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Financial Analysis of Electric Vehicles with Grid Integrated Solar PV System: A Case Study of Sajha Yatayat

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Abstract
Transport sector is a major source of GHG emissions and local pollutants in Kathmandu Valley.This research analyze financial viability of introducing rooftop grid integrated solar PV (GISPV) system for operating the electric vehicles (EVs) in the Kathmandu Valley's route by the Sahja Yatayat. It studied the effectiveness of implementing net metering approach in line with recent government policies and analyzed the cost and quantity of electricity needed for charging the EV, possibility of feeding excess generation to the utility grid and effects of different factors affecting the cost of electricity. While considering inflation in revenue collection, the project IRR is 3.8 percent higher in GISPV System and all other financial parameters NVP, Payback Period, Discounted Payback Period, and Benefit Cost(B/C) ratio are better in comparison to without GISPV System. When inflation is not considered in revenue, the Project NPV(NPR)would be (339,695,573.93), B/C Ratio be 0.68 other parameters like IRR, Simple Payback Period (Years), Discounted Payback Period (Years) are not favorable in GISPV System but still better in comparison without GISPV System. To achieve breakeven, inflation considered in revenue is 0.91 percent higher in without GISPV system in comparison to with GISPV system. By replacing the diesel-based bus with electric buses in the selected both route R1 and R2, the total GHG emission saving would be 1,261.46 tons of CO2 equivalent and revenue from carbon trading be NPR 808,030.52 per annum. Hence this research help in effective decision-making for solar PV system integration in EV in major cities' bus parks all over Nepal where there are enough rooftop area to run the EV in a more sustainable way in light of the economic rate of return.

Keywords
Electric Bus, Financial Analysis, Greenhouse Gas (GHG), Grid Integrated Solar PV(GISPV) System

1. Introduction

The world is shifting towards the renewable energy rather than fossil fuels resulting the significant progress in favor of electric mass transport. Out of all given potential solutions that do not utilize fossil fuels, electric vehicles (EVs) are among the most preferred options nowadays. The main advantage of EVs are that these vehicles have no emissions and it contains lesser moving parts which results low maintenance and operating costs. Since 1990, vehicles number on Nepal's roadway had increased by 14 percent per annum, driven by urbanization and economic growth. The higher share of this transport is private and majority of passenger vehicles in 2015. As a result, road transport sector has been primary means of transport in Nepal accounting about 80 percent among all trips[1]. This led to a corresponding surge in GHG emissions from transport sector. Annual GHG emissions is 2.41 million tons in 1995. Particulate matter (PM2.5), which includes dirt, dust, soot, smoke etc. released from the operation of ICE vehicles and burning of petroleum based fuels and has increased in Valley to an annual average level of 30.40 µg/m3[2]. Use of efficient vehicles that consume less and promote clean energy is one of the way of mitigating environmental pollution and GHG emission and prevent the health issues that are concern to the pollution. Present day vehicles in Kathmandu utilize the petroleum based fuel (diesel, petrol and CNG) for passengers. Electricity based transport system with private sector participation is needed promotion throughout the country[3]. So as to enhance the quality of life of urban cities that are undergoing the multiple challenges of urbanization, it is imperative to look forward into the development of passenger mass

transit using green energy and explore the key possibilities. So there need an effective national policy to solve issues related to mitigation of air pollutants which are detrimental to public health & environment, from the inefficient use of petroleum based fuel[4].

In an attempt to achieve the sustainable development goals and national 2nd Nationally Determined Contribution target through use of renewables in the transport sector, this research paper presents the model for development of electric bus transport including solar rooftops with net metering concept and financial analysis of electric busses with GISPV system with electric buses and the electricity required is generated from GISPV system.

