that each new vehicle sold is capable of meeting applicable emission standards. Usually, type approval requires emission testing of prototype vehicles representative of planned production vehicles. Under ECE and Japanese regulations, such compliance is required only for new vehicles. U.S regulations require that vehicles comply with emission standards throughout their useful lives when maintained according to the manufacturing specifications.

The advantage of a certification or type approval program is that it can influence vehicle design prior to mass production. It is more cost effective because the manufacturers identify and correct the problems before production actually begins.

Approval of a Vehicle

Vehicle manufacturers apply for approval of a vehicle type with regard to exhaust emissions, evaporative emissions and durability of pollution control devices to the authority responsible for conducting the tests. The application for approval also includes details like description of engines type comprising all the particulars, drawings of the combustion chamber and of the piston, description of evaporative control system, particulars concerning the vehicles, descript ions of pollution control devices etc. If the vehicle type submitted for approval meets the requirements of various types of tests mentioned, only then the approval of that vehicle is granted.

Conformity of Production

The conformity of production is a assembly line testing system. The objectives of assembly line testing are to enable regulatory authorities to identify certified production vehicles that do not comply with applicable emission standards, to take remedial actions (such as revoking certification and recalling vehicles) to correct the problem, and to discourage the manufacture of non-complying vehicles. This test provides an additional check on mass-produced vehicles to assure that the designs found adequate in certification are satisfactorily translated into production, and that quality control on the assembly line is sufficient to provide reasonable assurance that vehicles in use meet standards. The basic difference between TA and COP is that TA is based on prototype vehicle or design of the vehicle while COP measures emissions from real production vehicles.

As per the requirements set forth by the European Union, a sufficient number of random checks are made of serially-manufactured vehicles bearing the type approval mark of vehicles bearing all the types of tests mentioned above. The tolerance limits are provided for conformity of production in Type I tests.

National Ambient Air Quality Standards

Parameters	Units	Averaging Time	Concentration in Ambient Air, maximum	Test Methods
TSP (Total Suspended Particulates)	$\mu g/m^3$	Annual	-	
		24 hours *	230	High Volume Sampling
PM 10	$\mu g/m^3$	Annual	-	
		24 hours *	120	Low Volume Sampling
Sulphur Dioxide	$\mu g/m^3$	Annual	50	Diffusive sampling based on weekly averages
		24 hours **	70	To be determined before 2005.
Nitrogen Dioxide	$\mu g/m^3$	Annual	40	Diffusive sampling based on weekly averages
		24 hours **	80	To be determined before 2005.
Carbon Monoxide	$\mu g/m^3$	8 hours**	10,000	To be determined before 2005.
		15 minutes	100,000	Indicative samplers ***
Lead	$\mu g/m^3$	Annual	0.5	Atomic Absorption Spectrometry, analysis of PM10 samples****
		24 hours	-	
Benzene	$\mu g/m^3$	Annual	20****	Diffusive sampling based on weekly averages
		24 hours	-	

Note: * 24 hourly values shall be met 95% of the time in a year. 18 days per calendar year the standard may be exceeded but not on two consecutive days.

** 24 hourly standards for NO2 and SO2 and 8 hours standard for CO are not to be controlled before MoPE has recommended appropriate test methodologies. This will be done before 2005.

*** Control by spot sampling at roadside locations: Minimum one sample per week taken over 15 minutes during peak traffic hours, i.e. in the period 8am - 10am or 3pm - 6pm on a workday. This test method will be re-evaluated by 2005.

**** representativeness can be proven, yearly averages can be calculated from PM10 samples from selected weekdays from each month of the year.

***** To be re-evaluated by 2005.

These standards are the upper bound limits and pollution above this level will not be permitted and measures will be applied if the limit is crossed.

Vehicle Emission Standards for Green Stickers

Petrol operated vehicles

Types of vehicles	CO% by volume	HC (ppm)
Four Wheelers 1980 or older	4.5	1000
Four Wheelers1981 onwards	3	1000
Two-wheelers (two-stroke)	4.5	7800
Two –wheelers (four-stroke)	4.5	7800
Three-wheelers	4.5	7800

Gas Operated vehicles

Types of vehicles	CO% by volume	HC (ppm)
Four- wheelers vehicles	3	1000
Three wheelers vehicles	3	7800

