A Cost Benefit Analysis of introducing Electric Vehicles in Bhutan

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Abstract

Bhutan is reputed for its pristine environment and its unparalleled commitment towards environmental conservation. However, recent studies have found that carbon emissions are on the rise with rapidly increasing fossil fuel consumption, which now constitutes the most significant item in Bhutan's import basket. While Bhutan is a net exporter of hydroelectric energy the import of fossil fuel offsets nearly 70% of the exports of electricity to India. In the aftermath of the recent balance of payments challenges with India, the country is compelled to consider alternative mobility options to reduce its dependence on fossil fuel imports and harness its abundant hydro-power, but more importantly, to serve as a model for conservation efforts. With the vision to become the first full-fledged electric-vehicle city in the world, Bhutan must mobilize significant institutional and financial resources. As a stepping stone towards this initiative the government is considering the replacing of a fleet of taxis with electric vehicle equivalents. The relative upfront costs of adopting an electric platform are considered a major deterrent notwithstanding the future stream of savings on account of lower energy and maintenance costs and the intangible benefits to society as a whole. Hence, this paper conducts a Cost Benefit Analysis of the initiative. While most studies focus only on the end-user, this study takes a more comprehensive approach by studying the costs and benefits to both users as well as society taking into consideration various assumptions and scenarios. The macroeconomic and microeconomic implications of this initiative are assessed, and policy recommendations are also offered. Under all scenarios the EV option emerges as the most preferred model. Even the baseline scenario in which no incentives are offered reveals a favourable outcome for the EV. However, these outcomes are assessed over a relatively long time span of 8 and 10 years which gives rise to a time inconsistency problem, which is why some intervention may be necessary to nudge individuals in favour of the EV option.

Introduction

Environmental conservation forms a cornerstone of Bhutan's development agenda. The constitution explicitly states that "*the state shall maintain 60% of land as forest cover for all times to come.*" Hence, the pursuit of sustainable economic growth through clean energy solutions is critical. Currently Bhutan boasts of a 72% forest cover which is endowed with a very rich biodiversity and pristine environment. Given its vast hydropower potential of 30,000 MW and an existing capacity of 1480MW, Bhutan generates some of the cleanest electricity on earth making the country a carbon sequestration hotspot. An estimate by a group of international researches revealed that the benefit accruing from Bhutan's conservation efforts to the rest of the world amounted to $15.5 billion, which is roughly seven times the size of current National Output (Kubiszewski et.al., 2012). Consumption of fossil fuel is marginal and whatever is being imported can be attributed to automobiles. However, with the significant increase in the import of vehicles and increasing economic activity, the consumption of fossil fuel has been growing exponentially. While growth was suppressed temporarily in 2012 with the imposition of a ban on the import of vehicles, the upward trend is expected to resume with the recent lifting of the ban. The Royal Monetary Authority estimates that the elasticity of fuel consumption expressed as a percentage of GDP has been increasing with the figure reaching 6.9 in 2012 as compared to 6.4 in 2011 (RMA, 2014). Hence, the implications of increased vehicle and fuel imports have microeconomic, macroeconomic and environmental dimensions.

The microeconomic implications can be assessed in terms of the increased costs to individuals and businesses due to surging fuel prices. The macroeconomic implications are evident from the persistent current account deficit with India given that vehicle related fuel imports constitute 16% of imports from India (NSB, 2013). Confronted by a chronic shortfall of INR reserves in 2012 the government was forced to impose a temporary ban on the import of automobiles to alleviate the pressure on Bhutan's unsustainable Balance of Trade with India. The environmental implications are also visible from the deteriorating air quality in Thimphu where more than 50% of vehicles are registered. Records show that in each of the years 2011 and 2012, pollution levels in the capital city have doubled relative to the previous year (NEC, 2013).

In response to such concerns and a commitment to ensure environmentally sustainable growth, the government has declared a vision to transform Thimphu into the first electric vehicle city in the world. As part of its strategy it has entered into agreements with two global leaders in electric vehicle manufacturing- Nissan and Mahindra Reva. The government intends to begin by replacing the existing fleet of taxis- since they record the highest mileage among existing vehicles - with electric equivalents and gradually move towards converting other public transportation facilities and eventually vehicles driven by regular users. However, the initiative entails significant financial and institutional resources. To justify the investment required for this proposal we conduct a Cost Benefit Analysis taking into consideration various scenarios and assumptions.

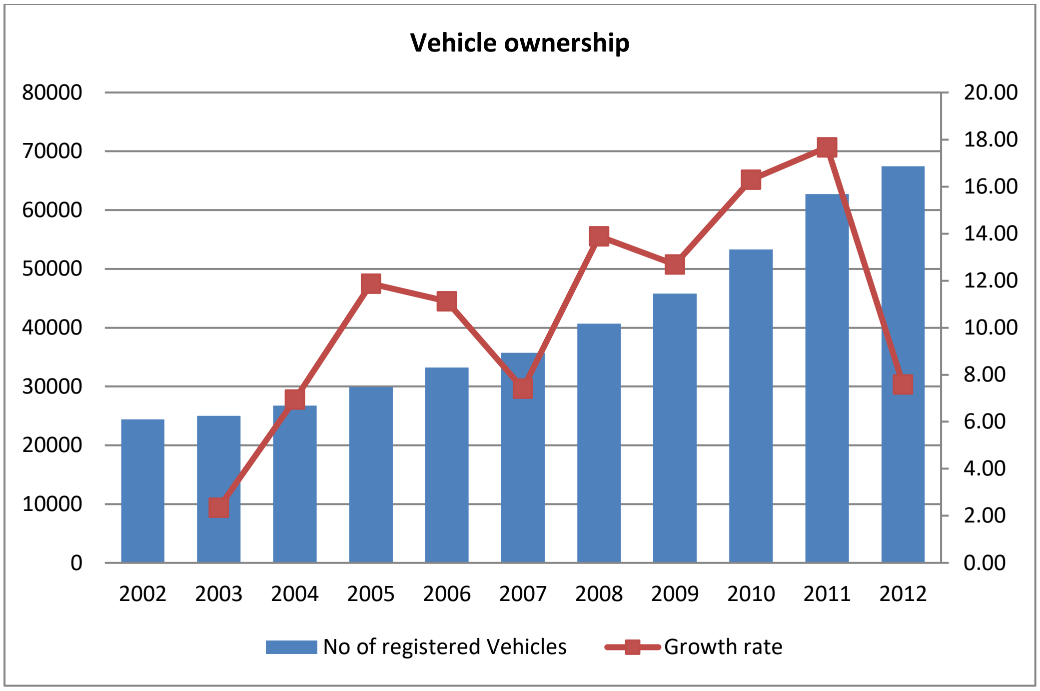

Figure 1: Vehicle ownership trends

Electric Vehicles

A plethora of factors such as erratic fuel prices and a global convergence towards environmental consciousness have made the electric vehicle a preferred option for mobility. However, concerns related to the unpredictability of battery durability, the exorbitant upfront costs and low mileage have impeded its adoption on a mass scale. Nevertheless, its potential in providing sustainable transportation solutions cannot be downplayed and hence, several governments have announced national strategies to adopt an electric vehicle platform as an alternative means of transportation. Germany, as articulated in its *National Development Plan for Electric Mobility,* has a target to deploy one million electric cars by 2020. Portugal has declared a range of incentives to switch to an electric option. Similarly, many countries have begun installing the requisite infrastructure to facilitate the conversion to an electric platform.

Electric vehicles offer a range of benefits over conventional combustion modes of transportation. Simultaneously disadvantages abound in making the platform more cost-effective and durable. The following section discusses some of the general and Bhutan-specific disadvantages and advantages of electric vehicles.

Advantages

Maintenance Costs: The maintenance cost of the electric vehicle is documented to be lower than that of ICEV's. This is primarily due to lower maintenance requirements related to the less sophisticated electric engine that does not require periodic replacement of engine oil filters and other associated parts. An internal combustion engine on the other hand is sophisticated and made up of thousands of parts.[1]

Lower running costs: With Bhutan arguably supplying the cheapest electricity in the world, the benefit to the user is immense. Moreover, given the unpredictability and magnitude of increases in fuel prices over the past few years, switching to an electric platform offers significant financial savings and certainty.

Disadvantages and Challenges

Exorbitant upfront costs: The high costs of purchasing an electric option are perhaps the most significant deterrent in buying an electric vehicle with the cost differential almost 100% in some cases.

Mileage: This could be a significant disadvantage since a fully charged Nissan Leaf is supposed to yield a driving distance of 84 miles. This makes inter-city transport challenging unless a comprehensive charging network is installed. Moreover, given Bhutan's hilly terrain it is assumed that this figure would be significantly lower.

Battery: The uncertainty surrounding the durability of battery is a major deterrent. Given that the replacement of a battery system would cost almost 50% of the initial cost of the car, concerns have been expressed that the Total Cost of Ownership could be significantly higher than what is publicized. However, with the frontiers of battery technology advancing continuously, it is projected that the costs of replacing a battery system could be reduced to 20% of its current cost by 2020.

Installation of related infrastructure: Making electric cars an attractive option requires a significant amount of state facilitation and coordination. First, the installation of an adequate number of public charging units is essential. Given the significant amount of time taken to fully charge a battery using the regular method; the provision of quick-charging stations is critical. Additionally, the establishment of service centres for electric cars would require a different set of skills and hence the necessary investment will entail significant costs.

The Government's Rationale and Plan

The overriding motivation for switching to electric vehicles has a macroeconomic and environmental dimension. During the wake of the Rupee crunch, which was the culmination of a persistent current account deficit with India, the Government decided to adopt a policy of promoting import substitution and the curtailing of unnecessary imports. The largest component in the import basket was that of vehicle fuel which amounted to INR 6.3 billion in 2012 (NSB, 2013).

[1] See www.greencarreports.com

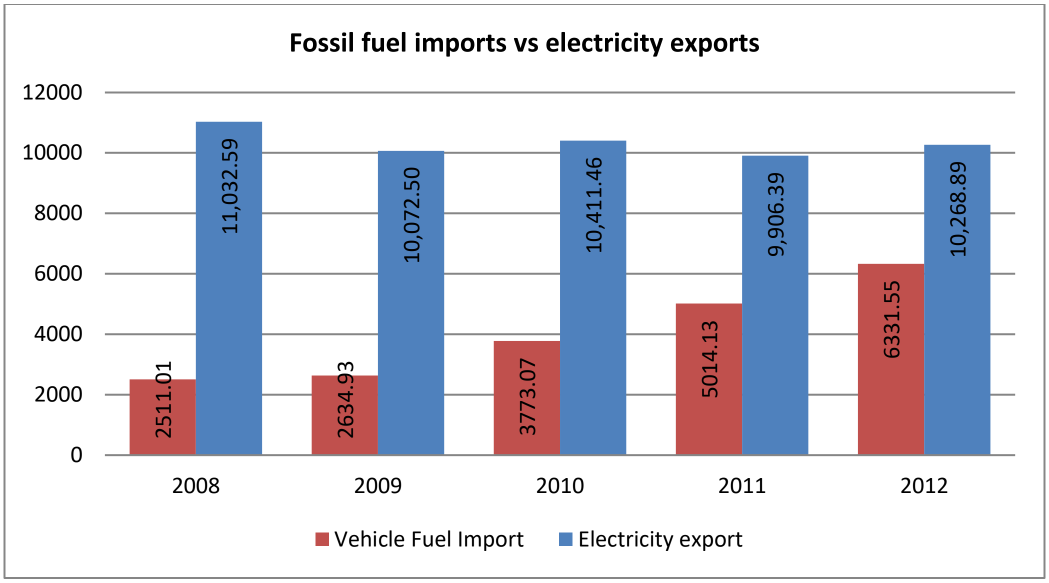

Figure 2: Energy export and import trends

Bhutan's fuel bill has been increasing rapidly over the years. Currently 15% of Bhutan's imports are composed of fuel imports which have grown by 152% since 2008 (NSB, 2013).

Given Bhutan's vast hydropower resources, the potential to substitute fossil fuel with electricity is immense. While Bhutan is still a net exporter of energy, the gap between electricity exports and fuel imports is narrowing with increasing fuel imports vis-à-vis stagnant electricity export figures, which will not increase till other power projects that are currently under construction become operational. While in 2008, net exports of energy was approximately INR 8 billion, in 2012 this decreased to about INR 3 billion almost offsetting the economic benefits of Bhutan's electricity endowments. The Macroeconomic implications are significant given Bhutan's Balance of Payment challenges.

From the environmental perspective, the most salient advantage of electric vehicles is that they emit virtually no pollutants. This confers a huge benefit in cities where congestion levels and the concentration of pollutants is particularly high. While some countries generate electricity by burning fossil fuel, in Bhutan electricity is generated predominantly through run-of-the-river hydroelectric schemes ensuring that the aggregated level of pollution is minimal as analysed using a well-to-tank approach.[2] This is a significant factor for Thimphu considering the increasing level of pollution concentration in a very small city, where nearly 50% of vehicles and 67% of taxis are registered (NSB, 2013).

The NEC reports that in Thimphu the number of days during which PM10 levels exceeded the national standards increased from 2% of sampling days to 11% from 2011 to 2012. While PM10 emissions can be

[2] A Well-to-Tank analysis involves measuring the level of pollution emitted from the stage of generating electricity to transferring it to a vehicle. See TIAX LLC, 2007

a result of other factors such as construction and burning of fuel wood, vehicle emissions is the primary contributor (NEC, 2011). Containing this upward trend is clearly a priority for Thimphu and switching to an electric vehicle platform is a possible strategy.