2. Electric Vehicles with Grid Integrated Solar PV System: A Literature Review

With the promotion of electric mass transport, there would be cutting down in GHG and ambient pollutant emissions, an enhancement in energy security and a reduction in energy technologies cost along with domestic employment generation[5]. The main benefit with the electric vehicles is that they don't have any tailpipe emissions. Besides this the drive train efficiency of electric is higher in comparison to ICE[6]. EVs perform efficient when operation in urban routes than on freeway routes[7]. This fact deemed as the electric bus may be financially viable and technologically efficient technology in urban road. However, it has not been easy to run electric vehicles because of many barriers against with the EV and the management and development of its infrastructure. It has been observed that the emergence and worldwide adoption of EVs have faced various challenges mostly in the development of supporting infrastructure, new technologies, and its financial investments[8]. Batteries having high storage capacity are required to run electric bus that requires long recharge time and are too expensive. Adoption of low carbon based mass transport is one of the best options for achieving the low carbon development (LCD) way in the current scenario. Nepal would be benefited from adoption of the electric mass transport in long run with increase in GDP and limiting the carbon footprint parallelly[9].The higher price of electric vehicles in comparison to fossil fuel based vehicles, lack of charging infrastructure, poor long-term planning and goal setting are the major top barriers against EV uptake in Nepal[10].

The 2nd Nationally Determined Contribution set target for transport sector include sales of 25 % of all private passenger vehicle including two wheelers and 20 % of all four wheeler public passenger based vehicle will be electric in 2025 vehicles and sales of 90 % of all private passenger based vehicle including two wheelers and 60 % of all four-wheeler public passenger vehicle will be electric in 2030 vehicles. Further it mention the development of 200 km electric rail network to support the public mass transfer and mass transportation of commodities[11] (SNDC, 2020).

GISPV System is directly connected to the electricity grid. GISPV System installed at rooftop can use electricity to operate its demand and, if the generation is not sufficient, required additional amount of electricity to fulfill its demand has drawn from the grid. In case if the generation is greater than inhouse requirement, the surplus electricity goes into the grid for the utility. GISPV system has two components, one is solar PV that produce electricity when sun rays strikes to them and another is an inverter that converts the direct current electricity from the solar PV to alternating current which is synchronized with the grid [12].

3. Conceptual Model

The purpose of this research is to explore the potential solar energy that can be harnessed through the utilization available rooftop space. This harnessed energy is further utilized for charging the high storage batteries of Sajha Yatayat's electric bus that can be run in selected route in Kathmandu Valley. It is envisaged that in the potential available rooftop space, necessary size of GISPV system can be install so that charging of batteries of electric bus can be done through the national grid at night time and equivalent amount of energy consume during charging can be generated by installed rooftop GISPV system throughout the daytime will replenish the grid. The provision of net metering can be implemented according to the "Grid Connected Alternative Electricity Development Guidelines, 2021". From this a balance of energy between supply to and consume from the grid can be achieved through the grid throughout the year.

4. Grid Connected Alternative Electricity Development Guidelines, 2021

The policy provision of rooftop solar PV net-metering in Nepal is came to the fore On April 26, 2021, Ministry of Energy, Water Resources and Irrigation (MoEWRI) launched "Grid Connected Alternative Electricity Development Guidelines 2021" and Grid Connected Alternative Electricity Development Guidelines 2018 have been annulled. The major provision in this guideline is only 10 percent of national grid connected electricity capacity that can be contracted for buyout by Nepal Electricity Authority, feed-in tariff for excess amount of electricity rate is NPR 7.30 per unit and classification of project on the basis of its capacity which is zero to one megawatt & greater than one megawatt[13].

5. Methodology and Assumptions

5.1 Methodology

The route taken as a reference in this research are Lagankhel-Budhanilkantha(R1) & Swayambhu - Suryabinayak(R2) as this route are most feasible routes among the routes are in Kathmandu Valley according to the study conducted by Global Green Growth Institute(GGGI,2018). The R1 is approximately 160 km and R2 is 198 km. Out of 40 electric bus 10 electric bus will run daily in each route. Total annual energy consumption by 10 electric buses of R1 be 393127 kWh and R2 be 484487.5 kWh. By considering battery efficiency 90 % and charger efficiency 94 %, total annual energy required to supply from the grid is 1037.36 MWh (sajha testing report citation). According to the net-metering provision, 1037.36 MWh amount of energy have to supply to the grid. For this required GISPV system size is 704 KWp from system design simulation output in PVsyst V7.2.11 and the necessary rooftop area is 3515 m2. The total available rooftop space would be 6317 m2 which is enough area to put 704 KWp solar PV panels. The features of 704 KWp GISPV system is given in table 1.

