KATHMANDU, NEPAL
VEHICLE CONVERSION
POLICY ADVICE PAPER

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PROJECT PARTNERS

ABOUT

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TITLE

Kathmandu, Nepal: Vehicle Conversion Policy Advice Paper

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Purpose
This paper aims to provide practical guidance for developing Vehicle Conversion policy in Nepal.

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Executive Summary

The government of Nepal amended the Motor Vehicle and Transport Management Act 2049 B.S. in March 2022 to ease restrictions on vehicle modifications. For three years, owners or operators were allowed to undertake modifications which resulted in more energy-efficient and environmentally friendly vehicles. This amendment provides an opportunity for owners and operators to convert their existing internal combustion engine (ICE) vehicles to electric vehicles (EV). EV conversion typically involves the removal of the existing internal combustion engine and integration of electric powertrain.

EV conversion has a significant potential in facilitating widespread EV adoption. Notably, there is a growing interest in EV conversion globally, and projections reveal substantial market growth for the sector in the next decade. Several countries have developed policies to encourage EV conversion. These policies involve the provision of subsidies to consumers that convert their vehicles to electric (e.g., private cars, commercial vehicles, trucks, buses, three-wheelers. and motorcycles), national guidelines for retrofitted EVs, and national targets for EV conversion.

EV conversion has significant environmental and socio-economic advantages. It prolongs the lifecycle of ICE vehicles, thereby minimizing the need for scrappage and their carbon footprint. The optimum vehicle conversion age depends on the vehicle type and the average daily mileage of the vehicle. Further, EV conversion enhances the accessibility and affordability of EVs. Converted two-, three-, and four-wheelers generally exhibit lower total cost of ownership (TCO) compared to their ICEV counterparts. While the Total Cost of Ownership (TCO) of converted three and four-wheelers compared to new EVs are 6% and 21% lower, respectively.

Despite these advantages, the widespread adoption and commercial success of EV conversion are hindered by multiple barriers, including policy, regulatory, technical, institutional, social, economic, and knowledge-related hindrances. Much work remains to be done for EV promotion and development in Nepal, including improvements in planning, policymaking, governance, energy security, financing, and research.

The SOLUTIONSplus project is the first project in Nepal which aims to demonstrate the viability of EV conversion of heavy-duty petroleum vehicles, including buses and mini trucks. These pilot projects demonstrate the technical and economic viability and environmental impacts of the EV conversion and assist in developing policies to address barriers. The financial viability was assessed using key performance indicators to determine its profitability (e.g., IRR, NPV, and payback period) and cost-effectiveness.

Comparing the acquisition costs and annual profitability reveals that the diesel bus, with an acquisition cost of NPR 4,747,500 (USD 35,965), remains a more profitable option than the converted e-bus, which costs NPR 8,507,500 (USD 64,450). In addition, new diesel buses bring in higher annual revenues with NPR 4,236,696 (USD 32,000), whereas converted e-buses yield NPR 2,267,004 (USD 17,174).

However, environmental impacts, especially GHG and harmful pollutants, must also be considered in EV conversion. In the SOLUTIONSplus project, buses and pick-up or mini trucks were selected for e-conversion since they are the second and third highest polluting sources in the transport sector. Reducing the impacts from these key contributors plays a significant role in decarbonization/lowering emissions in the country. To assess the environmental impact of the pilot, the team calculated the GHG, PM2.5, and NOx emissions using mileage data. The result

indicates that e-bus conversion is expected to reduce 15.14 tons of CO_2 annually. Similarly, the conversion will result in an annual reduction of 52 kg PM2.5 and 201.30 kg NOx.

The policy paper also outlines key insights and lessons learned from the pilot project. The proper facilities, tools, and equipment, along with the team's previous experiences, and guidance from experts significantly influenced the success of the pilot demonstration. Despite facing challenges such as the time-consuming process of procuring the EV conversion kits and difficulty in obtaining permits for commercial operations, the key outcomes were successfully accomplished. These include the advancements in engineering practices, system design, conversion methods/ techniques, and skill development among project participants. To sustain this success and facilitate project replication, ongoing capacity building and training are essential for EV conversion technicians and engineers, ensuring they possess the requisite knowledge and skills.

This policy paper strongly recommends formulating a national guideline for vehicle conversion in Nepal to strengthen and enhance the cohesion of policies and strategies. SOLUTIONSplus' pilot vehicle conversion project in Nepal can serve as a springboard for developing the national guideline, as it provides scientific evidence and context-sensitive insights from vehicle conversion activities. On the other side, a concrete master plan for vehicle conversion is required. As vehicle conversion is in its early stages in Nepal, more research and development, and capacity enhancement programs are indispensable.