Diesel Operated Vehicles

Types of vehicles	HSU
Older than 1994 A.D	75
1995 A.D onwards	65

Appendix C: Data on Vehicles

	Diesel fueled microbus	Petrol fueled cars (equivalent to REVA electric cars)	Diesel fueled cars (equivalent to REVA electric cars)	EV Tempo	EV battery microbus	Trolley bus	Electric car (REVA)
Vehicle lifetime (years)	20	20	20	10		20	15
Vehicle weight category (kgs.)	780	640	995	650	3860	7000	
Seating capacity (persons)	17	4	5	12	16	60	4
Distance traveled per day (km/day)	168	60	60	120	200	208	
Distance traveled per year (km)	50400	18000	18000	36000		62400	
Production cost of imported vehicle (price at port of entry) (Rs.)	830638	284201	441664		681000	4200000	344000
Customs rate and VAT on imported vehicle (%)	104.662	160.38	160.379	12.5			
Selling price of imported vehicle in market (Rs.)	1700000	740000	1150000				
Production cost of locally assembled vehicle (Rs.)				360889			
Selling price of locally assembled vehicle w/o batteries (Rs.)				406000			
Interest rate on loans to purchase vehicle (%)	13%						
Annual cost of wear and tear of tires (Rs./year)	6500	5000	5000	5100		74800	REV< Maruti
Cost of wear and tear of tires (Rs./km)	0.12897	0.2778	0.27778	0.1417		1.2	REV< Maruti
Maintenance/repair cost per year (Rs./year)	8000	12000	20000	18000		140400	4800
Maintenance/repair cost per km (Rs./km)	0.15873	0.6667	1.11111	0.5		2.25	
Salary, wages etc. per year (Rs./yr)	10800	36000	36000	48000		66000	
Diesel market price per liter (Rs./liter)	31	31	31	31			
Govt. subsidy on diesel (Rs/liter)	2.58	2.58	2.58	2.58			
Petrol market price per liter (Rs./liter)	54	54	54	54			
Govt. Surplus on petrol (Rs/liter)	7.50	7.50	7.50	7.50			
Fuel/energy consumption per km (liter/km or kwh/km)	0.1	0.0625	0.06667	0.27	0.5	1.33	
Fuel/energy consumption per km (km/liter or km/kwh)	10	16	15				
Fuel/energy cost per year (Rs./year)	188042	34875					
Fuel/energy cost per km (Rs./km)	3.731	1.9375	2.06667	1.28		5.72	
Price of imported battery set before customs (Rs/bat)	2696	2003	2003	61386	219000	2696	56000
Customs rate on imported battery set (%)	29.8	29.8	29.8	1		30	
Market price of imported battery set (Rs/bat)	3500	2600	2600	62000		3500	
Lifetime of imported battery (kms)	75600	36000	36000	27000		75600	50000
Lifetime of imported battery (years)	1.5	2	2	1.5		1.50	4
Total electricity consumption per imported battery charge (kwh/bat)				16	35		9
Total distance traveled per charge (km/charge)				60	70		80
Total electricity consumption per km for				0.27	0.5		0.1125

imported battery (kwh/km)							
Total weight of one imported battery set (kg)	15	10		336	1100	15	270
Market price of local battery set (Rs.)	2900	1640	1640	48000		2900	

Data on Vehicles (contd..)

	Diesel fueled microbus	Petrol fueled cars (equivalent to REVA electric cars)	Diesel fueled cars (equivalent to REVA electric cars)	EV Tempo	EV battery microbus	Trolley bus	Electric car (REVA)
Lifetime of local battery set (kms)	50400	18000	18000	36000		62400	
Lifetime of local battery set (years)	1	1	1	1		1	
Total electricity consumption per local battery (kwh)							
Total electricity consumption per km for local (kwh/km)							
Total weight of one local battery set (kg)	20	10	10	360		20	
NEAs tariff for charging batteries (Rs./kwh)				4.8			
NEAs subsidies for charging batteries (Rs./kwh)				4.75			
Charging stations' charge rate (Rs./kwh)				8.4			
NEA's tariff for direct use of electricity (trolley buses)(Rs./kwh)				4.8		4.25	
NEA's subsidy for direct use of electricity (trolley buses)(Rs./kwh)				4.75			
Trip fare for short trips (Rs./passenger)	6			6			
Number of short trip passengers per day	250	4	5	192			
Revenue per day (Rs./day)	1500			1150			
Revenue per km (Rs./km)	9			10			
Annual vehicle Route Permit (Rs.)	750			600			
Annual vehicle registration tax (Rs.)	750	750	750	600			
Annual vehicle Inspection charge (Rs.)	130	130	130	80			
Annual Vehicle Tax (Rs.)	9600	3600	5500	0			
Annual Income Tax (Rs.)	1200			0			
Annual vehicle Renewal charge (Rs.)	180	180	180	160			
PM10 (gm/km)	1.05	1.5	0.2	1.63063			
NO2 (gm/km)	9.1	13	2.7	5.35294			
SO2 (gm/km)	0.273	0.39	0.13	0.16059			
CO (gm/km)	1.904	2.72	62	2.88			
CO2-equiv (gm/km)	541.5	774	616	361			
NMVOC (gm/km)	0.675	0.96	2.6	0.45			
Air Toxics ($/km)	0.0002	0.00028	0.0002	0.00028			
Noise ($/km)	0.0004	0.0006	0.0002	0.00027			
PM10 (gm/km)	0.56226	0.8032	0.1071	0.87318			
NO2 (gm/km)	0.49567	0.7081	0.49	0.78			
SO2 (gm/km)	0.04912	0.0702	0.1011	0.0743			
CO (gm/km)	1.904	2.72	4.05	2.88			
CO2-equiv (gm/km)	365.568	522.24	224	192			
NMVOC (gm/km)	0.35986	0.5141	0.375	0.069			
Air Toxics (Rs/km)	0.0001	0.0001	6E-05	0.00015			
Noise (Rs/km)	0.00021	0.0003	9E-05	0.00014			