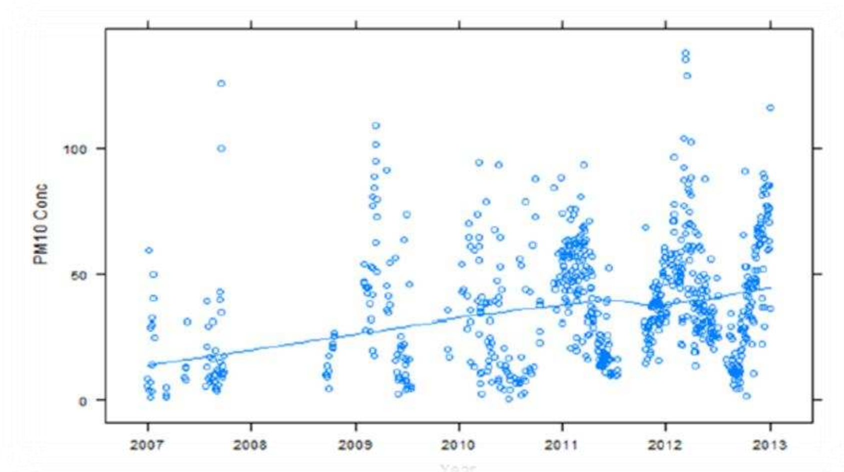

Figure 3: Particulate Matter trends in Thimphu
Source- NEC, 2013

Hence the Government has declared an ambitious vision to transform Thimphu into the first electric vehicle city in the world and intends to reduce fuel imports by 70% by the year 2020. To this end the Government has signed an agreement with Nissan Motors and Mahindra REVA. The Government intends to begin by replacing the existing fleet of taxis with their electric car equivalents, promoting adoption among regular users and then gradually introducing electric city buses. Of course the success of such a major undertaking can be derailed by coordination externalities and hence, requires significant government facilitation.

The Economic Rationale: A theoretical perspective

A plethora of theoretical arguments have been presented in favour of state intervention in a context of market failures. In his seminal paper on the prevalence of externalities, Ronald Coase expounded on the shortcomings of the existing Price system and analysed the problem as a "*divergence between the private and social product"* of a business entity (Coase, 1960). The private product of the business would simply be the product that its production system produces for which it can charge a certain price that takes into consideration the costs of production and perhaps a small premium. However, the social product would be more encompassing and include other spill-overs that can be attributed to the operation of the business such as the pollution and harmful effects of the product, or to take a more optimistic approach, the positive effects such as employment and social cohesiveness in addition to the product itself could be considered.

Theory predicts that the existence of such a divergence can result in a less than optimal allocation of resources. This phenomenon is technically referred to as *Market Failure* and theoretical recommendations on resolving the problem have also been presented. The problem can occur if a certain activity yields a Marginal Social Cost that is higher than the Marginal Private Cost. In this case a greater than optimal amount of the product will be produced. Conversely, if an activity yields a Marginal Social Benefit that is higher than the Marginal Private Benefit, too little of the product will be produced. In the former case the government may consider imposing a tax to align Marginal Social Cost with Marginal Social Benefit and in the latter it may consider subsidizing or incentivizing the activity to bring about a socially desirable level of production. The case with electric cars can be assessed in the latter context whereby owning such a car delivers social benefits such as reduced emissions and noise pollution. However, the private benefits are limited to reduced fuel spending and maintenance expenditure. Hence, there is a rationale for government intervention in such cases.

The problem can be illustrated conceptually using the following diagram. The conventional price system yields an equilibrium quantity of Q_1 where Marginal Private Benefit and Marginal Cost intersect. However, the private activity yields a positive externality depicted by the line MEB. Hence the aggregated Marginal Social Benefit is captured by MSB and the socially desirable output is *Q**. Since the Marginal Cost to the private entity does not motivate him to engage in the socially optimal level of production, an incentive may be necessary. If the state were to intervene and provide a subsidy or some other incentive equal to MEB (ba'), the socially efficient equilibrium could be achieved.

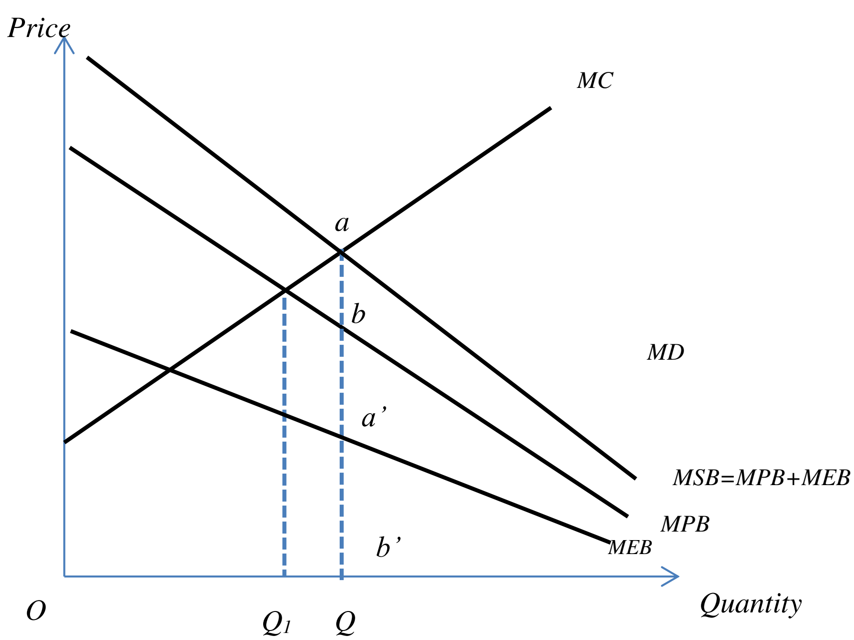

Figure 4: Externalities
Source: Rosen and Gayer, 2010

In addition to such divergences in social and private costs or benefits, the issue of time-inconsistency is equally pertinent to the discussion. Given that the benefits of EV ownership accrue over a longer time horizon, consumers tend to discount future benefits heavily and exhibit a strong preference towards immediate returns such as the lower upfront cost of an ICEV model as compared to an EV model.[3]

The following section presents the essence of the agreement and action plan between the RGoB and the two companies. The scope of this study is limited to an assessment of the costs and benefits of transitioning to a light vehicle electric option due to lack of a clear roadmap and agreement for penetration into other segments of the electric vehicle market in Bhutan.

Mahindra REVA

Mahindra proposes a 5 phase approach summarized in the figure below:

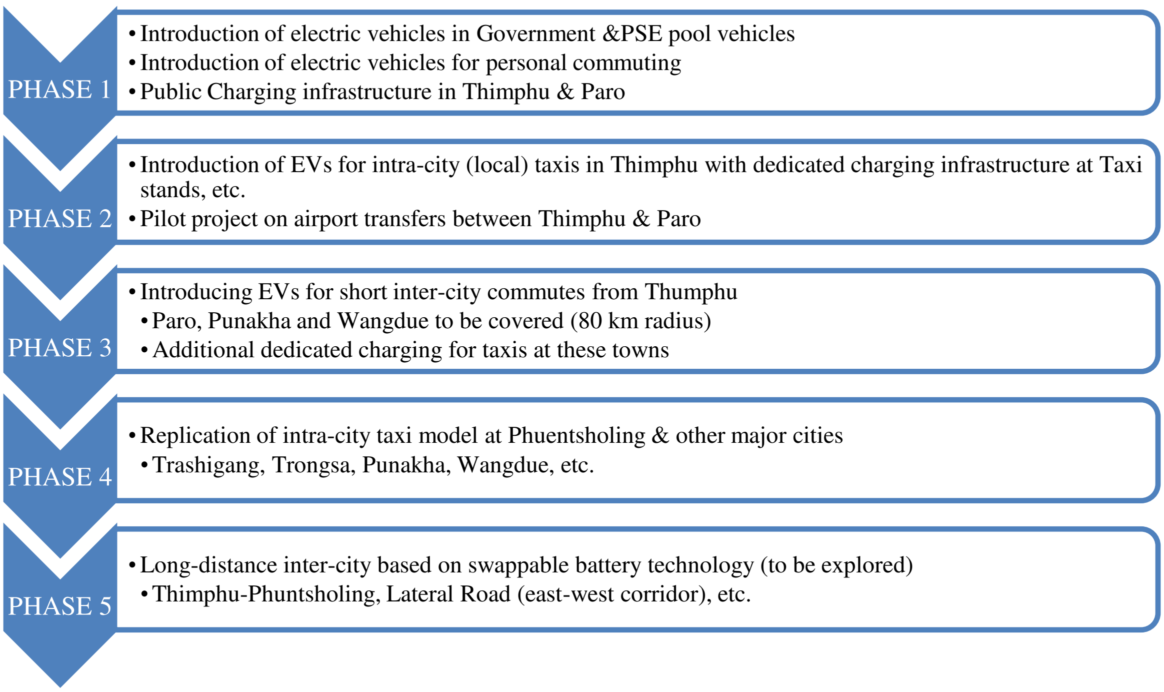

Figure 5: The Mahindra Proposal

The REVA e2o has already been commercially launched for regular users. It is not yet certain whether the proposal to introduce electric vehicles for government use will be pursued due to certain possible amendments in the pool vehicle system and hence, this aspect has been excluded from our analysis. The entire approach is likely to require a time frame of 18 months. However, in the absence of any clear timeline we make certain assumptions to facilitate analysis and these are presented in the relevant section below.

[3] See Hoch and Loewenstein for a discussion on the problem of time-inconsistency.

Nissan Motor Corporation Ltd.

The Government's arrangement with Nissan is more straightforward and precise. Based on a memorandum of understanding signed between the two parties, Nissan has committed to sell a total of 872 vehicles at highly discounted prices which can be categorized in three cost brackets.

Number of Vehicles	Cost Bracket (Nu.)	Type of Vehicles
72	1260000	Brand New Nissan Leaf
200	945000	Demo version Nissan Leaf
600	630000	Refurbished Nissan Leaf (driven for about 10000 Kms)

Table 1: Nissan's proposed price schedule

The agreement with Nissan also stipulates the installation of a quick charging network that will provide 53 charging points at a unit cost of USD 13000. The timeframe for the entire project is still unknown and hence we resort to assumptions for our analysis.

A Cost Benefit Analysis

Electric vehicles are a fairly recent phenomenon and their feasibility is still surrounded by a high degree of uncertainty. With the requisite upfront costs significantly higher than that of an Internal Combustion Engine Vehicle, the hesitation in making such an investment must be addressed through some form of state intervention. However, this entails the allocation of public resources which will involve a diversion of funds away from other purposes. Ultimately it is critical to decide whether or not the undertaking will make society better off for which we need to conduct a Cost Benefit Analysis.[4]

To make our problem tractable we make certain simplifying assumptions in addition to using existing data. We then discuss various scenarios to study the sensitivity of our results.

Basic Facts and Assumptions

The upfront costs, energy costs and mileage capacities of 4 models are reported below. Two ICEVs and two electric vehicle equivalents are presented. The cost of electricity is based on the progressive tariff regime approved by the Bhutan Electricity Authority whereby the unit cost increases beyond certain defined thresholds.

Facts						
Vehicle Model		**Upfront Cost**	**Energy Price**		**Fuel Consumption**	
					Km/L or kWh	***L or kWh/100 Km***
ICEV	Maruti Alto 800	270000	68 Per L		17	6.0
	Hyundai Accent	760000			14	7.1
EV	Mahindra REVA E20	690000	0-100 kWh 101-300 kWh >300	0.98 1.86 2.46	5.56	18
	Nissan Leaf	1260000			4.72	21.2
		945000				
		630000				

[4] Refer to Department of Finance and Administration, Australia, 2006 for a discussion of the merits of conducting a cost benefit analysis.

Table 2: Vehicle facts

The unit costs of driving each model are also calculated.

Particulars	Unit	Cost/distance			
		Alto 800	Accent	REVA E2o	Nissan Leaf
Per 100 km	Nu.	408	482.80	17.64	20.776
Per km	Nu.	4.08	4.83	0.18	0.21
Per Nu	Kms	0.25	0.21	5.67	4.81
Per 100 Nu	Kms	24.51	20.71	566.89	481.32
Per month energy consumption	kWh	-	-	291.6	343.44
Monthly Energy Cost in base year	Nu.	6701	7930	454.376	576.86

Table 3: Operational costs

For electricity consumption we calculated the monthly consumption since the billing practice in Bhutan is based on a monthly cycle. However the government is also considering providing electricity free of cost at all public charging stations as an incentive. Under such a scenario we assume that users would meet their entire energy requirements from public charging stations.

For aspects that are not clearly defined we make certain assumptions. Most of these assumptions are based on a survey carried out in 2011 as a part of a Transport Sector Capacity building study for the National Environment Commission.

Assumptions				
Daily distance travelled	60	Kms		
Utilization rate annually	90%			
Annual distance travelled	19710	Kms		
Annual increase in fuel price	7%			
Annual increase in electricity price	14%			
Maintenance				
ICEVs	5%	First year	10%	Annual increase thereafter
EVs	1%	First year	2%	Annual increase thereafter
Battery lifespan & cost (E2o)	5 years	250000		
Battery lifespan & cost (Leaf)	10 years	252000	Projected decrease due to technological progress	
Emissions per liter	2347.95 gms			
Cost of emissions	USD 25	Per ton of CO_2		

Table 4: Vehicle assumptions

While the daily distance travelled assumed by Mahindra REVA in its study ranges from 60 to 150 Kms for government vehicles and inter-city taxis we chose the more conservative figures reported in the NEC study. Doing so imposes more stringent parameters on the electric vehicle equivalents and decreases the probability of fulfilling the net present value requirement. This is because a higher driving distance daily would result in a higher annual fuel expenditure savings when converting to an electric car.

Additionally, we assume a 90% utilization rate for vehicles. This translates to 328.5 days of driving in a year and 19710 Kms of annual distance travelled for ICEVs.

The assumed increase in electricity prices is based on the approved increment by the Bhutan Electricity Authority. We have taken the approved increments between 2 time points and inferred the annual average increase. The assumed increase in fuel prices are taken from the NEC study as well although certain studies by the Energy Information Administration of the US also contain projections that take into account a low price and high price reference. Organizations like the IEA project that fossil fuels will constitute a fast decreasing share of total energy consumed due to the emergence of alternative sources such as shale and nuclear energy. However, its demand will still be large in absolute terms. This could possibly lead to a downward price trend. However, Bhutan's prices are determined by the Indian Gasoline market which forecasts an increase in gasoline prices given earlier trends whereby the real average growth rate between 1970 and 2011 was 5.62% and between 1991 and 2011 it was 6.72% (Agarwal, 2012). Hence an assumption of an annual growth of 7% is reasonable.