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List of Abbreviations

2W	Two-wheeler
3W	Three-wheeler
4W	Four-wheeler
AC	Alternating current
ASEAN	Association of Southeast Asian Nations
AWG	American wire gauge
CO2	Carbon dioxide
DC	Direct current
DoTM	Department of Transport Management
E3W	Electric three-wheeler
EHPS	Electro-hydraulic power steering
EPS	Electric power steering
EUR	Euro
EVs	Electric vehicles
GGGI	Global Green Growth Institute
GHG	Greenhouse gases
GmbH	Gesellschaft mit beschränkter Haftung (company with limited liability)
ICE	Internal combustion engine
IDR	Indonesian Rupiah
IGBT	Insulated-Grade Bipolar Transistor
IRR	Internal rate of return
kWh	Kilowatt-hour
MC	Motor controller
MoPIT	Ministry of Physical Infrastructure and Transport
MOSFET	Metal-Oxide-Semiconductor Field-Effect Transistor
NDCs	Nationally Determined Contributions
NPV	Net present value
OEM	Original equipment manufacturer
PWM	Pulse-width modulation
Rs	Rupees
SOC	State of charge
TCO	Total cost of ownership
VCU	Vehicle control unit
VD	Voltage decline
WD	Power dissipation
W2T	Well-to-tank
WTW	Well-to-wheel
ZAR	South African Rand

Introduction

1.1. About the SOLUTIONSplus Project in Kathmandu

Air pollution in Kathmandu Valley is increasing beyond health guidelines set by WHO for particulate matters and is a threat to the tourism industry which is a major economic activity in the valley (Dhakal, 2003). Increasing pollution is attributed to the use of old and poorly maintained vehicles, low quality and adulterated fuel, the prevalence of two-wheelers (2W) and two stroke engine vehicles, increasing congestion, and inadequate ill-serviced road infrastructure (Dhakal, 2003). The conversion of diesel vehicles to electric aimed to manage the rise of pollution.

The SOLUTIONSplus living lab project in Kathmandu aims to revolutionize urban mobility through the promotion of electric vehicles (EVs). The project's focus aligns with the city's commitment to sustainable development and environmental stewardship. By introducing and integrating EVs into the city's transportation ecosystem, the project seeks to reduce carbon emissions, alleviate traffic congestion due to improved public transport, and improve air quality. The initiative encompasses city-level demonstrations that will serve as testbeds for various innovative and integrated e-mobility solutions. These demonstrations not only showcase the viability of EVs in Kathmandu but also provide valuable insights into their impact on urban mobility and environmental sustainability. They include eight locally produced prototypes: a converted diesel bus and mini truck to electric, a remodeled electric three-wheeler (e3W) (Safa Tempo) for passenger and cargo use, a newly designed e3W for passenger and cargo use, an electric shuttle van, and an electric waste collection vehicle. In the converted vehicle prototypes, the existing chassis was retained, but key components such as the motor, battery set, and controller were replaced.

Figure 1. Images of converted e-bus and electric mini truck in Nepal under SOLUTIONSplus

The paper describes lessons from the SOLUTIONSplus EV conversion pilot demonstrations in Kathmandu by providing an overview of the vehicle conversion process (section 2), an overview of vehicle conversion policies and practices (section 3), lessons learned from the SOLUTIONSplus project (section 4), and last, conclusions and recommendations (section 5).

1.2. Objectives

The vehicle conversion in Nepal is carried out locally, albeit on a smaller scale, and has remained in the pilot phase. Currently, there are no existing technical and policy frameworks to support vehicle conversion in the country. With this, this paper aims to provide a generalized reference guide for the conversion of internal combustion engine (ICE) vehicles to EVs in Nepal, aiming to prompt action and discussions among policymakers on this topic.

Vehicle Conversion Overview

According to a Global Green Growth Institute (GGGI) technical report (2023), while the current market size is relatively limited, substantial growth is projected for the retrofitting sector in the next decade. It was estimated that the global value of the EV retrofitting sector was nearly USD 66 billion in 2023, and it is predicted to reach around USD 125 billion by 2032 (Primus Partners & EBTC, 2024). Vehicle conversion normally utilizes aging private and commercial ICE vehicles. The optimum vehicle conversion age is influenced by the vehicle type and average daily kilometer travelled. For example, the optimum vehicle conversion age ranges between 5 to 7 years for mopeds, 6.5 to 8 years for motorcycles, and 7.5 to 9 years for four-wheelers (4W) (Darekar et al., 2021).

1.3. Four steps of EV Conversion

The vehicle conversion process typically has four steps (GGGI, 2023), although other research at different granularities may describe the same general process in different numbers of steps. First, an initial inspection is conducted to determine if a vehicle is eligible for conversion. Second, thermal elements such as ICE, fuel tanks, and exhaust systems are removed. Third, technology is integrated by installing EV components such as electric motors, batteries, wiring and power controllers. The last step entails conducting technical tests and verifying the EV's performance. It is worth noting that specifics for each step may differ depending on the chosen vehicle to convert. Table 1 illustrates the main parts replaced in vehicle conversion, while Figure 2 illustrates the parts replaced for bus conversion.

Table 1. Vehicle conversion parts replacement

System to be disassembled	Power systems to be installed
Engine	Electric motor
Fuel Tank	Battery
Exhaust system and fuel injection system	Wirings and Controller

Professionals and enthusiasts alike undertaking EV conversion projects utilize a conversion kit, which typically consists of a motor, controller, shunt, transmission adapter kit, charger, chill plate, DC-DC (direct current) converter, throttle controller, and controller mount (Jang et al., 2023). However, these components vary per vehicle type. The required motor specifications and the number of batteries depend on the vehicle's size and usage. Smaller EVs, such as 2W and 3W, require fewer components than 4W (Jang et al., 2023).