Appendix D: Vehicles in Bagmati Zone

Year/ Vehicle Type	Bus	Minibus	Micro bus	Car/Jeep /Van	Truck/ Tanker	Tempo (Three Wheeler)	Motor cycle	Tractor	Other	Total
1993/94	792	1352		20748	3343	3844	37774	1623	2561	**72037**
1994/95	958	1388		22640	3781	3844	435s06	1635	2678	**80430**
1995/96	1045	1430		22248	4113	3844	49299	1670	3012	**86661**
1996/97	1163	1468		27153	4483	3844	58029	1672	3020	**100832**
1997/98	1298	1500		28915	4759	3925	64142	1672	3278	**109489**
1998/99	1403	1527		30919	4811	4262	71612	1672	3311	**119517**
1999/00	1632	1610		35965	5295	4778	94217	1672	3332	**148501**
2000/01	1744	1804		40674	5484	4949	112000	1673	3350	**171678**
2001/02	1858	2172		43409	6274	5073	100000	1673	3356	**163815**
2002/03	2061	2387	232	45361	6991	5073	121558	1677	3385	**188725**
2003/04*	2160	2434	347	48924	7015	5080	132312	1677	3385	**203334**

Appendix E: Vehicles in Kathmandu Valley

Year/ Vehicle Type	Bus	Minibus	Micro bus	Car/Jeep /Van	Truck/ Tanker	Tempo (Three Wheeler)	Motor cycle	Tractor	Other	Total
1993/94	673	1149		17636	2842	3267	32108	1380	2177	**61232**
1994/95	814	1180		19244	3214	3267	36980	1390	2276	**68365**
1995/96	888	1216		18911	3496	3267	41904	1420	2560	**73662**
1996/97	989	1248		23080	3811	3267	49325	1421	2567	**85708**
1997/98	1103	1275		24578	4045	3336	54521	1421	2786	**93065**
1998/99	1193	1298		26281	4089	3623	60870	1421	2814	**101589**
1999/00	1387	1369		30570	4501	4061	80084	1421	2832	**126225**
2000/01	1482	1533		34573	4661	4207	95200	1422	2848	**145926**
2001/02	1579	1846		36898	5333	4312	85000	1422	2853	**139243**
2002/03	1752	2029	197	38557	5942	4312	18324	1425	2877	**75415**
2003/04	1836	2069	295	41585	5963	4318	9141	1425	2877	**69509**

Appendix F: List of Persons Contacted

Name	Institution	Tel. No./email	Date
Mr. Adam Friedensohn	Himalayan Light Foundation	4425393/4437189	
Mr. Ashok Raj Pandey	Nepal Electric Vehicle Industry (NEVI)	4427111	April 1, 2004
Mr. Amit Kumar	REVA Electric Car Co. (P) Ltd	amitk@reva-ev.com	April 14, 2004
Mr. Balaram Timilsina	Trolley Bus Office	4470916	April 23, 2001
Mr. Bishow Ram Shrestha	Jana Utthan & Environment Electric Vehicle Pvt. Ltd. (JEEV)	4431675	March 26, 2004
Mr. Bhusan Tualadhar	Clean Energy Nepal (CEN)	4242381	April 1, 2004
Mr. Chiranjivi Gautam	ESPS/DANIDA	4268263/426982	May 6, 2004
Mr. Deepak Adhikari	Nepal Electricity Authority	4254657	March 9, 2004
Mr. Deepak Dithal	Nepal Electricity Authority	4287575	March 28, 2004
Mr. Ek Raj Pokharel	Department of Transport Management	4446342	March 18, 2004
Mr. Megesh Tiwari	Kathmandu Electric Vehicles Alliances (KEVA)	4467087	April 12, 2004
Ms. Meenakshi Kukreja	Society of Indian Automobile Manufacturers (SIAM)	91 11 24647810-12, 24648555 ext. 20	April 21, 2004
Mr. Murari Sigdel	Microbus Owner	5545946	March 18, 2004
Mr. Pravakar Khadka	Electric Vehicle Association of Nepal (EVAN)	4771088	April 4, 2004
Mr. Rajon Lohani	Jana Utthan & Environment Electric Vehicle Pvt. Ltd. (JEEV)	4431675	April 4, 2004
Mr. Ram Kazi Maharjan	Minibus Owner		March 18, 2004
Mr. Surya Prasad Shedai	Department of Customs	4259861	March 3, 2004
Mr. Rajendra Brd. Karki	Kulayan Battery Industry	025521039	May 6, 2004
Mr. Rekh Brd. Thapa	Kulayan Battery Dealer	4278162	April 15, 2004
Mr. Sher Sing Bhat	Nepal Electricity Authority	4278365/ 4287575	
Mr. Som Nath Gautam	Department of Transport Management	4446342	March 18, 2004
Mr. Taranath Phuyal	NEVI, Charging Station, Chabhil	4489283	April 4, 2004
Mr. Yadav Raj Gurung	Himalayan Light Foundation	4425393/4437189	

Appendix G: Sources of Data