Table 1: Features of Grid Integrated Solar PV System

Potential System Size	704kWp
Energy production	1040 MWh/year
Specific Production	1533kWh/kWp/year
Performance Ratio	0,76
Total Area	3515 m2
PV module	
Manufacturer	Longi
Model	LR4-66 HPH 400 M G2
Unit Nom. Power	400 Wp
Module Area	3515m2
No. of PV modules	80 Strings x 22 in series
Operating Condition	
Pmpp	644kWp
Vmpp	740V
Impp	870A
Inverter	
Manufacturer	Sungrow
Model	SG110-CX
Unit Nom. Power	110kWac
Operationg Voltage	200-1000V
Pnom ratio	1,17
Total Power	111kWac
Number of Inverter	6

5.2 Assumptions

With an objective to cut off the imported petroleum products consumption and petroleum fuel dependency, the grid integrated rooftop solar PV system for electric passenger mobility of 10 electric bus having motor capacity 103 Kw in each route R1 and R2 is taken for financial viability. The major expenses taken in this analysis are cost of solar panel, rooftop panel mounting structure, cost of electric bus, charger, battery and its associate infrastructure, O & M of solar PV system, charger and electric bus. The benefits accrued are counted in terms of CO2 GHG emission saving credit instead of diesel bus, passenger fare, advertisement revenue and salvage value of bus. The financial analysis of deploying ten electric buses as partial fleet in each route R1 and R2 is carried out in terms of NPV, IRR, B/C ratio, payback period,and discounted payback period. The assumptions under this analysis are listed as follows:

- The case study time frame is assumed to be 30 years (2023-2052) which is also the normal service life of a rooftop solar PV [14].
- The additional route distance is assumed to be 13 % of total distance for load demand safety according to questionnaire survey.
- Total operation(working) days considered is 350 and working hours per day is assumed to be 17 hours per day.

- The tire cost of electric vehicles is NPR 46200 and assume to be constant throughout the project life and replacement period of tire is every 3 years whereas life of the batteries is 8 years and its cost in 2031, 2039 and 2047 be NPR 2632172.155, NPR 1989673.44 and NPR 1575158.14 respectively as the battery cost is in decline way .
- The on an average revenue for advertisement considered is NPR 100,000 per bus per year according to questionnaire survey .
- The electric bus mileage is assumed to be 0.7 kWh/Km according to questionnaire survey.
- The diesel vehicles mileage is assumed to be 2.8 km/liter[15].
- Nepal Rastra Bank US Dollar Exchange rate is NPR 128.11 per USD Dollar and Indian Currency exchange rate is NPR 1.6 per INR according to 16th July, 2022.
- The annual maintenance of rooftop solar PV is assumed to be NPR 308,000 according to questionnaire survey.
- The depreciation rate of electric bus is assumed at 20 % per year at reducing balance method according to income tax act 2002 and GDP growth rate is assumed to 7.37 every year after 2027 AD which is average growth rate from 2011 to 2021.
- Assumed Inflation rate is 7.83 % which is averages of inflation rate from 1965 to 2021 and is assume to be constant through out the case study period.
- Assumed contingency is 5 % of the capital cost.
- Assumed discount rate is 12 %.
- Energy Degradation Rate of Solar Power Plant is 0.5 % per year.
- Custom Duty of Charger is 10 % according to finance bill 2022 [16].
- Excise Duty on EV is 30 % for electric vehicles having motor capacity 100-200KW according to finance bill 2022 [16].
- Road Development Tax is 2.5 % according to finance bill 2022 [16].
- Value Added Tax Rate is 13 %.
- Carbon Trading at a rate of $ 5 per ton of equivalent GHG emission saving.

Currently Sajha Yatayat run the diesel bus Ashok Leyland - Viking in both routes R1 and R2 with mileage is 2.8 km/liter and are considered for the study[15]. Recently in April, 2022 Sajha Yatayat procured 40 electric busses are make CHTC-China, 20 chargers are make GRASEN-China, training service and five years of annual maintenance contract (AMC), including spare parts and costing are as per contract amount.

For electric bus, the total capital cost be NPR 371,192,802.83, annual constant O & M cost be NPR 30,014,620 and variable annual O & M cost be is mention in assumption. Likewise for charger, total capital cost be NPR 32,074,104.63 and annual O & M cost be NPR 67,582.00 and for GISPV system, total capital cost be NPR 47,042,418.44 and annual O & M cost be NPR 364,000.00. The total annual revenue from electric bus be NPR 88,908,030.52 and salvage value of buses be NPR 7,963,826.094 after 15 years of operation is also consider.