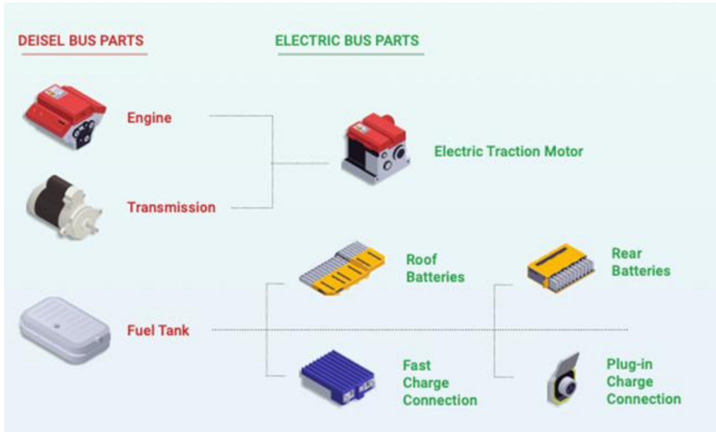


Figure 2. Conversion Diagram for Diesel-to-Electric Bus (Primus Partners & EBTC, 2024)

2.1.1 First step – conducting initial inspection

The first step of EV conversion is to conduct an initial inspection. Different studies that conducted EV conversion may describe the inspection differently, as there are different considerations to make the variety of vehicles work. However, the inspection step across different vehicles must be done because vehicles that are converted to EVs are unique, as they were not manufactured to be EVs, but to run on petroleum. Converting vehicles to EVs entails changing not only the parts that make the vehicle run but also ensuring that the holistic design change is cohesive. When planning to retrofit a vehicle, Nishana et al. (2022) wrote about how a study calculated motor parameters to see if motor specifications would make a sufficient replacement. Unlike building a vehicle from scratch, converting a vehicle entail having a point of comparison. Planning before conducting an inspection is important so that what should be looked out for becomes known. Determining the objectives and purpose of the conversion is an essential part of planning for a suitable configuration of equipment (Aggrawal et al., 2020).

Conducting initial inspection of buses

The conversion of a diesel bus to electric was carried out by the Nepalese transport operator Sajha Yatayat. During the pilot demonstration, the expert team initially inspected the vehicle's condition to assess the technical feasibility of the chassis and suspension systems. The vehicle was dismantled, and the chassis was removed. Next, the team checked the vehicle’s wear and tear, structural cracks, and bends. Vehicles deemed unfit were excluded.

Figure 3. Mini truck before and after EV conversion

Figure 4. Bus before and after EV conversion

Table 2. Summary of removed and installed components (Sajha Yatayat 2024)

Old Diesel bus		**New Converted bus**	
Engine	Type: E483 TCI, BS111 Power: 95Hp Torque: 285 Nm	**Motor**	Type: PMSM Power: 120kw (Peak) Torque: 1500 Nm
Fuel	Type: Diesel Capacity: 100 liters	**Battery**	Type: LiFePo4 Capacity: 56.2 kWh
Brake	Type: Hydraulic/oil Powered by engine	**Brake**	Hydraulic/oil Powered by electric pump

Figure 5. Technical inspection of vehicles to be converted

Simultaneously, the functionality of the chassis and suspension systems, defined as stress distribution and overall feasibility, were assessed by conducting a Displacement Analysis and Von-Mises Stress Analysis. Vehicles with good stress were included in the vehicle conversion, while vehicles with chassis and/or suspension problems were excluded. Results showed good stress distribution.

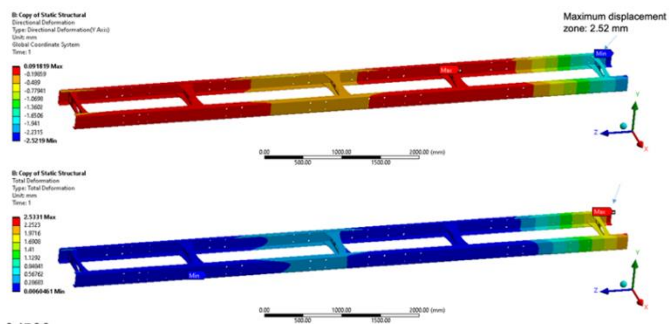


Figure 6. Displacement analysis of chassis for bus conversion (PEM motion 2024)

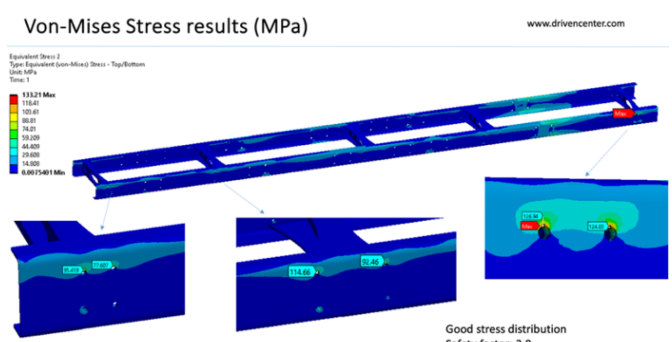


Figure 7. Von-Mises stress analysis of chassis for bus conversion (PEM motion 2024)

2.1.2 Second step – removing thermal elements

The second step of EV conversion is to remove the vehicle's thermal elements. Parts that will no longer be used must be removed to make space for the replacements that do not rely on petroleum. Dismantling mechanical systems comes before the installation of electrical components and the power system (Nishana et al, 2022). Additionally, parts that do not rely on petroleum but need maintenance must be taken out. A study explained that their inspection was followed by the removal of damaged parts, which was followed by the cleaning of the retained parts (Yiangkamolsing et al, 2019). The selection of the best replacement parts was done according to the developed requirements for the conversion process, such as considering the most appropriate speed and torque of motors (Yiangkamolsing et al., 2019).