Since no official figures on the battery replacement costs have been released, we refer to certain studies. While it is estimated that battery replacement at present would cost about 50% of the vehicle's cost, projections show that advancements in battery technology could bring the battery prices for the leaf down to USD 4000 within the next decade.[5] This translates to one third of the current costs and an Ngultrum equivalent of 253000. As for the REVA E_2O, the battery currently costs 250000 and we use this figure since the replacement for this model will occur nearer in the future than that for the leaf.

Estimating CO_2 emissions can be extremely challenging. Various methods have been proposed although not without each one having their shortcomings. While some measure emissions per km we use an estimate expressed in terms of the amount of fuel consumed since different models consume differing amounts of fuel based on their efficiency. The estimation of other pollutants like N_2O and CH_4 are much more difficult and since CO_2 constitutes 95% of emissions, we do not take into consideration other pollutants. The Environmental Protection Agency of the US estimates the amount of CO_2 emissions per litre to be 2347.95 grams (EPA, 2011). Furthermore in assigning a monetary cost to the amount of emissions we use the IMF's figure of USD 25 per ton of carbon emissions (Litterman, 2013).

The maintenance assumptions are also borrowed from the survey conducted by the NEC which reports that ICEVs have higher maintenance costs than EVs. We use the following formula to forecast maintenance expenditure:

ICEVs

$$MC_0 = Price \times .05 MC_t = MC_0(1 + .10)^t; t > 0$$

Where MC is Maintenance Cost; Price is the upfront price of the vehicle and t refers to the year.

EVs

$$MC_0 = Price \times .02 MC_t = MC_0(1 + .10)^t; t > 0$$

[5] See www.technologyreview.com for a more detailed discussion on technological advancements in the field of lithium-ion batteries.

Similarly the energy prices can be captured as follows:

Fuel

$$FuelP_t = FuelP_{t-1}(1+r)^t$$

Electricity

$$ElecP_t = ElecP_{t-1}(1+r)^t$$

The calculations at the society level are slightly more complicated and require some more assumptions. Since we know that the government intends to replace the entire fleet of taxis with their electric vehicle equivalents which currently amounts to 5299 (RSTA, 2013), we assume a total deployment of 5000 EVs. In the absence of a clear time-bound roadmap we make the critical assumption that the deployment of all 873 Nissan Leaf vehicles and the installation of the necessary charging network will be completed in the first year. This has the added implication of imposing stricter thresholds for passing because all investment costs are frontloaded to the first year and cannot be discounted in future years.

In the case of the REVA E_2O we assume that 1000 units will be deployed annually after the first year. In the first year 600 Nissan Leafs and 128 E_2O's will be deployed as taxis and 272 Nissan Leaf's will be deployed for regular individuals. This would ensure that the virtually the entire existing fleet of taxis are replaced by the end of the 11th Five Year Plan. However, an implicit and rather significant assumption is that the total number of taxis does not increase. This is subject to debate but we offer the argument that Bhutan's per capita taxi figure is already very high with approximately 1 taxi for every 137 citizens or 7 taxis for every 1000 citizens. A city like Singapore, which is considered to have a rather high taxi density, has a ratio of 5.2 taxis for every 1000 citizens.[6] However, this is probably due to a range of other factors such as higher car ownership rates and the efficient public transportation systems that exist in other countries.

At the aggregate level we can also reasonably assume that 1000 units of existing taxis begin phasing out annually since a number of these taxis are also approaching the end of their legally permitted operational period of 8 years. Hence, we can draw comparisons between the scenario whereby those taxis phasing out would be replaced by the usual ICEV models or the alternative scenario whereby they are replaced by their EV equivalents.

In selecting the discount rates we refer to the interest rates offered on the safest assets in Bhutan- fixed deposit returns. Since the bond market is not as vibrant as in other capital markets, the fixed deposit return is an appropriate indicator of the opportunity cost of investing in an alternative project. The interest rates we consider are 5% and 7% which are the returns on a less than 1 year and more than 1 year deposit respectively (RMA, 2014).

Methodology

[6] http://app.lta.gov.sg/data/apps/news/press/2012/27072012_Factsheet_ImprovingTaxiAavailability.pdf

An abundance of literature exists on the practice of Cost Benefit Analysis. The approach we adopt can be categorized into two stages. First, we assess the cost and benefits for the individual user taking into consideration the models under comparison and various parameters. Second, we aggregate the results and include other prerequisite investments that need to be undertaken by the Government and the monetized value of certain intangibles like emissions. We then apply different scenarios to test the sensitivity of our results.

Since the returns to the investment are realized over a number of years we apply the Net Present Value approach to facilitate comparisons of Net Benefits from different years.[7] As the investment under consideration does not yield any direct cash flows, except for taxis, the Net Benefit in this study pertains to cost savings and other monetized positive externalities of the Electric Vehicle relative to Internal Combustion Engine Vehicles. Hence the Analysis we undertake is more holistic than a simple financial analysis.[8]

For the 600 Nissan Leafs that are going to be deployed as taxis the appropriate benchmark of comparison is the Maruti Alto 800 which currently dominates the taxi market. We use the same model as a benchmark for the E_2O. As for the remaining 272 Nissan Leafs targeted towards regular drivers, the selected benchmark is the Hyundai Accent due to their similar dimensions.

Individual User Analysis

The approach can be formally captured as presented below:

$$Cost_t^V = FC_t + Energy_t + Maintenance_t + Registration_t + Insurance_t$$

Where Cost is the Annual Cost of operating a vehicle, FC is either the upfront cost of the vehicle or the annual financing cost if a loan is availed.

For scenarios where we consider loan financing for vehicle purchases we calculate the annual instalment cost as:

$$FC = \frac{P}{\left[\left(1 - \left(\frac{1}{1+i}\right)^t\right) \Big/ i\right]}$$

Where P is the principal amount; i is the applied interest and t the loan term.[9]

We also calculate the Total Cost of Ownership to facilitate comparisons:

[7] See Rosen & Gayer, 2010 for a discussion of the advantages of the Net Present Value over other calculations
[8] See Perkins, 1994 for a detailed explanation of the significance of economic cost benefit analysis.
[9] See http://www.wikihow.com/Calculate-an-Annual-Payment-on-a-Loan

$$TCO_x = \sum_{0}^{T} Cost_t$$

Hence the annual net benefit can be presented as:

$$Net\ Benefit_t = \frac{(Cost_t^{EV} - Cost_t^{ICEV})}{(1+r)^t}$$

Accordingly the stream of net benefits can be presented as:

$$Net\ Present\ Value = (Cost_0^{EV} - Cost_0^{ICEV}) + \frac{(Cost_1^{EV} - Cost_1^{ICEV})}{(1+r)^1} + \frac{(Cost_2^{EV} - Cost_2^{ICEV})}{(1+r)^2} + \cdots + \frac{(Cost_t^{EV} - Cost_t^{ICEV})}{(1+r)^t}$$

Hence we summarize this as:

$$NPV = \sum_{0}^{T} \frac{(Cost_t^{EV} - Cost_t^{ICEV})}{(1+r)^t}$$

Society Level Analysis

We then move to assess the cost and benefits from the societal point of view. We do this by first aggregating the results of each model, and then taking into account the externalities in the form of emissions and fuel imports, which is a significant factor for Bhutan. This can be depicted as:

$$Social\ Cost_t^V = \sum_{0}^{T} FC_t^V + \sum_{0}^{T} Energy_t^V + \sum_{0}^{T} Maintenance_t^V + \sum_{0}^{T} Emissions_t^V$$

As a result the Stream of Benefits can be captured as:

$$NPV = \sum_{0}^{T} \frac{(Social\ Cost_t^{EV} - Social\ Cost_t^{ICEV})}{(1+r)^t}$$

For the society level analysis we consider only one scenario in which the state provides free electricity and no other incentives are offered.

Results of a Cost Benefit Analysis

We start with a presentation of the results from the individual level analyses of operating various vehicle models. As highlighted earlier, the appropriate benchmark for the REVA E_2O is the Alto 800 which is the most common taxi model in operation. Similarly, the 600 Nissan Leaf's designated as taxis will also be assessed against this benchmark model despite significant differences in dimensions and their intrinsic values. The other 272 Nissan Leaf's destined for regular commuting will be assessed against the Hyundai Accent given similarities in dimensions. We also conduct individual level analyses for state intervention alternatives such as the provision of free electricity, low cost financing options and vehicle buy back schemes.

Individual level Analysis

REVA vs. Alto 800

The REVA E_20 and Alto 800 are both manufactured in India and easily accessible to the Bhutanese market. The Alto is perhaps the most common car in the Indian subcontinent due to its fuel efficiency and affordability. The REVA E_2O represents a significant advancement over its predecessor, the REVA, in terms of structural improvements as well as mechanical dynamics.

Studying the Total Cost of Ownership of each model presents useful insights and an alternative perspective in assessing the relative costs of each model. Most potential buyers are usually deterred by the exorbitant upfront costs associated with buying an electric option. Due to differences in the cost structure of EVs and ICEVs the TCO approach is useful. This is also crucial in understanding the relative consumer preferences and valuation of different models (Bradley & Alawi, 2013).[10]

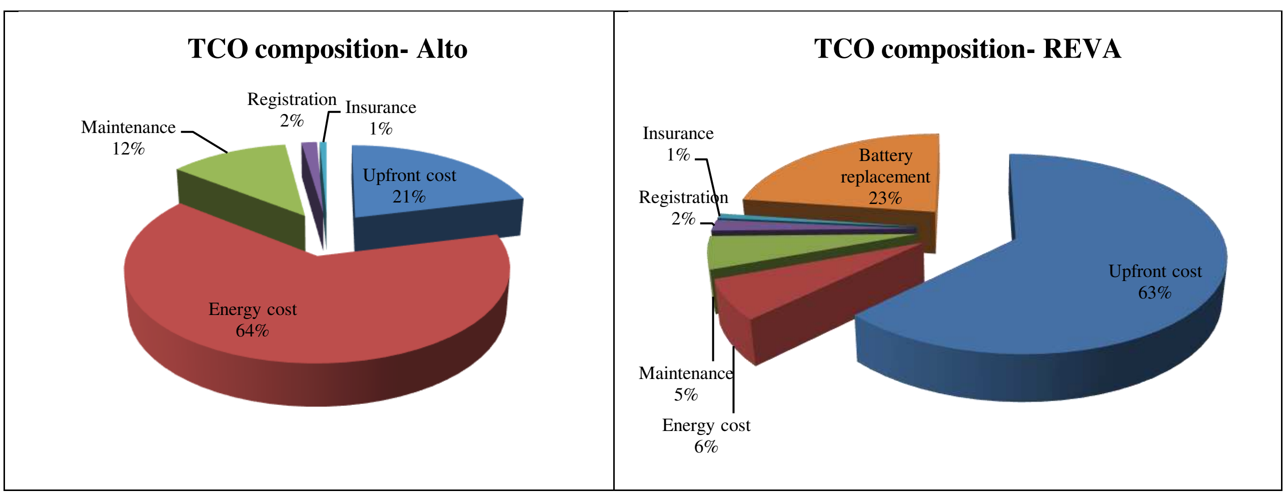

Figure 6: TCO of the Alto 800 and E_2O

[10] The authors present a sophisticated model of TCO and find that such a comprehensive model shows PHEVs to have a lower net cost of ownership than other studies which implies a shorter payback period and higher consumer preference.

The TCO reveals the significant difference in cost structure of the 2 models and hence the inadequacy of simply comparing the models on the basis of upfront costs or fuel economy. While energy costs represent the most significant burden for Alto owners, upfront costs are the most significant burden for REVA owners. A plotting of the smoothed cost curves for each model also provides additional insight.

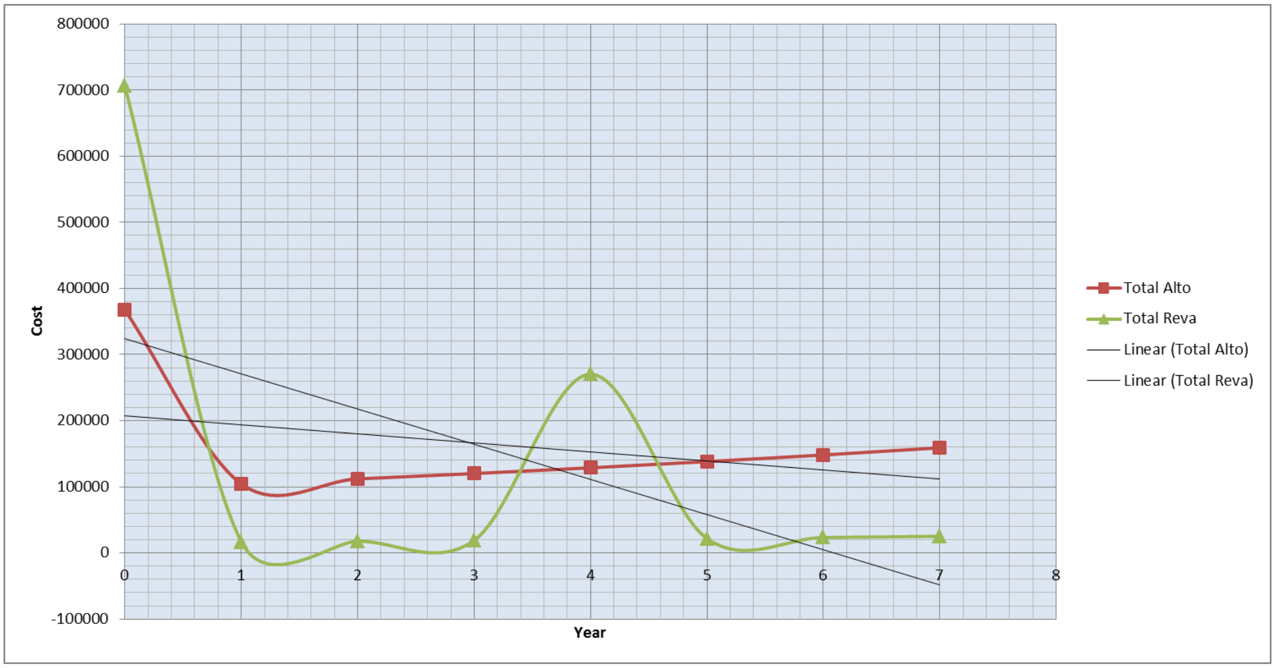

Figure 7: Total annual cost trends for REVA and Alto

While the REVA's cost in the first year is extremely high, this drops significantly then onwards with another spike towards the end of the fifth year due to battery replacement assumptions. However, this is also subject to change depending on the assumptions of fuel price increases and financing options.