6. Result and Discussion

The total investment for this case study project be NPR 450,309,325.91. Major cost be associated with Electric Vehicles (82 %) followed by GISPV System (11%) and Charging Infrastructure (7 %) are presented in figure 1.

6.1 Sensitivity Analysis

In order to analyze the effects of vary of input parameters in IRR, NPV, benefit cost ratio(B/C)Payback Period, and Discounted Payback

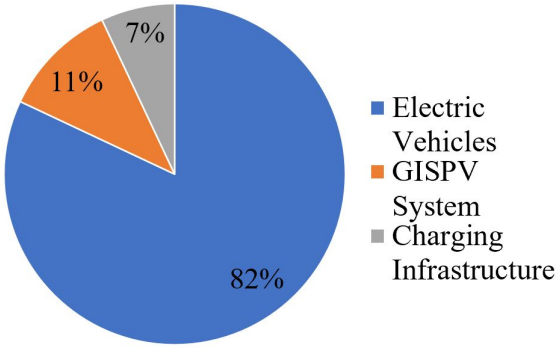

Figure 1: Cost breakdown of Case Study System

Period, sensitivity analysis was done. The major input parameters are discount rate, inflation, capital subsidy, VAT, excise duty of EV, custom duty of charger and road development tax rate. The sensitivity graph of each input parameters are presented from figure 2 to figure 8.