When removing parts, there is a need to find an adequate electric replacement, given the purpose the converted vehicle will be used for. EVs have batteries, controllers, and electric motors (Tiwari et al., 2022). Batteries give control over the controller, and the controller controls electric engines; this is because batteries provide power that turns a transmission that turns wheels (Tiwari et al., 2022). These batteries are rechargeable (Tiwari et al., 2022). Lithium-ion batteries, with high energy densities between 80 to 150 Wh/kg, are used for EVs (da Silva et al., 2019). Lithium-ion battery characteristics, in terms of power capacity and stored energy, depend on the charge-depleting mode range, the type of operation in charge-depleting mode (pure or mixed electric), the steering cycle, vehicle design, type of recharging, among other factors (da Silva et al., 2019). The battery power of EVs is limited by the number of kW the battery can supply (da Silva et al., 2019). Two factors affect the distance that can be traveled in charge-depleting mode. On one hand, the storage capacity determines the distance that can be traveled in charge-depleting mode (da Silva et al., 2019). On the other hand, the weight of the battery system, which is related to the amount of energy the battery can store, determines distance as well (da Silva et al., 2019). Batteries can degrade with use, quantified as deep cycles and shallow cycles, and have their longevity affected (da Silva et al., 2019).

Several kinds of electric motors can be used on converted vehicles; selection of which must rely on the performance required from the converted vehicle (Aggrawal et al., 2020).

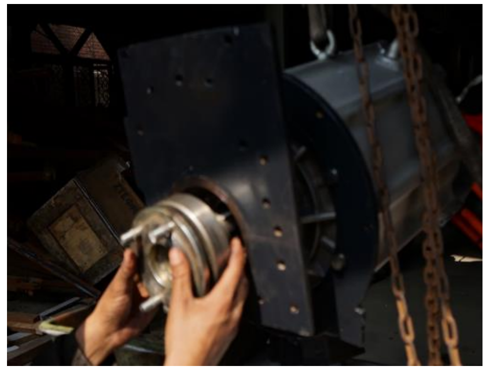
2.1.3 Third step – integrating the technology

During EV conversion, technology integration involved carefully assembling the electric motor on the chassis at the designated engine location. This process involved coupling the motor’s shaft to the gearbox, as well as fitting the necessary mountings to support various components. The placement of the electrical components was carefully designed by considering several factors such as weight balance and optimal wire length. Finally, the battery was positioned considering vehicle dynamics and load balancing.

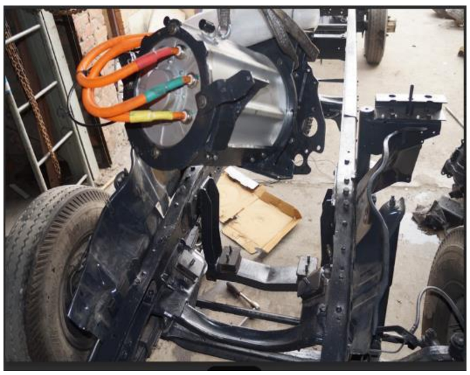
Integrating the technology for bus conversion

During the pilot, the conversion kit, which included an electric motor (120kW Peak, PMSM,1500Nm torque), four packs of batteries (56kWh, LiFePo4), an onboard charger (6.6kwh), a DC-DC convertor (560v-27v), a VCU, and supporting components (i.e., display, cooling, brake switch, accelerator, wire harness, etc.), were internationally procured through the institutional procurement process. Next, the project team carefully installed the conversion kit, along with the other supporting components, as shown in Figure 8. The engine was replaced with an electric motor. To take over vertical force and prevent bending, the roller bearing was fixed on the motor shaft. While fitting the motor to the chassis, four rubber mountings were placed. The front two rubber mountings were installed in a slanted position to resist both horizontal and vertical vibration shock and to prevent the motor’s unusual movement. Meanwhile, the two mountings at the back were installed for vertical support, restricting motion in the horizontal direction and enabling coupling with the gear shaft. The motor was coupled with the existing gear box (Sajha Yatayat, 2024).

Replacing engine with motor



Fixing roller bearing on the motor shaft

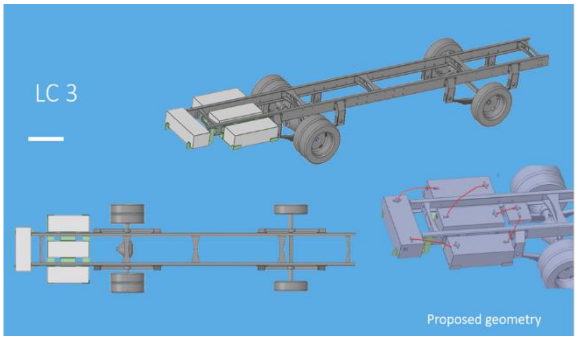


Motor fitted to chassis, with 4 rubber mounting

Motor fitted to chassis, coupling with the gear box

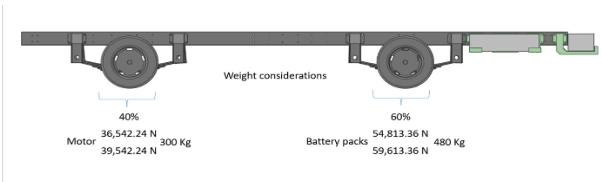
Figure 8. Conversion kit installation (Sajha Yatayat, 2024)