We then calculate the flow of annual discounted cost savings when comparing the electric model to its internal combustion based benchmark.

Scenario	Baseline		Free Electricity		Buy-Back Scheme		Concessional loan	
Discount	5%	7%	5%	7%	5%	7%	5%	7%
NPV	80850	49829	140057	104856	319385	288211	306048	286496

Table 5: NPV for REVA vs. Alto

The NPV using both discount rates are positive although it could have been higher if not for the significant battery costs that have to be incurred in the fourth year. The provision of free electricity by the state results in an almost 73% and 110% increase in the NPV at discount rates of 5% and 7% respectively. Incorporating another form of state intervention such as a depreciated buy-back scheme at 50% of the initial cost significantly improves the situation for the individual. Tweaking the financing modality for the purchase of electric vehicles also results in a much higher NPV although not as high as that under the depreciated buy-back scheme.

Nissan Leaf vs. Alto 800 and Hyundai Accent

The Nissan Leaf is a more high-end model with larger dimensions, higher capacity and a greater durability. Hence, the intrinsic value of the model would definitely be much higher than that of the Alto 800 making them incomparable. However, since one category of the model has been earmarked for the taxi market, which is currently dominated by the Alto, we need to overlook the intrinsic value aspects and simply compare the financial returns. Regarding the other two categories designated for regular users we use the Hyundai Accent 2013 model which has similar dimensions.

The TCO comparisons for the two categories of the Leaf and Hyundai Accent reveal interesting facts.

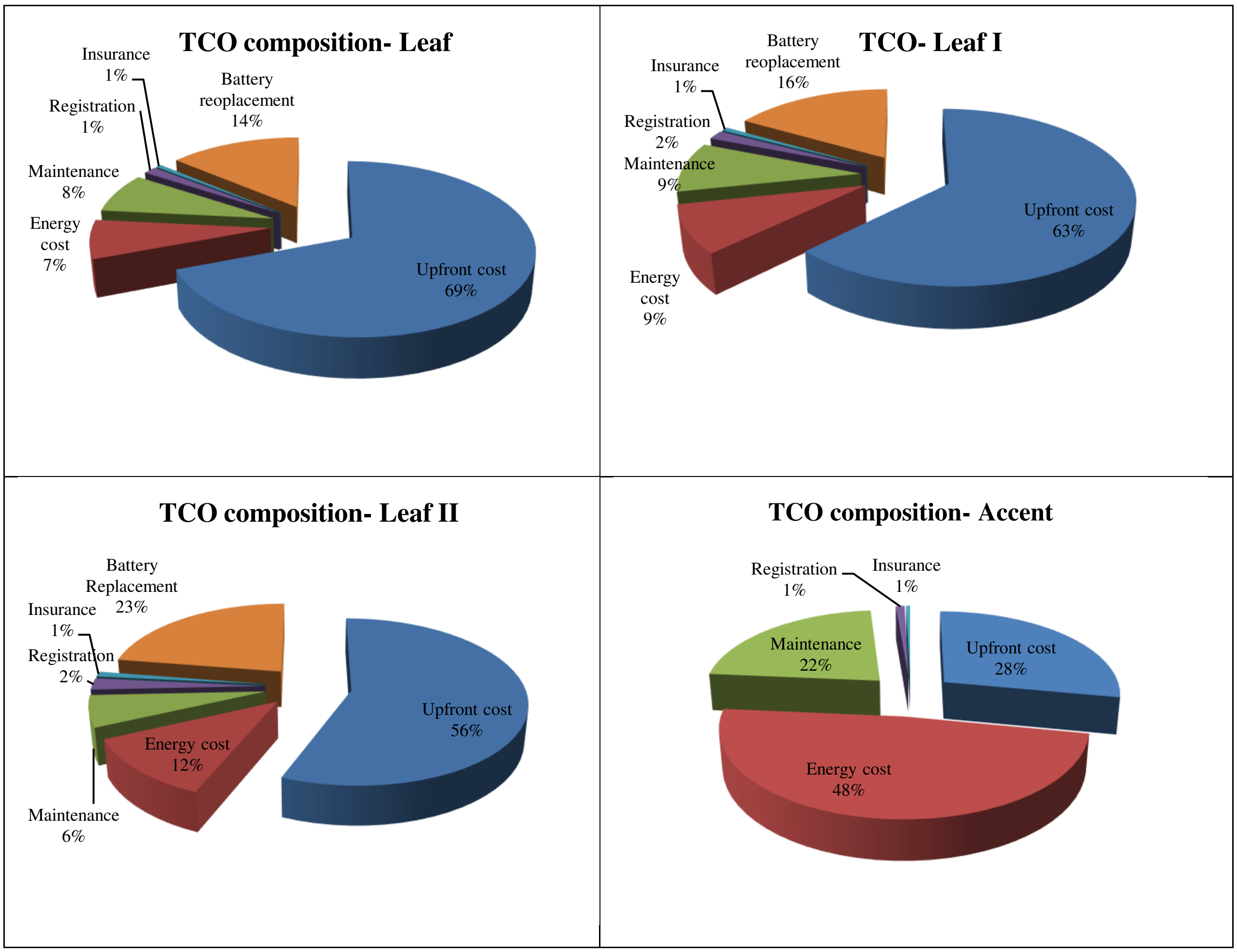

Figure 8: TCO for higher-end models

The proportion of upfront cost for the lower cost category of the leaf is 63% as opposed to that of its regular cost model for which the figure is 69%. The taxi category model presents an even lighter upfront cost burden at 56%. At its highest, the burden of energy cost represents only 12% of TCO. Hence, the EV option is consistently characterized by a high fixed cost component while the ICEV is more variable-cost oriented.

We then study the cost curves which again present a similar trend. The linear trend line shows a much faster deceleration of cost for every electric vehicle option.

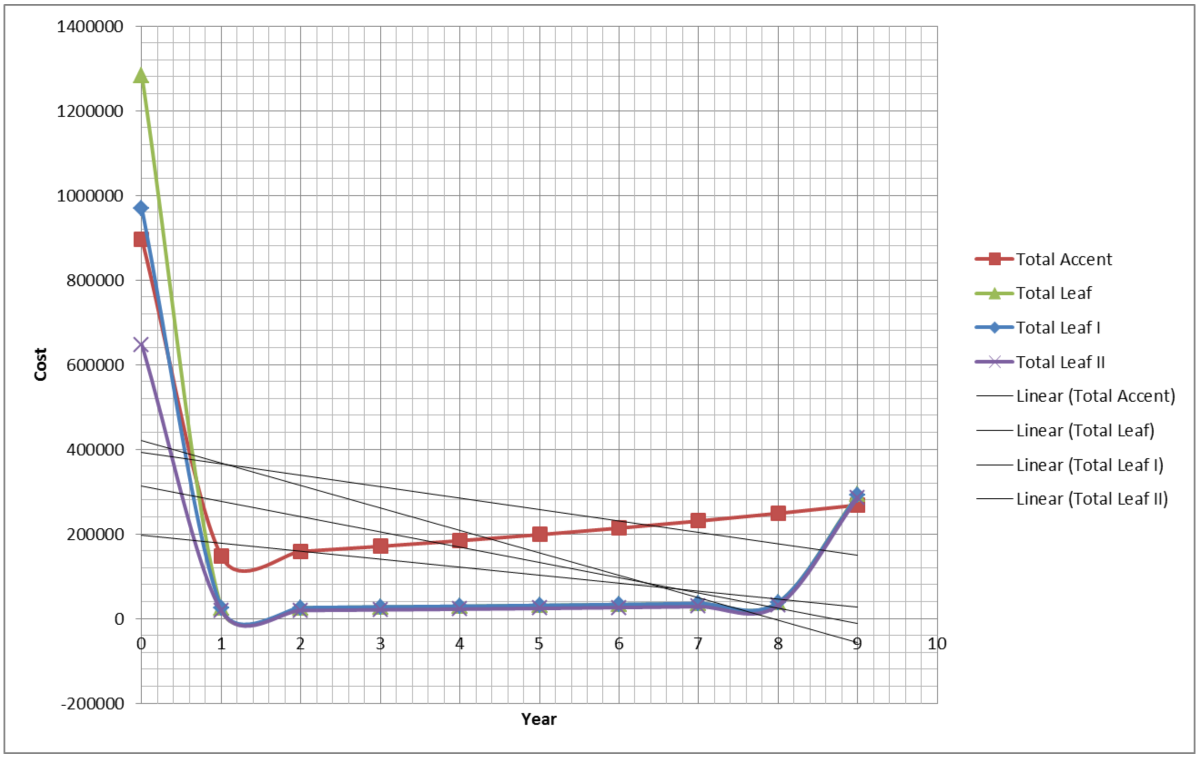

Figure 9: Annual cost trends for the higher-end models

The Net Present Value for all scenarios presents a significantly favourable result for the Electric Vehicle option.

		Leaf		Leaf I		Leaf II	
Discount rate		5%	7%	5%	7%	5%	7%
NPV	Baseline	633671	550089	947740	864126	363671	315594
	Free electricity	736714	643687	1050784	957724	466715	409192
	Buy-back scheme	1047139	961017	1327740	1244126	510561	461581
	Concessional loan	658429	609582	956901	886138	528297	494499

Table 6: NPV for Leaf

The most favourable option for the individual user is the Buy-back scheme for which the net benefit reaches as high as 1.3 million Ngultrums over a span of 10 years. However it is interesting to note that the most favourable option for the Leaf II model is the availing of a concessional loan although the net benefit is not significantly higher than that under a buy-back scheme. It must also be highlighted that even in the absence of any state intervention the EV option presents a very attractive package. This would significantly reduce the burden of financing any subsidy by the government.

Society-level Analysis

In conducting the society-level calculations we consider the two most likely scenarios in which the government either provides free electricity or low cost financing to purchase electric vehicles. It can be discerned that the methodology exhibits a strong bias against imports which is a significant factor in today's context. We do not include insurance and registration costs since these are relatively pecuniary expenses and they cancel out because we have assumed the same constant amount for all models.

Free Electricity

The cost of providing such an incentive can be equated either to the amount of export revenue forgone or the revenue earned by the Bhutan Power Corporation, whichever is higher. Since the export tariff is determined bilaterally between the Governments of India and Bhutan, we assume a constant rate of INR 2.25 per unit, which is why the domestic revenue earned by BPC exceeds the potential export earnings from the fourth year onwards.

Year	0	1	2	3	4	5	6	7	8	9
					(r=5%)					
Annual Costs savings	-295981638	-106858564	16699513	142045111	268098701	540789497	550296024	559867434	569486435	579133908
Cumulative cost savings	-295981638	-402840202	-386140689	-244095578	24003123	564792621	1115088644	1674956078	2244442513	2823576421
					(r=7%)					
Annual Costs savings	-295981638	-104861208	16081067	134227918	248608971	492102822	491393608	490595834	489697125	488684637
Cumulative cost savings	-295981638	-400842845	-384761779	-250533861	-1924890	490177932	981571540	1472167374	1961864499	2450549137

	8 years		10 years	
	(r=5%)	(r=7%)	(r=5%)	(r=7%)
NPV	1,674,956,078.03	1,472,167,374.02	2,823,576,421.25	2,450,549,136.52

Table 7: Society level NPV with free electricity

However, it must be noted that the aggregate society-level net benefits of not providing such an incentive does not change due to certain factors. The total cost to society in providing such an incentive can be measured as the amount expended by individuals on electricity, which would also include corporate costs of supplying electricity, and if the potential export revenue is higher than domestic revenue, it would include the revenue forgone.

The NPV over a course of 8 years is Nu. 1.7 billion and 1.5 billion for discount rates of 5% and 6% respectively. This figure is much higher 2 years later with a NPV of Nu. 2.8 billion and 2.45 billion for discount rates of 5% and 6% respectively. The bulk of this benefit can be attributed due to lower fuel imports which would otherwise have amounted to a total of 5.4 billion Ngultrums over a course of 10 years.

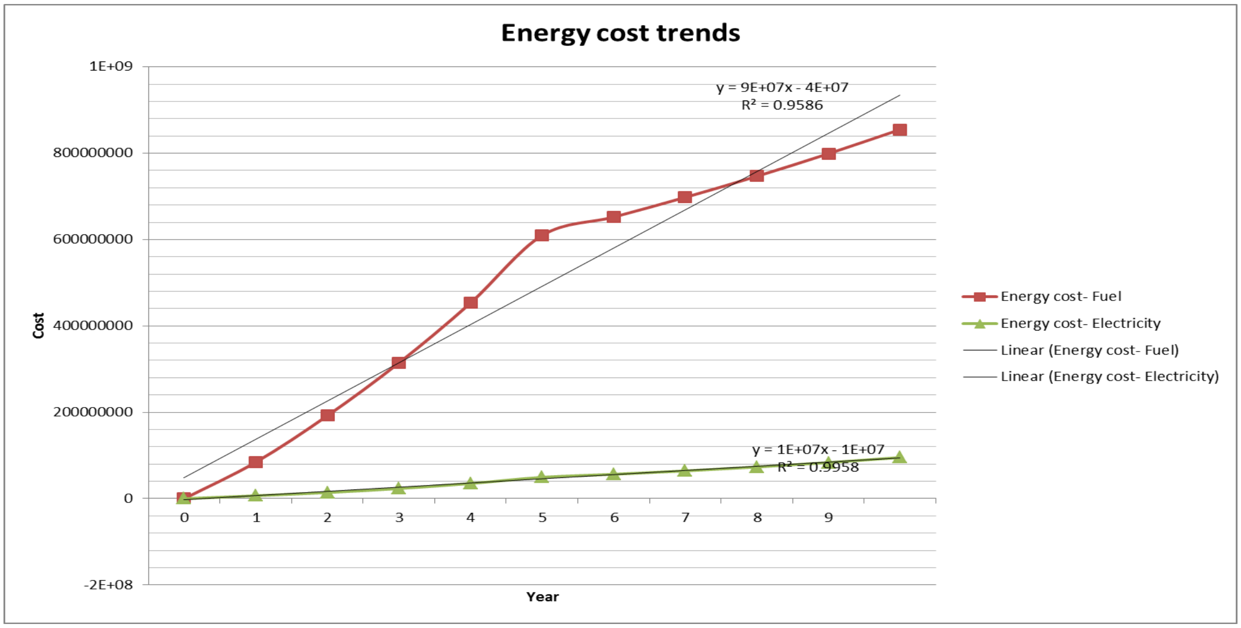

Figure 10: Energy cost trends

The aggregate cost differential between the two different models is significant from the graph above. The trend line for fossil fuels represents a much faster acceleration in aggregate costs as compared to hydro-electric energy.