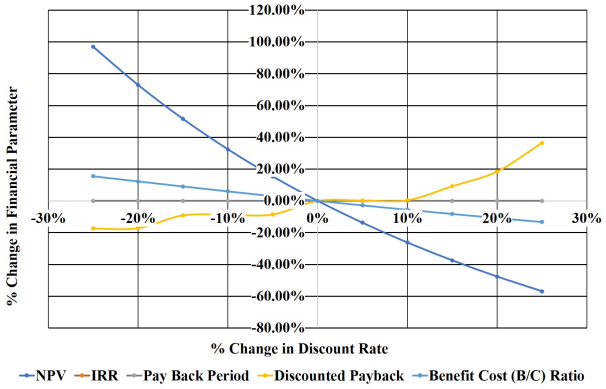

Figure 2: Sensitivity Analysis on Multiple Discount Rates

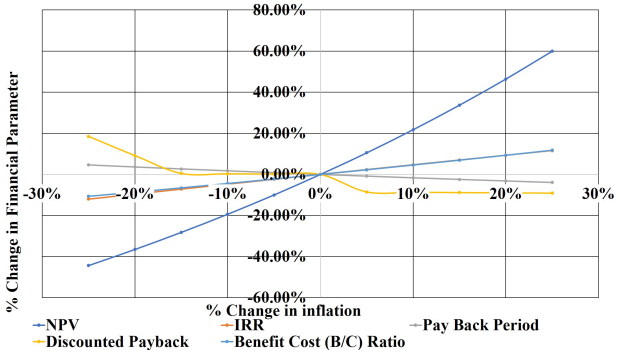

Figure 3: Sensitivity Analysis on Multiple Inflation Rates

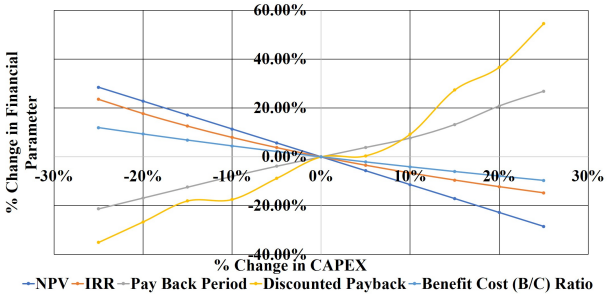

Figure 4: Sensitivity Analysis on Multiple CAPEX Condition

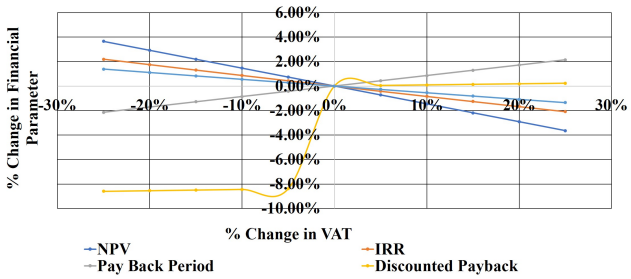

Figure 5: Sensitivity Analysis on Multiple VAT Rates

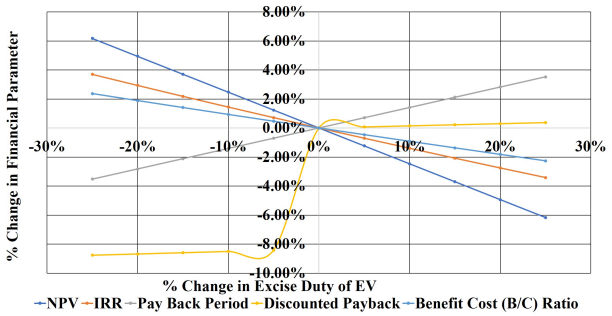

Figure 6: Sensitivity Analysis on Multiple Excise Duty Rates on EV

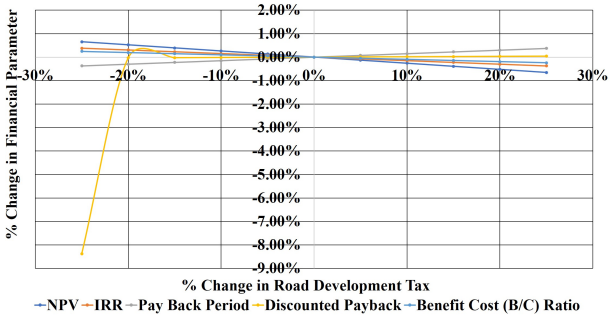

Figure 7: Sensitivity Analysis on Multiple Road Development Tax Rates

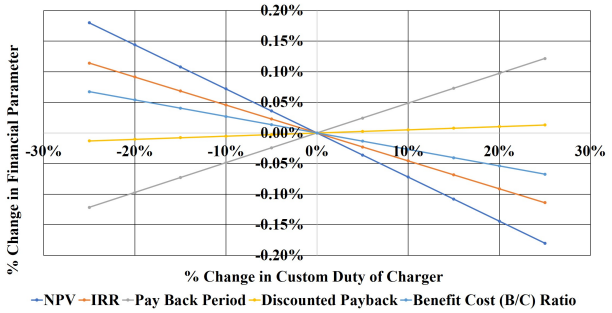

Figure 8: Sensitivity Analysis on Multiple Custom Duty of Chargers

On performing sensitivity analysis, it was found that discount rate as shown in figure 2 and inflation rate as

shown in figure 3 is highly sensitive input parameter. This analysis might be useful for the investors and policy-makers as they could perform study & evaluate in order to make EVs and its infrastructure more economical to implement.

6.2 Financial Analysis at Different Scenario

6.2.1 Scenario 1: Inflation Consideration in Revenue

To perform the financial viability analysis of EV only or EV with GISPV system, three different scenarios were created.