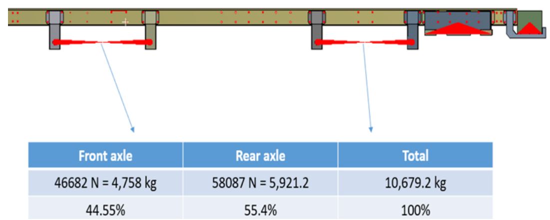
The expert team conducted a load balancing analysis to determine the optimal positioning of the battery and to ensure an optimal weight distribution in the chassis. This distribution, combined with the front-mounted motor and gearbox load, ensured even weight distribution throughout the vehicle. This analysis preceded the installation of four 115 kg battery packs at the rear end of the bus, which were connected to the body using six rubber mountings for damping (shock absorber), insulation, and air flow.



Placement of batteries at the rear end

Battery positioning





Load balancing analysis

Figure 9. Battery placement, positioning, and load analysis

2.1.4 Fourth step – conducting technical tests and verification

The fourth step of EV conversion is to conduct technical tests and verification, done to ensure that vehicles meet standards and to understand vehicle performance on the road. To do so, it is crucial that the technical tests are conducted under conditions that closely resemble the vehicle's usual travel routes.

A dynamic simulation of the chassis was carried out to see the performance of the components installed. Even at the slope of 20 degrees, the weight of the battery packs does not show undesirable behavior at static and dynamic motion.

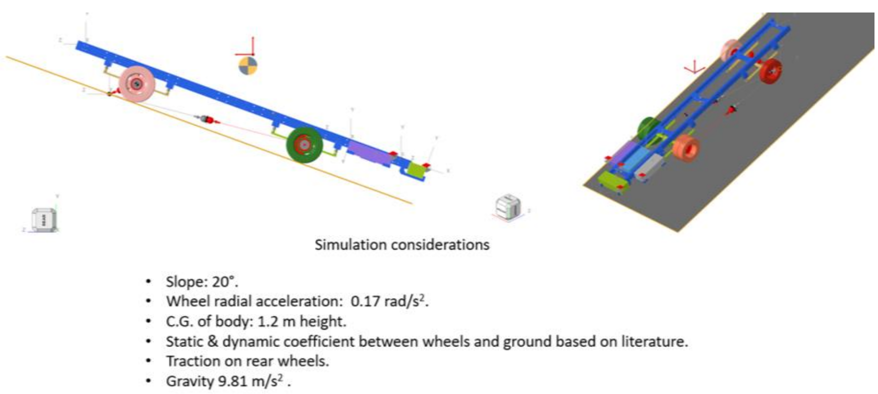


Figure 10. Performance analysis

The project team for the bus conversion conducted the first run and first test, with careful consideration. The vehicle test run shows smooth operation with 40 passengers.

Figure 11. Technical testing and verification

1.4. Converted EV components

Components are needed to convert a conventional vehicle to electric. Several product choices are available in the market for each component. Therefore, a careful selection based on the type and size of an EV is essential (PEM motion, 2024).

Electric motor

In vehicle conversion, the electric motor replaces the ICE, converting electrical energy into mechanical energy to drive the transmission shaft. The electric motor has fewer moving parts, with only three rotating components, the rotor and two bearings, compared to the ICE's numerous moving parts. This makes the electric motor more efficient, simpler, durable, and low maintenance. Motor selection should consider efficiency, power, wiring simplicity, and cost (PEM motion, 2024). There are three main types of electric motors used in EV conversion: DC motors, three-phase induction motors, and brushless DC (BLDC) motors, each with different performance characteristics and efficiencies. Typically, DC motors used are wound series, while BLDC motors are synchronous motors with a permanent magnet rotor.

Motor controller

The MC or speed controller's design depends on the motor type and regulates the EV's power requirements. It adjusts motor shaft rotation by managing power. For DC motors, control is achieved via pulse-width modulation (PWM) (Figure 12).

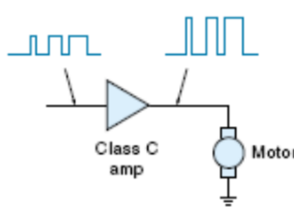


Figure 12. PWM drive for DC motor

To meet higher power demand, PWM amplifiers can use transistors [i.e., metal-oxide-semiconductor field-effect transistor (MOSFET) and insulated-gate bipolar transistor (IGBT)]. Several components already have IGBT power modules, which make them simpler and more robust. Control for three-phase induction motors and BLDC motors involves a similar inverter transistor arrangement for all three phases, differing mainly in control strategy. Each transistor is managed by a programmable control unit that processes signals from the accelerator pedal, motor speed sensor, voltage and current. The control unit appropriately processes those signals into phases' regulation of the electric motor (PEM motion 2024).