Low cost financing

Incorporating low cost financing requires increasing the time frame of the entire study to 12 years. This is unavoidable because of the assumption that 1000 electric vehicles will be deployed annually for five years, which requires increasing the time frame to account for the loan term of 8 years and 10 years for some models. The last batch of vehicles will be deployed in the year 4 which implies an additional 7 years to complete the repayment of the loan and hence the requirement to extend the time period till year 11.

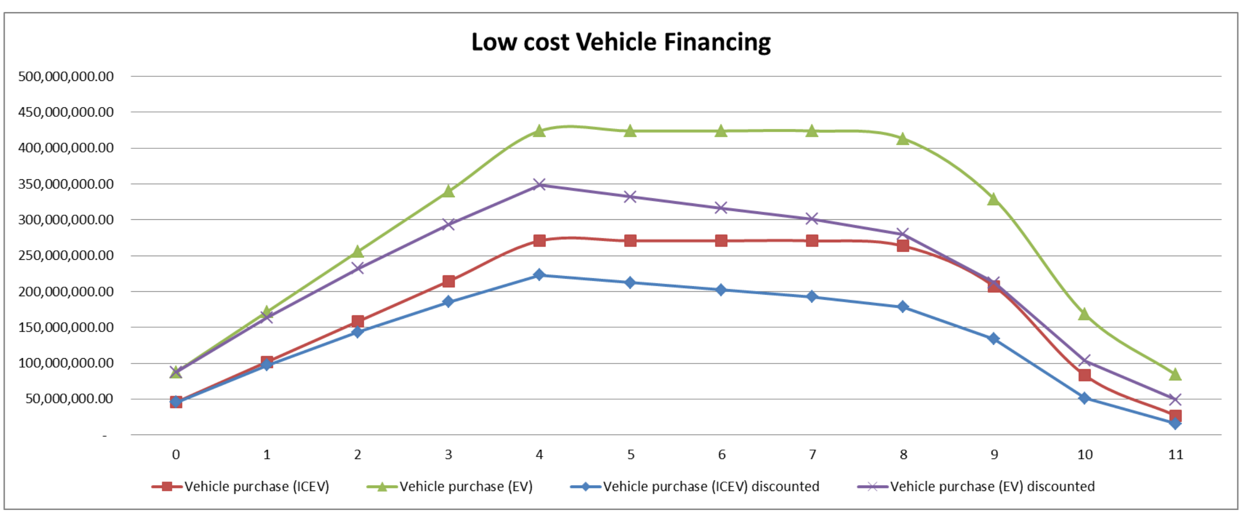

Figure 11: Vehicle financing cost

The NPV under such a scenario is significantly higher than that in which free electricity is provided. This is perhaps because the exorbitant upfront costs are spread throughout future years at concessional rates which are also further discounted. As is evident in the graph the deceleration in costs is significant when incorporating the discount factor.

Year	0	1	2	3	4	5	6	7	8	9	10	11
(r =5%)												
Annual Costs savings	(8,149,810.88)	136,035,622.30	226,644,647.73	320,975,111.71	391,530,205.72	234,327,496.28	256,019,535.10	277,264,992.49	300,548,935.68	500,470,712.25	535,515,118.11	563,423,642.22
Cumulative cost savings	(8,149,810.88)	127,885,811.42	354,530,459.15	675,505,570.86	1,067,035,776.58	1,301,363,272.86	1,557,382,807.95	1,834,647,800.44	2,135,196,736.12	2,635,667,448.37	3,171,182,566.48	3,734,606,208.70
(r =7%)												
Annual Costs savings	(8,149,810.88)	133,492,900.38	218,251,134.71	303,310,833.73	363,067,486.08	213,231,253.11	228,615,795.29	242,959,390.07	258,439,781.65	422,307,077.55	443,431,917.53	457,821,097.36
Cumulative cost savings	(8,149,810.88)	125,343,089.51	343,594,224.22	646,905,057.95	1,009,972,544.03	1,223,203,797.14	1,451,819,592.42	1,694,778,982.50	1,953,218,764.14	2,375,525,841.69	2,818,957,759.22	3,276,778,856.59

	12 years	
	(r = 5%)	(r =7%)
NPV	3,734,606,208.70	3,276,778,856.59

Table 8: Society level NPN with concessional financing

	Mode of financing		Discounted amount	
Model	Total nominal upfront	Total nominal Concessional	Total discounted upfront	Total discounted Concessional
EV	3,093,240,000.00	3,546,691,560.98	2,825,350,797.46	2,720,735,985.77
ICEV	1,483,280,000.00	2,184,571,171.72	1,360,686,636.12	1,679,988,865.32
Difference	1,609,960,000	1,362,120,389.26	1,464,664,161	1,040,747,120.45

Table 9: Cost difference due to concessional financing

The cost difference between the Electric and the Internal Combustion model is much lower in the scenario where concessional financing is provided. The figure is even lower when discounted making the outcome more favourable for the Electric Vehicle.

Recommendations

While the Electric Vehicle is undoubtedly the superior alternative for the individual as well as society as a whole, various bottlenecks exist in deploying them on a large scale. Some of these factors are technological in nature and will require time and a pushing of the technological frontier. However, some factors such as the time-inconsistency problem and the installation of the requisite infrastructure can be addressed through policy mechanisms and sectorial coordination.

In order to alleviate the burden of the upfront cost, the government should explore avenues for mobilizing concessional financing from multi-lateral institutions such as the ADB, which as part of its overarching medium term vision- Strategy 2020- has declared the extending of support for Environmental purposes as a priority (ADB, 2008). These loans which have a relatively long amortization schedule and highly discounted interest rates can then be channelled towards the purchasing of Electric Vehicles. Similarly, support could be sought from other multilateral institutions like the World Bank, the GEF and UNFCCC. Alternatively the government could dig into some its existing funds such as the Bhutan Trust Fund which is sitting on nearly 2 billion Ngultrums worth of very conservative-return assets.

Some countries such as the US and Portugal have conducted vehicle buy-back programs at a depreciated rate to remove old and fuel-inefficient vehicles from operation. The US initiated the Car Allowance Rebate System (CARS) to trade in an older, less fuel-efficient vehicle for a voucher that can be used to purchase newer and more fuel-efficient vehicles.[11] However, this could be a prohibitively expensive affair for the government although the cars could be sold across the border to second hand Indian establishments, which would then defeat the purpose of reducing carbon emissions.

Other forms of incentives such as tax credits to businesses that invest in electric cars could also be explored. Government affiliated institutions should be required to allocate a certain quota of their fleet for electric vehicles as well.

While these policy measures will be critical, no incentives will be adequate without the requisite infrastructure in place. The state could explore some form of PPP model in which the quick charging stations upon installation are contracted to a private player for operation. Similarly all major locations and every government building should be equipped with at least a regular charging station.

With more detailed engineering analysis and planning, the government could gradually introduce a smart-grid system whereby a lower tariff could be applied for charging during off-peak hours and vehicles could also supply electricity to the grid when not in operation. This would also facilitate electricity load smoothing and optimize electricity consumption.

[11] See Gayer and Parker, 2013 for an evaluation of the Scheme.

Conclusion

While studies reveal that exorbitant fixed costs such as those associated with the battery would have to come down by 80% before electric vehicles can be rolled out of a large scale, it is evident that they are a worthy investment whether from the individual or society's point of view. Even the baseline scenario in which no incentives are offered presents a favourable outcome for the EV option. At the aggregate level, the net benefits are significant and primarily attributable to reduced fuel imports. However, the massive upfront costs give rise to a time-inconsistency problem, thereby deterring individuals from investing in such an option. In such a case the state needs to assume a paternalistic role and apply policy measures such as providing access to concessional loans or supplying free electricity at charging stations.

This study has taken numerous simplifying assumptions to make the CBA problem tractable. However, with more clarity from the RGoB and relevant stakeholders the estimates can be sharpened. Furthermore, there is ample scope for more rigorous and detailed modelling exercises, which would also yield more robust results. Further research could be more academic oriented by defining a Societal Welfare Function and developing a CBA model based on such a specification. Similarly, Bhutan specific models that forecast fuel prices and growth in the number of automobiles would make the results more robust.

Detailed research related to the most suitable type of infrastructure and the electric-charging scheme is also critical. To induce buyers, a more intensive discussion of the possible incentives must be undertaken.

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Table 10: Alto Vs REVA- Baseline

Costs \ Year	0	1	2	3	4	5	6	7
Maruti Alto 800								
Upfront cost	270000							
Energy cost	80416.80	86046	92069	98514	105410	112789	120684	129132
Maintenance	13500	14850	16335	17969	19765	21742	23916	26308
Registration	2500	2500	2500	2500	2500	2500	2500	2500
Insurance	1100	1100	1100	1100	1100	1100	1100	1100
Total Alto	***367516.8***	***104495.98***	***112004.19***	***120082.54***	***128775.37***	***138130.61***	***148200.01***	***159039.49***
REVA E20								
Upfront cost	690000							
Energy cost	5453	6216	7086	8078	9209	10498	11968	13644
Maintenance	6900	7038	7179	7322	7469	7618	7771	7926
Registration	2500	2500	2500	2500	2500	2500	2500	2500
Insurance	1100	1100	1100	1100	1100	1100	1100	1100
Battery replacement					250000			
Total Reva	***705952.51***	***16853.86***	***17864.84***	***19000.47***	***270277.86***	***21716.50***	***23338.64***	***25169.58***

Year	0	1	2	3	4	5	6	7
(r = 5%) $\frac{Costs_{Alto} - Costs_{Reva}}{(1+r)^t}$								
Annual cost savings	-338436	83469	85387	87318	-116414	91213	93173	95139
Cumulative cost savings	-338436	-254967	-169580	-82261	-198676	-107462	-14289	80850
(r = 7%) $\frac{Costs_{Alto} - Costs_{Reva}}{(1+r)^t}$								
Annual cost savings	-338436	81909	82225	82513	-107952	83002	83200	83367
Cumulative cost savings	-338436	-256527	-174302	-91789	-199741	-116739	-33539	49829

	(r=5%)	(r=7%)
NPV $\sum_{0}^{T} \frac{Costs_{Alto} - Costs_{Reva}}{(1+r)^t}$	80850	49829

Costs \ Year	0	1	2	3	4	5	6	7
Maruti Alto 800								
Upfront cost	270000							
Energy cost	80416.80	86046	92069	98514	105410	112789	120684	129132
Maintenance	13500	14850	16335	17969	19765	21742	23916	26308
Registration	2500	2500	2500	2500	2500	2500	2500	2500
Insurance	1100	1100	1100	1100	1100	1100	1100	1100
Total Alto	***367516.8***	***104495.98***	***112004.19***	***120082.54***	***128775.37***	***138130.61***	***148200.01***	***159039.49***
REVA E20								
Upfront cost	690000							
Energy cost								
Maintenance	6900	7038	7179	7322	7469	7618	7771	7926
Registration	2500	2500	2500	2500	2500	2500	2500	2500
Insurance	1100	1100	1100	1100	1100	1100	1100	1100
Battery replacement					250000			
Total Reva	***700500.00***	***10638.00***	***10778.76***	***10922.34***	***261068.78***	***11218.16***	***11370.52***	***11525.93***

Year	0	1	2	3	4	5	6	7
(r = 5%)								
Annual cost savings $\frac{Costs_{Alto} - Costs_{Reva}}{(1+r)^t}$	-332983	89389	91814	94297	-108838	99439	102104	104835
Cumulative cost savings	-332983	-243595	-151780	-57484	-166322	-66882	35222	140057
(r = 7%)								
Annual cost savings $\frac{Costs_{Alto} - Costs_{Reva}}{(1+r)^t}$	-332983	87718	88414	89107	-100926	90487	91175	91864
Cumulative cost savings	-332983	-245265	-156851	-67744	-168670	-78183	12992	104856

	(r=5%)	(r=7%)
NPV $\sum_{0}^{T} \frac{Costs_{Alto} - Costs_{Reva}}{(1+r)^t}$	140057	104856

Costs \ Year	0	1	2	3	4	5	6	7
Maruti Alto 800								
Upfront cost	270000							
Energy cost	78840	84359	90264	96582	103343	110577	118318	126600
Maintenance	13500	14850	16335	17969	19765	21742	23916	26308
Registration	2500	2500	2500	2500	2500	2500	2500	2500
Insurance	1100	1100	1100	1100	1100	1100	1100	1100
Total	***365940***	***102808.80***	***110198.92***	***118150.89***	***126708.51***	***135919.06***	***145833.65***	***156507.49***
REVA E20								
Upfront cost = (Reva cost - .5*Cost of alto)	455000							
Energy cost	5453	6216	7086	8078	9209	10498	11968	13644
Maintenance	4550	4641	4734	4828	4925	5024	5124	5227
Registration	2500	2500	2500	2500	2500	2500	2500	2500
Insurance	1100	1100	1100	1100	1100	1100	1100	1100
Battery Replacement					250000			
Total	***468602.51***	***14456.86***	***15419.90***	***16506.63***	***267734.14***	***19121.91***	***20692.15***	***22470.17***