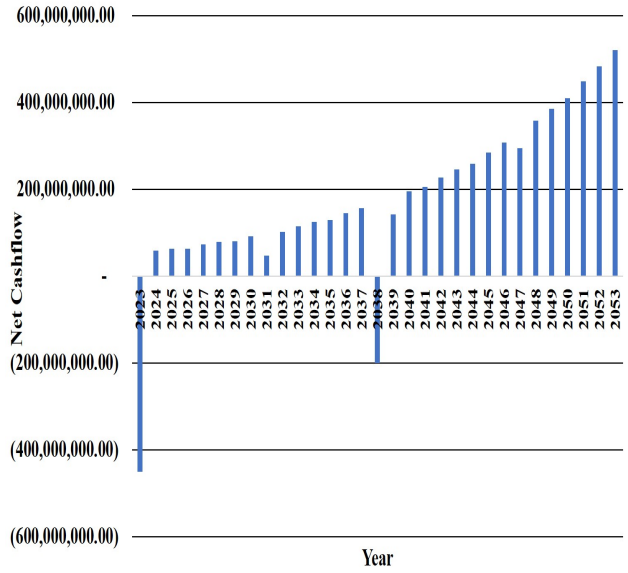

Figure 9: Net Cashflow EV with GISPV System

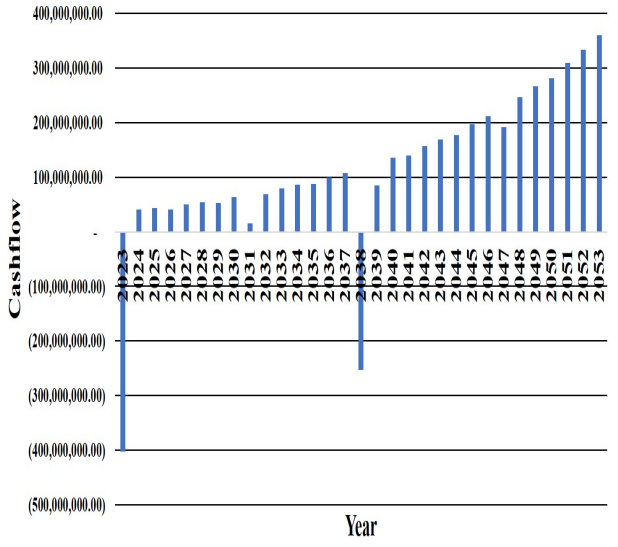

Figure 10: Net Cashflow EV only

The net cash flow for 30 years' time frame of EV with GISPV System and EV only is shown in Figure 9 and Figure 10 simultaneously. There is substantial negative cash flow in 2023 indicate that capital expenditures are incurred and in 2038 indicate that new buses have to be procured.

Table 2: Financial Analysis Parameters when inflation is considered in revenue

Without Grid Integrated Solar PV	
Project IRR	15,05%
Project NPV(NPR)	146996909,73
B/C Ratio	1,11
Simple Payback Period (Years)	8,57
Discounted Payback Period (Years)	19
With Grid Integrated Solar PV	
Project IRR	18,85%
Project NPV(NPR)	393467236,26
B/C Ratio	1,37
Simple Payback Period (Years)	6,37
Discounted Payback Period (Years)	11

The net cashflow is smoothly increasing throughout the timeframe except 2031, 2039 and 2047 due to substantial expenses in battery replacement. From the Discounted Cash Flow (DCF) financial model in scenario 1, it was found that all financial parameters like IRR, NPV, B/C Ratio, Simple Pay Back Period and Discounted Payback Period are available and better with GISPV system in comparisons to without GISPV system as the net cashflow through the lifetime is negative.

6.2.2 Scenario 2: Inflation is not Consideration in Revenue

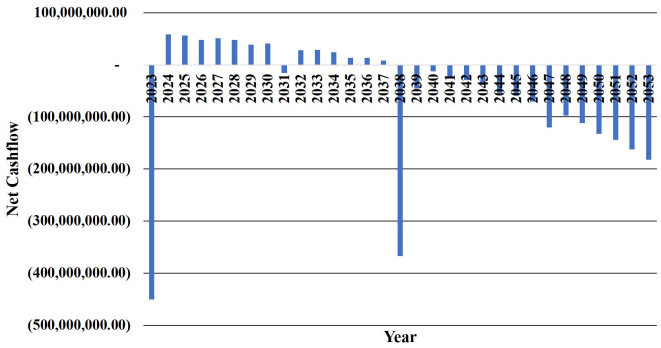

Figure 11: Net Cashflow EV with GISPV System

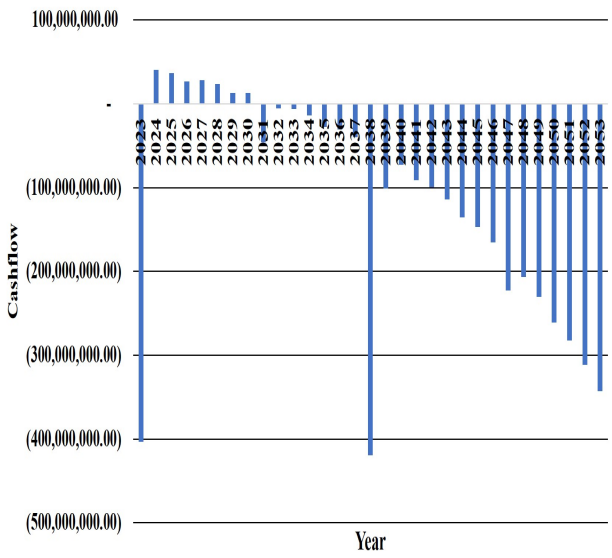

Figure 12: Net Cashflow EV only

The net cash flow for 30 years' time frame of EV with GISPV System and EV only is shown in Figure 11 and Figure 12 simultaneously. There is substantial negative cash flow in 2023 indicate that capital expenditures are incurred and in 2038 indicate that new buses have to be procured.