Table 3. Performance and efficiency of electric motors example (PEM motion, 2024)

Electric Motor type	efficiency (%)	max.power (kW)	max.torque (Nm)	battery (Vdc)	max.current (A)
DC motor [6]	88	52	150	144	500
3 phase induction motor[7]	88	47	163	96	650
BLDC motor[8]	95	30	150	144	250

Battery

An EV's battery works similar to a fuel tank in an ICE vehicle by storing energy (i.e., electrical) to support vehicle propulsion. Several types of batteries are used in vehicle conversions to electric, each with its advantages based on characteristics and energy cost. Lithium polymer batteries are preferred for their high specific energy, energy density, and power density, offering a more compact size for the same capacity. However, these batteries require a more complex management system compared to lead-acid batteries, which rely on simple electrochemical reactions that naturally balance the potential in each cell without special regulation.

Table 4. Main characteristics of various batteries (PEM motion, 2024)

System	Voltage (V)	Specific Energy ($Whkg^{-1}$)	Energy Density (WhL^{-1})	Power Density (Wkg^{-1})	Specific Energy of Cell ($Whkg^{-1}$)	Specific Energy of Battery (100%SOC)($Whkg^{-1}$)
Sealed lead-acid (LA)	2.1	30-40	60-75	180	20-35	20-35
Nickel-cadmium (Ni-Cd)	1.2	40-60	50-150	150	40-60	40-60
Nickel-metal hydride (Ni-MH)	1.2	30-80	140-300	250-1000	50-70	40-70
Lithium-ion $LiCoO_2$	3.6	160	270	1800		
Lithium polymer	3.7	130-200	300	3000		
Lithium-ion $LiFePO_4$	3.25	80-120	170	1400		

Table 5. Energy cost, advantages, and disadvantages of various batteries (PEM motion, 2024)

System	Voltage(V)	Energy Cost ($Wh\$^{-1}$)	Advantages	Disadvantages
Sealed lead-acid (LA)	2.1	5-8	Cheap	Heavy
Nickel-cadmium (Ni-Cd)	1.2	2-4	Reliable, inexpensive, high discharge rate, good low temperature behaviour	Heavy, toxic material, memory effect
Nickel-metal hydride (Ni-MH)	1.2	1.4-2.8	High energy density, environment friendly	Higher internal resistance, gas formation, self-discharge
Lithium-ion $LiCoO_2$	3.6	3-5	High specific energy, lowself-discharge	Expensive, requires safety electronics
Lithium polymer	3.7	3-5	High specific energy, lowself-discharge	Expensive, requires safety electronics
Lithium-ion $LiFePO_4$	3.25	0.7-1.6	Safe	Technology in development

Gearbox adapter plate

In EV conversion, the ICE drive system is replaced with an electric one while retaining original equipment manufacturer (OEM) components from the transmission to the wheels. An adapter plate connects the electric motor to the OEM transmission and ensures that both remain aligned. The shape and dimensions of the adapter plate can vary (PEM motion, 2024).

Figure 13. Gearbox adapter plate

Accelerator sensor

The accelerator sensor analogy in EV works similarly to an ICEV's throttle position sensor. The sensor sends input from the driver's foot to the MC, which adjusts the motor's power accordingly. This sensor construction is commonly made from a potentiometer or Hall effect sensor or pot box (PEM motion, 2024).

Figure 14. Foot pedal including Hall effect sensor

Power cable

Power cables transmit high-power electrical energy from the battery to the MC, unlike standard vehicle wiring, as they can handle high voltage and currents. Welding cables are suitable for vehicle conversions due to their high current capacity and flexibility, easing installation. Cable selection is based on the required current between the battery and the MC. Table 5 provides recommended cable sizes per American Wire Gauge (AWG) standards. More attention should be put on voltage decline (VD) from cable resistance and power dissipation (WD), which causes cable heat. When the battery used is high voltage, VD will be insignificant; therefore, AWG 2/0 can be used. A cable test of 1000 A for several seconds to one minute will increase cable heat extensively. A temperature upsurge will enlarge cable resistance, which will amplify the existing WD (PEM motion, 2024).

Table 6. Cable parameters and calculated values (PEM motion, 2024)

AWG	Diameter	Ohm/1Kft	V_D†/10ft	W_D†/ft	Area/ft	W†/in^2
2/0	0.47" – 0.53"	0.0779	0.78V	78W	18 in^2	4.3 W/in^2
4/0	0.60" – 0.66"	0.0490	0.49V	49W	24.1 in^2	2 W/in^2

† at 1000 Amps. of current

EV fuses and circuit breaker

EV fuses and circuit breakers protect the battery circuit from short circuits, component failures, or excessive current. EV fuses unlike standard fuses, designed for high DC voltage, disconnect the circuit to prevent fires during short circuits (PEM motion 2024).

Figure 15. High current fuse and air Circuit breaker 250A/160V

Contactor

The contactor is the main switch for electricity flow from the battery to the MC. It is electronically controlled by the MC or ignition key, functioning like a relay but designed to handle high currents (PEM motion, 2024).

Figure 16. Kilovac LEV200 contactors

DC-DC converter

Electrical systems in EV conversion should be provided according to vehicle standards. Headlamps, signs, dashboards and other features typically use a 12 VDC system. A reliable power supply is necessary, which is provided by a DC-DC converter which functions like an ICE system's alternator, supplying electricity for lamps and battery accessories (12 V or 24 V) (PEM motion, 2024).