Year	0	1	2	3	4	5	6	7
(r = 5%)								
Annual cost savings $\frac{Costs_{Alto} - Costs_{Reva}}{(1+r)^t}$	-102663	84145	85967	87804	-116022	91514	93383	95258
Cumulative cost savings	-102663	-18518	67450	155254	39232	130745	224128	319385
(r = 7%)								
Annual cost savings $\frac{Costs_{Alto} - Costs_{Reva}}{(1+r)^t}$	-102663	82572	82784	82972	-107588	83275	83387	83472
Cumulative cost savings	-102663	-20091	62693	145665	38077	121352	204739	288211

	(r=5%)	(r=7%)
NPV $\sum_{0}^{T} \frac{Costs_{Alto} - Costs_{Reva}}{(1+r)^t}$	319385	288211

Table 11: Alto Vs. REVA- Free electricity

Table 12: Alto Vs. REVA- Depreciated buy-back scheme

Costs \ Year	0	1	2	3	4	5	6	7
Maruti Alto 800								
Vehicle financing cost	56264.41	56264.41	56264.41	56264.41	56264.41	56264.41	56264.41	56264.41
Energy cost	78840	84359	90264	96582	103343	110577	118318	126600
Maintenance	13500	14850	16335	17969	19765	21742	23916	26308
Registration	2500	2500	2500	2500	2500	2500	2500	2500
Insurance	1100	1100	1100	1100	1100	1100	1100	1100
Total	***152204.41***	***159073.21***	***166463.33***	***174415.30***	***182972.92***	***192183.48***	***202098.07***	***212771.91***
REVA E20								
Vehicle financing cost	84049.27	84049.27	84049.27	84049.27	84049.27	84049.27	84049.27	84049.27
Energy cost	5453	6216	7086	8078	9209	10498	11968	13644
Maintenance	5900	6018	6138	6261	6386	6514	6644	6777
Registration	2500	2500	2500	2500	2500	2500	2500	2500
Insurance	1100	1100	1100	1100	1100	1100	1100	1100
Battery Replacenent					250000			
Total	***99001.78***	***99883.13***	***100873.71***	***101988.53***	***353244.69***	***104661.69***	***106261.74***	***108070.17***

Year	0	1	2	3	4	5	6	7
(r = 5%)								
Annual cost savings $\dfrac{Costs_{Alto} - Costs_{Reva}}{(1+r)^t}$	53203	56372	59492	62565	-140083	68576	71515	74410
Cumulative cost savings	53203	109574	169066	231631	91548	160123	231638	306048
(r = 7%)								
Annual cost savings $\dfrac{Costs_{Alto} - Costs_{Reva}}{(1+r)^t}$	53203	55318	57289	59122	-129900	62402	63860	65203
Cumulative cost savings	53203	108520	165809	224931	95031	157433	221293	286496

	(r=5%)	(r=7%)
NPV $\sum_{0}^{T} \dfrac{Costs_{Alto} - Costs_{Reva}}{(1+r)^t}$	306048	286496

Table 13: Alto Vs. REVA- Low cost financing

Costs \ Year	0	1	2	3	4	5	6	7	8	9
Hyundai Accent										
Upfront cost	760000									
Energy cost	95160	101821	108949	116575	124735	133467	142809	152806	163502	174948
Maintenance	38000	41800	45980	50578	55636	61199	67319	74051	81456	89602
Registration	2500	2500	2500	2500	2500	2500	2500	2500	2500	2500
Insurance	1100	1100	1100	1100	1100	1100	1100	1100	1100	1100
Total Accent	***896759.88***	***147221.07***	***158528.55***	***170752.94***	***183970.99***	***198266.03***	***213728.64***	***230457.22***	***248558.77***	***268149.57***
Nissan Leaf (72 units)										
Upfront cost	1260000									
Energy cost	6922	7891	8996	10256	11692	13328	15194	17322	19747	22511
Maintenance	12600	12852	13109	13371	13639	13911	14190	14473	14763	15058
Registration	2500	2500	2500	2500	2500	2500	2500	2500	2500	2500
Insurance	1100	1100	1100	1100	1100	1100	1100	1100	1100	1100
Battery reoplacement										252000.00
Total Leaf	***1283122.349***	***24343.48***	***25705.32***	***27226.99***	***28930.22***	***30839.81***	***32984.01***	***35395.02***	***38109.51***	***293169.29***

Upfront cost difference	500000									
			(r = 5%)							
$$\frac{Costs_{Accent} - Costs_{Leaf}}{(1+r)^t}$$										
Annual Costs savings	-386362	117026	120475	123983	127552	131183	134874	138627	142440	-16128
Cumulative cost savings	-386362	-269336	-148862	-24878	102674	233857	368731	507358	649799	633671
			(r = 7%)							
$$\frac{Costs_{Accent} - Costs_{Leaf}}{(1+r)^t}$$										
Annual cost savings	-386362	114839	116013	117160	118280	119373	120438	121475	122483	-13609
Cumulative cost savings	-386362	-271524	-155511	-38351	79929	199302	319740	441214	563698	550089

	(r = 5%)	(r =7%)
NPV $$\sum_{0}^{T}\frac{Costs_{Accent} - Costs_{Leaf}}{(1+r)^t}$$	633671	550089

Table 14: Accent Vs. Leaf (72 units) – Baseline

Costs \ Year	0	1	2	3	4	5	6	7	8	9
Hyundai Accent										
Upfront cost	760000									
Energy cost	95160	101821	108949	116575	124735	133467	142809	152806	163502	174948
Maintenance	38000	41800	45980	50578	55636	61199	67319	74051	81456	89602
Registration	2500	2500	2500	2500	2500	2500	2500	2500	2500	2500
Insurance	1100	1100	1100	1100	1100	1100	1100	1100	1100	1100
Total Accent	***896759.88***	***147221.07***	***158528.55***	***170752.94***	***183970.99***	***198266.03***	***213728.64***	***230457.22***	***248558.77***	***268149.57***
Nissan Leaf (200 units)										
Upfront cost	945000									
Energy cost	6922	7891	8996	10256	11692	13328	15194	17322	19747	22511
Maintenance	12852	13109.04	13371.2208	13638.64522	13911.41812	14189.64648	14473.43941	14762.9082	15058.16636	15359.32969
Registration	2500	2500	2500	2500	2500	2500	2500	2500	2500	2500
Insurance	1100	1100	1100	1100	1100	1100	1100	1100	1100	1100
Battery reoplacement										250000.00
Total Leaf I	***968374.3488***	***24600.52***	***25967.51***	***27494.41***	***29202.99***	***31118.04***	***33267.81***	***35684.49***	***38404.76***	***291470.45***

Upfront cost difference	185000									
			(r = 5%)							
Annual Costs savings $\frac{Costs_{Accent} - Costs_{Leaf}}{(1+r)^t}$	-71614	116781	120237	123752	127328	130965	134663	138421	142240	-15033
Cumulative cost savings	-71614	45167	165404	289156	416484	547449	682111	820533	962773	947740
			(r = 7%)							
Annual cost savings $\frac{Costs_{Accent} - Costs_{Leaf}}{(1+r)^t}$	-71614	114599	115784	116942	118072	119174	120249	121295	122312	-12685
Cumulative cost savings	-71614	42984	158768	275710	393782	512956	633204	754499	876811	864126

	(r = 5%)	(r =7%)
NPV $\sum_{0}^{T} \frac{Costs_{Accent} - Costs_{Leaf}}{(1+r)^t}$	947740	864126

Table 15: Accent vs Leaf (200 units)- Baseline

Costs \ Year	0	1	2	3	4	5	6	7	8	9
Maruti Alto 800										
Upfront cost	270000									
Energy cost	80417	86046	92069	98514	105410	112789	120684	129132	138171	147843
Maintenance	13500	14850	16335	17969	19765	21742	23916	26308	28938	31832
Registration	2500	2500	2500	2500	2500	2500	2500	2500	2500	2500
Insurance	1100	1100	1100	1100	1100	1100	1100	1100	1100	1100
Total	***367516.8***	***104495.98***	***112004.19***	***120082.54***	***128775.37***	***138130.61***	***148200.01***	***159039.49***	***170709.48***	***183275.30***
Nissan Leaf										
Upfront cost	630000									
Energy cost	6922	7891	8996	10256	11692	13328	15194	17322	19747	22511
Maintenance	6300	6426	6555	6686	6819	6956	7094.823241	7237	7381	7529
Registration	2500	2500	2500	2500	2500	2500	2500	2500	2500	2500
Insurance	1100	1100	1100	1100	1100	1100	1100	1100	1100	1100
Battery Replacement										252000
Total	***646822.3488***	***17917.48***	***19150.80***	***20541.37***	***22110.89***	***23884.10***	***25889.19***	***28158.30***	***30728.05***	***285640.21***

	0	1	2	3	4	5	6	7	8	9
Upfront cost difference	360000									
(r =5%) $\frac{Costs_{Alto} - Costs_{Leaf}}{(1+r)^t}$										
Annual Costs savings	-279306	82456	84221	85987	87753	89515	91270	93015	94745	-65985
Cumulative cost savings	-279306	-196850	-112629	-26642	61111	150627	241897	334912	429657	363671
(r =7%) $\frac{Costs_{Alto} - Costs_{Leaf}}{(1+r)^t}$										
Annual Costs savings	-279306	80914	81102	81255	81374	81456	81501	81506	81470	-55680
Cumulative cost savings	-279306	-198391	-117289	-36034	45340	126796	208297	289803	371273	315594

	5 years		10 years	
	(r = 5%)	(r =7%)	(r = 5%)	(r =7%)
NPV $\sum_{0}^{T} \frac{Costs_{Alto} - Costs_{Leaf}}{(1+r)^t}$	61111	45340	363671	315594

Table 16: Alto vs. Leaf (600 units) - Baseline

Costs / Year	0	1	2	3	4	5	6	7	8	9
Hyundai Accent										
Upfront cost	760000									
Energy cost	95160	101821	108949	116575	124735	133467	142809	152806	163502	174948
Maintenance	38000	41800	45980	50578	55636	61199	67319	74051	81456	89602
Registration	2500	2500	2500	2500	2500	2500	2500	2500	2500	2500
Insurance	1100	1100	1100	1100	1100	1100	1100	1100	1100	1100
Total Accent	***896759.88***	***147221.07***	***158528.55***	***170752.94***	***183970.99***	***198266.03***	***213728.64***	***230457.22***	***248558.77***	***268149.57***
Nissan Leaf (72 units)										
Upfront cost	880000									
Energy cost	6922	7891	8996	10256	11692	13328	15194	17322	19747	22511
Maintenance	8800	8976	9156	9339	9525	9716	9910	10108	10311	10517
Registration	2500	2500	2500	2500	2500	2500	2500	2500	2500	2500
Insurance	1100	1100	1100	1100	1100	1100	1100	1100	1100	1100
Battery reoplacement										252000.00
Total Leaf	***899322.3488***	***20467.48***	***21751.80***	***23194.39***	***24816.97***	***26644.30***	***28704.60***	***31030.01***	***33657.20***	***288627.94***

Upfront cost difference	120000									
		(r = 5%)								
$\frac{Costs_{Accent} - Costs_{Leaf}}{(1+r)^t}$										
Annual Costs savings	-2562	120718	124061	127467	130936	134470	138068	141729	145454	-13201
Cumulative cost savings	-2562	118155	242216	369682	500619	635089	773157	914886	1060340	1047139
		(r = 7%)								
$\frac{Costs_{Accent} - Costs_{Leaf}}{(1+r)^t}$										
Annual cost savings	-2562	118461	119466	120452	121418	122364	123289	124193	125075	-11139
Cumulative cost savings	-2562	115899	235365	355817	477235	599598	722888	847081	972156	961017

	(r = 5%)	(r =7%)
NPV $\sum_{0}^{T}\frac{Costs_{Accent} - Costs_{Leaf}}{(1+r)^t}$	1047139	961017

Table 17: Accent vs. Leaf (72 units) – Depreciated buy-back scheme

Costs \ Year	0	1	2	3	4	5	6	7	8	9
Hyundai Accent										
Upfront cost	760000									
Energy cost	95160	101821	108949	116575	124735	133467	142809	152806	163502	174948
Maintenance	38000	41800	45980	50578	55636	61199	67319	74051	81456	89602
Registration	2500	2500	2500	2500	2500	2500	2500	2500	2500	2500
Insurance	1100	1100	1100	1100	1100	1100	1100	1100	1100	1100
Total Accent	***896759.88***	***147221.07***	***158528.55***	***170752.94***	***183970.99***	***198266.03***	***213728.64***	***230457.22***	***248558.77***	***268149.57***
Nissan Leaf (200 units)										
Upfront cost	565000									
Energy cost	6922	7891	8996	10256	11692	13328	15194	17322	19747	22511
Maintenance	12852	13109.04	13371.2208	13638.64522	13911.41812	14189.64648	14473.43941	14762.9082	15058.16636	15359.32969
Registration	2500	2500	2500	2500	2500	2500	2500	2500	2500	2500
Insurance	1100	1100	1100	1100	1100	1100	1100	1100	1100	1100
Battery reoplacement										250000.00
Total Leaf I	***588374.3488***	***24600.52***	***25967.51***	***27494.41***	***29202.99***	***31118.04***	***33267.81***	***35684.49***	***38404.76***	***291470.45***

Upfront cost difference	-195000									
		(r = 5%)								
$\frac{Costs_{Accent} - Costs_{Leaf}}{(1+r)^t}$										
Annual Costs savings	308386	116781	120237	123752	127328	130965	134663	138421	142240	-15033
Cumulative cost savings	308386	425167	545404	669156	796484	927449	1062111	1200533	1342773	1327740
		(r = 7%)								
$\frac{Costs_{Accent} - Costs_{Leaf}}{(1+r)^t}$										
Annual cost savings	308386	114599	115784	116942	118072	119174	120249	121295	122312	-12685
Cumulative cost savings	308386	422984	538768	655710	773782	892956	1013204	1134499	1256811	1244126

	(r = 5%)	(r =7%)
NPV $\sum_{0}^{T} \frac{Costs_{Accent} - Costs_{Leaf}}{(1+r)^t}$	1,327,740.39	1,244,125.62