Table 3: Financial Analysis Parameter (Inflation is not consider in revenue

Without Grid Integrated Solar PV	
Project IRR	Not favorable
Project NPV	-586165900
B/C Ratio	0,55
Simple Payback Period (Years)	Not favorable
Discounted Payback Period (Years)	Not favorable
With Grid Integrated Solar PV	
Project IRR	Not favorable
Project NPV	-339695573
B/C Ratio	0,68
Simple Payback Period (Years)	Not favorable
Discounted Payback Period (Years)	Not favorable

When there is not inflation consideration in the annual revenue generation, the IRR, Simple Payback Period (Years), and Discounted Payback Period (Years) are not available in both with and without GISPV system as the net cashflow through the lifetime is negative. But all other financial parameter is available and still better with GISPV system in comparisons to without GISPV.

6.2.3 Scenario 3: Inflation in Revenue to achieve breakeven

Table 4: Inflation in Revenue to achieve breakeven

Without Grid Integrated Solar PV	
For breakeven, inflation in revenue be	5,58%
Project IRR	12,00%
Project NPV	0
B/C Ratio	1
Simple Payback Period (Years)	9,41
Discounted Payback Period (Years)	29
With Grid Integrated Solar PV	
For breakeven, inflation in revenue be	4,67%
Project IRR	12,00%
Project NPV	0
B/C Ratio	1
Simple Payback Period (Years)	7,82
Discounted Payback Period (Years)	29

From the Goal Seek analysis, there should be 5.58 % annual inflation in revenue generation in case of without GISPV system whereas 4.67 % of annual inflation in revenue generation in case of with GISPV system to achieve breakeven.

7. Conclusion

Transport sector has been considered as one of the major sources of GHG emission and local pollutants emission. Use of alternative fuel-based vehicle especially public vehicles is one of the potential policy intervention measures for mitigating the GHG & local pollutants emission. The total investment required for this case studied project is estimated to be NPR 450,309,325.91. Among input parameters discount rate, inflation, capital subsidy, VAT, excise duty of EV & charger and road development tax rate on IRR, NPV, B/C ratio, Payback Period and Discounted Payback Period, sensitivity analysis showed that the discount rate and inflation rate are the highly sensitive parameter. When we consider the inflation in revenue, the project IRR would be 15.07 %, project NPV(NPR)would be 148968629.6, B/C ratio would be 1.11, simple payback period (Years)would be 8.57 and discounted payback period (Years)would be 19.01 in without GISPV system whereas the project IRR would be 18.87 %, project NPV(NPR)would be 395438956.2, B/C ratio would be 1.37, simple payback period (Years)would be 6.37 and discounted payback period (Years)would be 11.00

in with GISPV system. Again, when inflation is not considered in revenue, the project NPV(NPR) would be -584194180.6, B/C Ratio would be 0.55 and other parameters like IRR, Simple Payback Period (Years), Discounted Payback Period (Years)would be non favorable in without GISPV system whereas the Project NPV would be NPR -337723854, B/C Ratio would be 0.67 and other parameters like IRR, Simple Payback Period (Years), Discounted Payback Period (Years) would be non favorable in with GISPV system. To achieve breakeven, inflation considered in revenue should be 5.58 % in option without GISPV system and 4.67 % available in option with GISPV system. Hence solar PV system integration in EV can be a more sustainable way in light of economic rate of return in major cities bus park where there is enough rooftop area in the country.

Similar study done for financial viability of electric vehicles by Sheth et al. and found that NPV was NPR 11769600 and IRR was 12.73 % [17]. And in our case study the NPV is NPR 395438956.2 and IRR is 18.87 % which is desirable financial parameter for financial viability of project. Thus validating the outcome of this study.

8. Recommendation

Further studies on the potential introduction of the rooftop Solar PV system integration EV charging stations can be carried out out considering other cities in Nepal and other parts of the world. Alternate financial model such as Public Private Partnership in this conceptual model can be done to examine the financial parameter.

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