Figure 17. BRUSA BSC623-12V

Volt Meter, Ampere and SOC-meter

Standard indicators and meters, such as the speedometer, odometer, RPM meter, and light indicators, are essential. In a converted vehicle, additional meters are necessary to provide the driver with adequate information: a voltmeter to monitor battery voltage, an ammeter to display current flow, and a State of Charge (SOC) meter which functions like a fuel gauge. These three components should be on the dashboard at a minimum. Additional indicators include motor temperature, MC status, charging state, State of Health (SOH), Time to Full during charging, Distance to Empty prediction, and DC-DC converter status (PEM motion, 2024).

Auxiliary parts

Auxiliary parts (i.e. vacuum pumps, power steering pumps, air conditioner compressor) in converted EVs are optional and depend on the specific vehicle needs. Modern vehicles often use vacuum boosters for braking assistance, requiring an electric vacuum pump powered by a DC-DC converter to maintain optimal braking. For vehicles with power steering, the hydraulic pump driven by the ICE pulley is replaced by an electro-hydraulic power steering (EHPS) system driven by an electric motor. Alternatively, Electric power steering (EPS) can be used for better energy efficiency.

Table 7. Summary of replaced components

Internal Combustion Engine Vehicle	**Electric Vehicle**
Internal Combustion Engine (ICE)	Electric motor
Engine control unit (ECU)	Motor Controller (MC)
Fuel tank	Battery
ICE gearbox adapter plate	EV gearbox adapter plate
Throttle position sensor	Accelerator sensor
Wiring harness	Power Cable
Fuse	EV fuses and circuit breaker
Relay	Contactor

Alternator	DC-DC converter
Speedometer, odometer, RPM meter (standard for ICE and EVs)	Voltmeter, ampere, and SOC-meter
Auxiliary parts	
Hydraulic pump	Electro-hydraulic power steering (EHPS) / Electric power steering (EPS)
Vacuum booster	Vacuum pump

1.5. Benefits of vehicle conversion

Vehicle conversion is an intermediary solution that can facilitate widespread EV adoption and involves substituting a vehicle's ICE with an electric motor (Darekar, Gawande, Karkaria, & Karandikar, 2021; Hoeft, 2021). Several factors motivate ICE vehicle owners to purchase converted vehicles, such as the desire to contribute to environmental sustainability, lower vehicle operating and maintenance costs, and extend vehicle lifetime (Hoeft, 2021). Some main drivers for conversion include reducing pollutants, advancing renewable energy, and prolonging lives of vehicles. It preserves vintage vehicles, particularly those with sentimental significance. When considering EV conversion, it is essential to evaluate its technical, economic, and environmental impacts. Further, selecting the most appropriate EV conversion schemes should consider the technology already accessible to the country (Sharma et al., 2023).

Economic Benefits

One benefit of EV conversion is to improve the affordability and accessibility of EVs, which accelerates EV uptake (Prasad et al, 2023). A GGGI study (Jang et al., 2023) noted that the TCO (total cost of ownership) of converted EVs is substantially lower than its ICE counterparts for 2Ws, 3Ws, and 4Ws. However, the TCO of a converted 2W is higher than a new electric 2W. On the other hand, the TCOs of converted 3Ws and 4Ws are 6% and 21% lower than those of new EVs, respectively. Table 7 compares the TCO and emissions of new ICE vehicles, new EVs, and converted EVs (Jang et al., 2023). New and converted EVs have similar CO2 emissions, while TCOs are lower in 3W and 4W converted EVs compared to new ICE vehicles.

Table 8. TCO and CO_2 emission comparison between new ICE, new EV, converted EV

		New ICEV	**New EVs**	**Converted EVs**
2W	TCO (USD in thousands)	3.1	1.7	2.4
	CO_2 emission (in tons)	0.4	0.3	0.3
3W	TCO (USD in thousands)	27.5	16.1	15.2
	CO_2 emission (in tons)	7.1	2.7	2.7
4W	TCO (USD in thousands)	100.7	82.9	65.2
	CO_2 emission (in tons)	3.8	1.8	1.8

The TCO for converted three- and four-wheelers EVs, as summarized in Table 8, is favourable due to the lower capital expenses including vehicle[1] and battery replacement costs are lower, compared to purchasing an either a new ICEV or EV. Furthermore, operating costs (e.g., electricity costs and maintenance costs) between the converted EV and the brand-new EV are

[1] For converted EVs, vehicle costs include the following costs: used ICEV, conversion kit, and service fee

the same. Both of which are notably lower than the fuel and maintenance costs of ICEVs. However, the TCO for new electric two-wheelers are lower due to the lower upfronts costs of new electric two wheelers compared to the vehicle costs of converted variants.

Environmental Benefits

An environmental benefit of EV conversion is mitigating land and air pollution as it reduces ICE vehicle scrappage and carbon footprint (Jang et al., 2023). Retrofitting vehicles prolongs the lifespan by 8 to 10 years (Primus Partners & EBTC, 2024). By reusing an ICE vehicle's structure, vehicle conversion reduces the production process's carbon footprint. A medium-sized ICE vehicle emits about 24 tons of carbon dioxide throughout its lifecycle, and 5.6 tons (or 23.3%) emanates from the production process (Prasad et al, 2023). Furthermore, it reduces scrappage by scaling down the number of potentially discarded vehicles and reducing the potential for land pollution due to improper disposal of vehicle scraping (GGGI, 2023). EVs also have no tailpipe emissions, reducing their greenhouse gas (GHG) emissions by up to 90% compared to ICE vehicles (Watts et al., 2021).