Table 18: Accent vs. Leaf (200 units) – depreciated buy-back scheme

Costs \ Year	0	1	2	3	4	5	6	7	8	9
Maruti Alto 800										
Upfront cost	270000									
Energy cost	80417	86046	92069	98514	105410	112789	120684	129132	138171	147843
Maintenance	13500	14850	16335	17969	19765	21742	23916	26308	28938	31832
Registration	2500	2500	2500	2500	2500	2500	2500	2500	2500	2500
Insurance	1100	1100	1100	1100	1100	1100	1100	1100	1100	1100
Total	***367516.8***	***104495.98***	***112004.19***	***120082.54***	***128775.37***	***138130.61***	***148200.01***	***159039.49***	***170709.48***	***183275.30***
Nissan Leaf										
Upfront cost	495000									
Energy cost	6922	7891	8996	10256	11692	13328	15194	17322	19747	22511
Maintenance	4950	5049	5150	5253	5358	5465	5574.503975	5686	5800	5916
Registration	2500	2500	2500	2500	2500	2500	2500	2500	2500	2500
Insurance	1100	1100	1100	1100	1100	1100	1100	1100	1100	1100
Battery Replacement										252000
Total	***510472.3488***	***16540.48***	***17746.26***	***19108.74***	***20649.61***	***22393.59***	***24368.87***	***26607.57***	***29146.31***	***284026.83***

	0	1	2	3	4	5	6	7	8	9
Upfront cost difference	225000									
(r =5%) $\frac{Costs_{Alto} - Costs_{Leaf}}{(1+r)^t}$										
Annual Costs savings	-142956	83767	85495	87225	88955	90683	92405	94117	95816	-64945
Cumulative cost savings	-142956	-59188	26306	113531	202487	293170	385574	479691	575507	510561
(r =7%) $\frac{Costs_{Alto} - Costs_{Leaf}}{(1+r)^t}$										
Annual Costs savings	-142956	82201	82329	82425	82489	82519	82514	82472	82391	-54802
Cumulative cost savings	-142956	-60754	21574	103999	186488	269007	351521	433992	516384	461581

	5 years		12 years	
	(r = 5%)	(r =7%)	(r = 5%)	(r =7%)
NPV $\sum_{0}^{T} \frac{Costs_{Alto} - Costs_{Leaf}}{(1+r)^t}$	202487	186488	510561	461581

Table 19: Alto vs. Leaf (600 units)- depreciated buy-back scheme

Costs / Year	0	1	2	3	4	5	6	7	8	9
Hyundai Accent										
Upfront cost	89095.19	89095.19	89095.19	89095.19	89095.19	89095.19	89095.19	89095.19	89095.19	89095.19
Energy cost	95160	101821	108949	116575	124735	133467	142809	152806	163502	174948
Maintenance	38000	41800	45980	50578	55636	61199	67319	74051	81456	89602
Registration	2500	2500	2500	2500	2500	2500	2500	2500	2500	2500
Insurance	1100	1100	1100	1100	1100	1100	1100	1100	1100	1100
Total Accent	***225855.065***	***236316.26***	***247623.73***	***259848.13***	***273066.18***	***287361.22***	***302823.82***	***319552.41***	***337653.95***	***357244.76***
Nissan Leaf (72 units)										
Upfront cost	147710.44	147710.44	147710.44	147710.44	147710.44	147710.44	147710.44	147710.44	147710.44	147710.44
Energy cost	6922	7891	8996	10256	11692	13328	15194	17322	19747	22511
Maintenance	12600	12852	13109	13371	13639	13911	14190	14473	14763	15058
Registration	2500	2500	2500	2500	2500	2500	2500	2500	2500	2500
Insurance	1100	1100	1100	1100	1100	1100	1100	1100	1100	1100
Battery reoplacement										252000.00
Total Leaf	***170832.7871***	***172053.92***	***173415.76***	***174937.42***	***176640.65***	***178550.25***	***180694.45***	***183105.46***	***185819.94***	***440879.73***

Upfront cost difference	58615.2533									
		(r = 5%)								
$\frac{Costs_{Accent} - Costs_{Leaf}}{(1+r)^t}$										
Annual Costs savings	55022	61202	67309	73349	79330	85256	91135	96970	102767	-53912
Cumulative cost savings	55022	116225	183533	256882	336212	421468	512603	609573	712340	658429
		(r = 7%)								
$\frac{Costs_{Accent} - Costs_{Leaf}}{(1+r)^t}$										
Annual cost savings	55022	60058	64816	69312	73563	77581	81380	84972	88369	-45492
Cumulative cost savings	55022	115081	179897	249209	322772	400352	481732	566705	655073	609582

	(r = 5%)	(r =7%)
NPV $\sum_{0}^{T} \frac{Costs_{Accent} - Costs_{Leaf}}{(1+r)^t}$	658429	609582

Table 20: Accent vs. Leaf (72 units) – concessional financing

Costs \ Year	0	1	2	3	4	5	6	7	8	9
Hyundai Accent										
Upfront cost	89095.19	89095.19	89095.19	89095.19	89095.19	89095.19	89095.19	89095.19	89095.19	89095.19
Energy cost	95160	101821	108949	116575	124735	133467	142809	152806	163502	174948
Maintenance	38000	41800	45980	50578	55636	61199	67319	74051	81456	89602
Registration	2500	2500	2500	2500	2500	2500	2500	2500	2500	2500
Insurance	1100	1100	1100	1100	1100	1100	1100	1100	1100	1100
Total Accent	***225855.065***	***236316.26***	***247623.73***	***259848.13***	***273066.18***	***287361.22***	***302823.82***	***319552.41***	***337653.95***	***357244.76***
Nissan Leaf (200 units)										
Upfront cost	110782.83	110782.83	110782.83	110782.83	110782.83	110782.83	110782.83	110782.83	110782.83	110782.83
Energy cost	6922	7891	8996	10256	11692	13328	15194	17322	19747	22511
Maintenance	12852	13109.04	13371.2208	13638.64522	13911.41812	14189.64648	14473.43941	14762.9082	15058.16636	15359.32969
Registration	2500	2500	2500	2500	2500	2500	2500	2500	2500	2500
Insurance	1100	1100	1100	1100	1100	1100	1100	1100	1100	1100
Battery reoplacement										250000.00
Total Leaf I	***134157.1775***	***135383.35***	***136750.33***	***138277.24***	***139985.82***	***141900.87***	***144050.63***	***146467.31***	***149187.59***	***402253.28***

Upfront cost difference	21687.64372									
(r = 5%) $\frac{Costs_{Accent} - Costs_{Leaf}}{(1+r)^t}$										
Annual Costs savings	91698	96127	100565	105018	109486	113972	118479	123008	127561	-29013
Cumulative cost savings	91698	187824	288390	393407	502893	616865	735344	858352	985914	956901
(r = 7%) $\frac{Costs_{Accent} - Costs_{Leaf}}{(1+r)^t}$										
Annual cost savings	91698	94330	96841	99238	101526	103711	105797	107789	109689	-24482
Cumulative cost savings	91698	186028	282869	382107	483633	587344	693142	800930	910620	886138

	(r = 5%)	(r =7%)
NPV $\sum_{0}^{T} \frac{Costs_{Accent} - Costs_{Leaf}}{(1+r)^t}$	956901	886138

Table 21: Accent vs. Leaf (200 units) – concessional financing

Costs / Year	0	1	2	3	4	5	6	7	8	9
Maruti Alto 800										
Upfront cost	49758.18	49758.18	49758.18	49758.18	49758.18	49758.18	49758.18	49758.18	49758.18	49758.18
Energy cost	80417	86046	92069	98514	105410	112789	120684	129132	138171	147843
Maintenance	13500	14850	16335	17969	19765	21742	23916	26308	28938	31832
Registration	2500	2500	2500	2500	2500	2500	2500	2500	2500	2500
Insurance	1100	1100	1100	1100	1100	1100	1100	1100	1100	1100
Total	***147274.9801***	***154254.16***	***161762.37***	***169840.72***	***178533.55***	***187888.79***	***197958.19***	***208797.67***	***220467.66***	***233033.48***
Nissan Leaf										
Upfront cost	73855.22	73855.22	73855.22	73855.22	73855.22	73855.22	73855.22	73855.22	73855.22	73855.22
Energy cost	6922	7891	8996	10256	11692	13328	15194	17322	19747	22511
Maintenance	6300	6426	6555	6686	6819	6956	7094.823241	7237	7381	7529
Registration	2500	2500	2500	2500	2500	2500	2500	2500	2500	2500
Insurance	1100	1100	1100	1100	1100	1100	1100	1100	1100	1100
Battery Replacement										252000
Total	***90677.56796***	***91772.70***	***93006.02***	***94396.59***	***95966.11***	***97739.32***	***99744.41***	***102013.52***	***104583.27***	***359495.42***

Upfront cost difference	24097.03909									
(r =5%) $\frac{Costs_{Alto} - Costs_{Leaf}}{(1+r)^t}$										
Annual Costs savings	56597	59506	62364	65171	67928	70634	73289	75890	78435	-81518
Cumulative cost savings	56597	116104	178468	243639	311568	382202	455491	531380	609815	528297
(r =7%) $\frac{Costs_{Alto} - Costs_{Leaf}}{(1+r)^t}$										
Annual Costs savings	56597	58394	60054	61585	62990	64275	65444	66500	67446	-68787
Cumulative cost savings	56597	114991	175046	236631	299621	363896	429340	495840	563286	494499

	5 years		10 years	
	(r = 5%)	(r =7%)	(r = 5%)	(r =7%)
NPV $\sum_{0}^{T} \frac{Costs_{Alto} - Costs_{Leaf}}{(1+r)^t}$	311568	299621	528297	494499

Table 22: Alto vs. Leaf (600 units) – concessional financing

Costs \ Year	0	1	2	3	4	5	6	7	8	9
Hyundai Accent										
Upfront cost	760000									
Energy cost	95160	101821	108949	116575	124735	133467	142809	152806	163502	174948
Maintenance	38000	41800	45980	50578	55636	61199	67319	74051	81456	89602
Registration	2500	2500	2500	2500	2500	2500	2500	2500	2500	2500
Insurance	1100	1100	1100	1100	1100	1100	1100	1100	1100	1100
Total Accent	***896759.88***	***147221.07***	***158528.55***	***170752.94***	***183970.99***	***198266.03***	***213728.64***	***230457.22***	***248558.77***	***268149.57***
Nissan Leaf (72 units)										
Upfront cost	1260000									
Energy cost										
Maintenance	12600	12852	13109	13371	13639	13911	14190	14473	14763	15058
Registration	2500	2500	2500	2500	2500	2500	2500	2500	2500	2500
Insurance	1100	1100	1100	1100	1100	1100	1100	1100	1100	1100
Battery reoplacement										252000.00
Total Leaf	***1276200***	***16452.00***	***16709.04***	***16971.22***	***17238.65***	***17511.42***	***17789.65***	***18073.44***	***18362.91***	***270658.17***

Upfront cost difference	500000									
		(r = 5%)								
$\frac{Costs_{Accent} - Costs_{Leaf}}{(1+r)^t}$										
Annual Costs savings	-379440	124542	128634	132842	137171	141626	146213	150937	155806	-1617
Cumulative cost savings	-379440	-254898	-126264	6579	143750	285376	431589	582526	738331	736714

		(r = 7%)								
$\frac{Costs_{Accent} - Costs_{Leaf}}{(1+r)^t}$										
Annual cost savings	-379440	122214	123871	125532	127199	128876	130562	132262	133976	-1365
Cumulative cost savings	-379440	-257226	-133355	-7824	119376	248251	378814	511076	645052	643687

	(r = 5%)	(r =7%)
NPV $\sum_{0}^{T} \frac{Costs_{Accent} - Costs_{Leaf}}{(1+r)^t}$	736714	643687

Table 23: Accent vs. Leaf (72 units) – Free electricity

Table 24: Accent vs. Leaf (200 units) – Free electricity

Costs \ Year	0	1	2	3	4	5	6	7	8	9
Hyundai Accent										
Upfront cost	760000									
Energy cost	95160	101821	108949	116575	124735	133467	142809	152806	163502	174948
Maintenance	38000	41800	45980	50578	55636	61199	67319	74051	81456	89602
Registration	2500	2500	2500	2500	2500	2500	2500	2500	2500	2500
Insurance	1100	1100	1100	1100	1100	1100	1100	1100	1100	1100
Total Accent	***896759.88***	***147221.07***	***158528.55***	***170752.94***	***183970.99***	***198266.03***	***213728.64***	***230457.22***	***248558.77***	***268149.57***
Nissan Leaf (200 units)										
Upfront cost	945000									
Energy cost	0	0	0	0	0	0	0	0	0	0
Maintenance	12852	13109.04	13371.2208	13638.64522	13911.41812	14189.64648	14473.43941	14762.9082	15058.16636	15359.32969
Registration	2500	2500	2500	2500	2500	2500	2500	2500	2500	2500
Insurance	1100	1100	1100	1100	1100	1100	1100	1100	1100	1100
Battery reoplacement										250000.00
Total Leaf I	***961452***	***16709.04***	***16971.22***	***17238.65***	***17511.42***	***17789.65***	***18073.44***	***18362.91***	***18658.17***	***268959.33***

Upfront cost difference	185000									
		(r = 5%)								
$\frac{Costs_{Accent} - Costs_{Leaf}}{(1+r)^t}$										
Annual Costs savings	-64692	124297	128397	132611	136947	141408	146001	150731	155606	-522
Cumulative cost savings	-64692	59605	188002	320613	457560	598968	744969	895700	1051306	1050784
		(r = 7%)								
$\frac{Costs_{Accent} - Costs_{Leaf}}{(1+r)^t}$										
Annual cost savings	-64692	121974	123642	125313	126991	128677	130373	132082	133804	-440
Cumulative cost savings	-64692	57282	180923	306237	433228	561905	692278	824360	958164	957724

	(r = 5%)	(r =7%)
NPV $\sum_{0}^{T} \frac{Costs_{Accent} - Costs_{Leaf}}{(1+r)^t}$	1050784	957724

Costs \ Year	0	1	2	3	4	5	6	7	8	9
Maruti Alto 800										
Upfront cost	270000									
Energy cost	80417	86046	92069	98514	105410	112789	120684	129132	138171	147843
Maintenance	13500	14850	16335	17969	19765	21742	23916	26308	28938	31832
Registration	2500	2500	2500	2500	2500	2500	2500	2500	2500	2500
Insurance	1100	1100	1100	1100	1100	1100	1100	1100	1100	1100
Total	***367516.8***	***104495.98***	***112004.19***	***120082.54***	***128775.37***	***138130.61***	***148200.01***	***159039.49***	***170709.48***	***183275.30***
Nissan Leaf										
Upfront cost	630000									
Energy cost										
Maintenance	6300	6426	6555	6686	6819	6956	7094.823241	7237	7381	7529
Registration	2500	2500	2500	2500	2500	2500	2500	2500	2500	2500
Insurance	1100	1100	1100	1100	1100	1100	1100	1100	1100	1100
Battery Replacement										252000
Total	***639900***	***10026.00***	***10154.52***	***10285.61***	***10419.32***	***10555.71***	***10694.82***	***10836.72***	***10981.45***	***263129.08***

	0	1	2	3	4	5	6	7	8	9
Upfront cost difference	360000									
(r =5%) $\frac{Costs_{Alto} - Costs_{Leaf}}{(1+r)^t}$										
Annual Costs savings	-272383	89971	92381	94847	97372	99958	102608	105325	108110	-51474
Cumulative cost savings	-272383	-182412	-90031	4816	102187	202146	304754	410079	518189	466715
(r =7%) $\frac{Costs_{Alto} - Costs_{Leaf}}{(1+r)^t}$										
Annual Costs savings	-272383	88290	88959	89627	90293	90959	91626	92293	92963	-43435
Cumulative cost savings	-272383	-184094	-95134	-5507	84786	175745	267371	359664	452627	409192

	5 years		12 years	
	(r = 5%)	(r =7%)	(r = 5%)	(r =7%)
NPV $\sum_{0}^{T} \frac{Costs_{Alto} - Costs_{Leaf}}{(1+r)^t}$	102187	84786	466715	409192

Table 25: Alto vs. Leaf (600 units) – Free electricity

Costs \ Year	0	1	2	3	4	5	6	7	8	9
4728 Maruti Alto 800 + 272 Hyundai Accent										
Units of vehicles										
Alto	728	1000	1000	1000	1000					
Accent	272									
Alto	196,560,000.00	270,000,000.00	270,000,000.00	270,000,000.00	270,000,000.00					
Accent	206,720,000.00									
Annual fuel consumption (litres)	1,241,572.32	2,640,982.32	4,040,392.32	5,439,802.32	6,839,212.32	6,839,212.32	6,839,212.32	6,839,212.32	6,839,212.32	6,839,212.32
Energy cost	84,426,917.76	192,157,873.60	314,557,471.37	453,151,439.24	609,607,231.00	652,279,737.17	697,939,318.77	746,795,071.09	799,070,726.06	855,005,676.89
Emissions volume	2,915,152,762.97	6,200,900,892.43	9,486,649,021.89	12,772,397,151.34	16,058,145,280.80	16,058,145,280.80	16,058,145,280.80	16,058,145,280.80	16,058,145,280.80	16,058,145,280.80
Emission Cost	4,591,365.60	9,766,418.91	14,941,472.21	20,116,525.51	25,291,578.82	25,291,578.82	25,291,578.82	25,291,578.82	25,291,578.82	25,291,578.82
Maintenance	20,164,000.00	35,680,400.00	52,748,440.00	71,523,284.00	92,175,612.40	101,393,173.64	111,532,491.00	122,685,740.10	134,954,314.11	148,449,745.53
Total	***512,462,283.36***	***507,604,692.51***	***652,247,383.58***	***814,791,248.75***	***997,074,422.22***	***778,964,489.63***	***834,763,388.59***	***894,772,390.01***	***959,316,618.99***	***1,028,747,001.23***
872 Nissan Leaf + 4728 E2o										
Units of vehicles										
E2O	128	1000	1000	1000	1000					
Leaf	872									
Vehicle purchase (EV)										
E2O	75,520,000.00	590,000,000.00	590,000,000.00	590,000,000.00	590,000,000.00					
Leaf	657,720,000.00									
Annual electricity consumption (kWh)	4,041,653.76	7,540,853.76	11,040,053.76	14,539,253.76	18,038,453.76	18,038,453.76	18,038,453.76	18,038,453.76	18,038,453.76	18,038,453.76
Energy cost (Subsidy from BPC)	6,758,208.15	14,133,957.30	23,442,455.32	35,080,307.22	49,517,285.53	56,449,705.51	64,352,664.28	73,362,037.28	83,632,722.50	95,341,303.65
Export forgone of equivalent electricity volume (INR 2/ kWh)	9,093,720.96	16,966,920.96	24,840,120.96	32,713,320.96	40,586,520.96	45,096,134.40	45,096,134.40	45,096,134.40	45,096,134.40	45,096,134.40
Maintenance										
126000	907200	925344	943850.88	962727.8976	981982.4556	1001622.105	1021654.547	1042087.638	1062929.39	1084187.978
945000	2570400	2621808	2674244	2727729	2782284	2837929	2894688	2952582	3011633	3071866
630000	2570400	2621808	2674244	2727729	2782284	2837929	2894688	2952582	3011633	3071866
E2O	755200	6670304	12703710	18857784	25134940	25637639	26150392	26673399	27206867	27751005
Installation of charging stations	59,307,000.00									
Total	***808,443,920.96***	***619,806,184.96***	***633,836,170.24***	***650,356,277.49***	***671,198,775.20***	***88,764,824.97***	***97,314,086.13***	***106,982,687.57***	***117,925,785.79***	***130,320,228.21***

Year	0	1	2	3	4	5	6	7	8	9
(r =5%) $\frac{Benefits - Costs}{(1+r)^t}$										
Annual Costs savings	-295981638	-106858564	16699513	142045111	268098701	540789497	550296024	559867434	569486435	579133908
Cumulative cost savings	-295981638	-402840202	-386140689	-244095578	24003123	564792621	1115088644	1674956078	2244442513	2823576421
(r =7%) $\frac{Costs_{ICEV} - Costs_{EV}}{(1+r)^t}$										
Annual Costs savings	-295981638	-104861208	16081067	134227918	248608971	492102822	491393608	490595834	489697125	488684637
Cumulative cost savings	-295981638	-400842845	-384761779	-250533861	-1924890	490177932	981571540	1472167374	1961864499	2450549137

	8 years		10 years	
	(r = 5%)	(r =7%)	(r = 5%)	(r =7%)
NPV $\sum_{0}^{T} \frac{Costs_{ICEV} - Costs_{EV}}{(1+r)^t}$	1,674,956,078.03	1,472,167,374.02	2,823,576,421.25	2,450,549,136.52

Table 26: Society-level analysis with free electricity

Table 27: Society level analysis with concessional financing

Costs / Year	0	1	2	3	4	5	6	7	8	9	10	11
4728 Maruti Alto 800 + 272 Hyundai Accent												
Units of vehicles												
Alto	728	1000	1000	1000	1000							
Accent	272											
Vehicle purchase (ICEV)	45,734,982.01	101,999,396.32	158,263,810.62	214,528,224.93	270,792,639.23	270,792,639.23	270,792,639.23	270,792,639.23	263,590,794.20	207,326,379.90	83,110,720.57	26,846,306.26
Vehicle purchase (ICEV) discounted	45,734,982.01	97,142,282.21	143,549,941.61	185,317,546.64	222,781,774.45	212,173,118.52	202,069,636.69	192,447,273.04	178,408,624.98	133,644,433.05	51,022,772.87	15,696,479.26
Alto	7,638,645.03	63,903,059.34	120,167,473.64	176,431,887.95	232,696,302.25	232,696,302.25	232,696,302.25	232,696,302.25	225,494,457.22	169,230,042.91	83,110,720.57	26,846,306.26
Accent	38,096,336.98	38,096,336.98	38,096,336.98	38,096,336.98	38,096,336.98	38,096,336.98	38,096,336.98	38,096,336.98	38,096,336.98	38,096,336.98		
Annual fuel consumption (litres)	1,241,572.32	2,640,982.32	4,040,392.32	5,439,802.32	6,839,212.32	6,839,212.32	6,839,212.32	6,839,212.32	6,839,212.32	6,839,212.32	6,839,212.32	6,839,212.32
Energy cost- Fuel	84,426,917.76	192,157,873.60	314,557,471.37	453,151,439.24	609,607,231.00	652,279,737.17	697,939,318.77	746,795,071.09	799,070,726.06	855,005,676.89	914,856,074.27	978,895,999.47
Emissions volume	2,915,152,762.97	6,200,900,892.43	9,486,649,021.89	12,772,397,151.34	16,058,145,280.80	16,058,145,280.80	16,058,145,280.80	16,058,145,280.80	16,058,145,280.80	16,058,145,280.80	16,058,145,280.80	16,058,145,280.80
Emission Cost	4,591,365.60	9,766,418.91	14,941,472.21	20,116,525.51	25,291,578.82	25,291,578.82	25,291,578.82	25,291,578.82	25,291,578.82	25,291,578.82	25,291,578.82	25,291,578.82
Maintenance	20,164,000.00	35,680,400.00	52,748,440.00	71,523,284.00	92,175,612.40	101,393,173.64	111,532,491.00	122,685,740.10	134,954,314.11	148,449,745.53	163,294,720.08	179,624,192.09
Total	***154,917,265.37***	***339,604,088.83***	***540,511,194.20***	***759,319,473.68***	***997,867,061.45***	***1,049,757,128.86***	***1,105,556,027.82***	***1,165,565,029.24***	***1,222,907,413.19***	***1,236,073,381.13***	***1,186,553,093.73***	***1,210,658,076.63***
872 Nissan Leaf + 4728 E2o												
Units of vehicles												
E2O	128	1000	1000	1000	1000							
Leaf	872											
Vehicle purchase (EV)	87,863,155.29	171,912,424.70	255,961,694.10	340,010,963.51	424,060,232.92	424,060,232.92	424,060,232.92	424,060,232.92	413,301,926.44	329,252,657.03	168,098,538.82	84,049,269.41
Vehicle purchase (EV) discounted	87,863,155.29	163,726,118.76	232,164,801.91	293,714,254.20	348,875,403.08	332,262,288.65	316,440,274.91	301,371,690.39	279,739,012.21	212,239,198.41	103,197,920.88	49,141,867.09
E2O	10,758,306.48	94,807,575.89	178,856,845.30	262,906,114.71	346,955,384.12	346,955,384.12	346,955,384.12	346,955,384.12	336,197,077.63	252,147,808.22	168,098,538.82	84,049,269.41
Leaf	77,104,848.80	77,104,848.80	77,104,848.80	77,104,848.80	77,104,848.80	77,104,848.80	77,104,848.80	77,104,848.80	77,104,848.80	77,104,848.80		
Annual electricity consumption (kWh)	4,041,653.76	7,540,853.76	11,040,053.76	14,539,253.76	18,038,453.76	18,038,453.76	18,038,453.76	18,038,453.76	18,038,453.76	18,038,453.76	18,038,453.76	18,038,453.76
Energy cost- Electricity	6,758,208.15	14,133,957.30	23,442,455.32	35,080,307.22	49,517,285.53	56,449,705.51	64,352,664.28	73,362,037.28	83,632,722.50	95,341,303.65	108,689,086.16	123,905,558.22
Export forgone of equivalent electricity volume (INR 2/ kWh)	9,093,720.96	16,966,920.96	24,840,120.96	32,713,320.96	40,586,520.96	45,096,134.40	45,096,134.40	45,096,134.40	45,096,134.40	45,096,134.40	45,096,134.40	45,096,134.40
Maintenance												
126000	907200	925344	943850.88	962727.8976	981982.4556	1001622.105	1021654.547	1042087.638	1062929.39	1084187.978	1105871.738	1127989.173
945000	2570400	2621808	2674244	2727729	2782284	2837929	2894688	2952582	3011633	3071866	3133303	3195969
630000	2570400	2621808	2674244	2727729	2782284	2837929	2894688	2952582	3011633	3071866	3133303	3195969
E2O	755200	1718380	3541316	6241203	9835581	13501847	17241437	21055820	24838907	27857163	30095292	31537691
Installation of charging stations	59,307,000.00											
Battery replacement					32,000,000.00	250,000,000.00	250,000,000.00	250,000,000.00	250,000,000.00			
Total	***163,067,076.25***	***196,766,685.42***	***290,635,470.07***	***387,750,659.99***	***521,959,649.34***	***750,689,265.77***	***762,465,364.93***	***775,425,341.12***	***778,859,752.05***	***459,679,043.94***	***314,255,395.29***	***247,012,446.05***

Year	0	1	2	3	4	5	6	7	8	9	10	11
(r =5%)												
Annual Costs savings	(8,149,810.88)	136,035,622.30	226,644,647.73	320,975,111.71	391,530,205.72	234,327,496.28	256,019,535.10	277,264,992.49	300,548,935.68	500,470,712.25	535,515,118.11	563,423,642.22
Cumulative cost savings	(8,149,810.88)	127,885,811.42	354,530,459.15	675,505,570.86	1,067,035,776.58	1,301,363,272.86	1,557,382,807.95	1,834,647,800.44	2,135,196,736.12	2,635,667,448.37	3,171,182,566.48	3,734,606,208.70
(r =7%)												
Annual Costs savings	(8,149,810.88)	133,492,900.38	218,251,134.71	303,310,833.73	363,067,486.08	213,231,253.11	228,615,795.29	242,959,390.07	258,439,781.65	422,307,077.55	443,431,917.53	457,821,097.36
Cumulative cost savings	(8,149,810.88)	125,343,089.51	343,594,224.22	646,905,057.95	1,009,972,544.03	1,223,203,797.14	1,451,819,592.42	1,694,778,982.50	1,953,218,764.14	2,375,525,841.69	2,818,957,759.22	3,276,778,856.59

	12 years	
	(r = 5%)	(r =7%)
NPV	3,734,606,208.70	3,276,778,856.59