1.6. Barriers to EV Conversion

The following table identifies barriers or gaps to EV conversion's widespread adoption and commercial success, experienced in different countries and settings. Barriers are classified into six groups: policy and regulatory, technical, institutional, social, economic, and knowledge-related hindrances (Table 9).

Table 9. Barriers to EV conversion

Barriers	Description
Policy and regulatory	o Inadequate EV conversion standards and regulations o Limited legislative frameworks and political commitment o Engine product modifications require a formal process and approval o Restricted opportunities by allowing only government-declared vehicle conversions o Lack of long-term planning, goals, and policy (e.g., relating to tax exemptions, rewards, and subsidies) in the government o Insufficient emphasis on electric public transport in existing policies
Technical	o Insufficient skilled labor and workshops o Insufficient infrastructure and charging facilities o Limited lifespan of batteries o No government approved lithium battery recycling system o Safety issues o Limited local industry and conversion kits o Insufficient data on performance and dependability of vehicles o Challenges in converting larger buses (e.g. longer than 12 meters) o Energy shortage during the dry season
Institutional	o Lead agency for vehicle conversion may need further development o Lack of coordination among government tiers (i.e., central, provincial, and local governments) o Relatively small EV market results to market dominance by a few

	o Lack of sufficient technical facilities for effective monitoring by the assigned department responsible for approving all conversion parts
Social	o Limited public understanding o Insufficient environmental awareness o Negative public perception
Economic	o High initial capital cost o Expensive conversion parts (battery, motor, and controller) o Costs for battery replacement and disposal o Increased electricity pricing o Investment in EV conversion without clear policies carries risks o Potential impact on electrical supply stability as a result of increased energy demand and consumption from EVs. o Challenges in revenue collection and ensuring economic sustainability o Limited or no government subsidies available for electrification. o Difficulties in obtaining insurance coverage for batteries. o Banks encounter challenges in financing larger vehicle conversions
Knowledge	o Inadequate dissemination of accurate information about EVs o Lack of information campaigns and programs promoting EV conversion o Limited public understanding of government initiatives and benefits

As an example, the EV industry in the Southeast Asia region is expected to grow rapidly, however, there are challenges to electric mobility, which include some of the following: range anxiety, product quality, charging infrastructure, cost, environment (Bathan-Baterina et al, 2020). Thus, policies are needed to incentivize, standardize, align taxation norms, and facilitate the set-up of charging infrastructure (Bathan-Baterina et al, 2020).

Vehicle Conversion Policies and Practices

1.7. International Conversion Policies and Practices

A review of international EV conversion policies and practices reveals that several national governments, including France, Germany, and Indonesia provide purchase subsidies to owners that convert their existing ICE vehicles to electric.

In France, converted EVs have received subsidies amounting to around EUR 5,000 per vehicle since 2020 (Clean Technica), mandated by a recently passed law allowing the retrofitting of ICE vehicles, including cars, commercial vehicles, trucks and buses above five years old. Renault Group, one of the biggest vehicle manufacturers in France, offers retrofitted commercial vehicles, vintage cars, and bicycles. According to the company, the average retrofitting cost is between EUR 15,000 to EUR 20,000 before the subsidy.

In Germany, EV conversion is regulated and certified by a relatively advanced system, and is mostly done by professional firms (Hoeft, 2021). Through a case study of EV Engineering GmbH, a Germany-based Startup, Hoeft (2021) illustrated the collaborations necessary for running a vehicle conversion business (Figure 18). At the core, the startup oversees business operations, branding and marketing, the supply of kits, and training. On the other hand, venture capital firms provide financial resources and networks. Industry firms, mostly car suppliers and manufacturers, supply technical knowledge and special components. At the same time, universities contribute to technical development for electrification solutions. The government confers grants and subsidies, while the Technical Inspection Association approves and certifies conversion kits and converted vehicles.

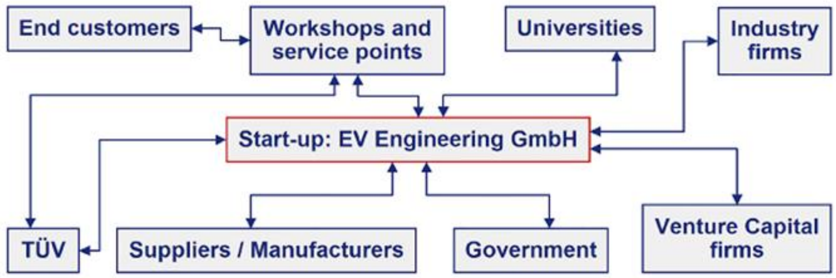


Figure 18. Collaboration between EV conversion startup and its key partners (Hoeft, 2021)

In India, EV conversion is supported by several regulations, particularly for registration, fitness, and lifespan of converted EVs (Primus Partners & EBTC, 2024). The Motor Vehicle Act (sections 41(7), 41(10), 56, 59), the Central Motor Vehicles Rules (rules 62 and 189), and Registered Vehicle Scrapping Facilities (section 8) provides guidelines for new and retrofitted EVs. EV retrofitting is gaining traction due to the rising demand for affordable solutions for transport decarbonization (Jang et al., 2023). In addition, the number of E3W conversion startups in India is increasing, targeting a large share of the country's market.

In Indonesia, government subsidies for converted e-motorcycles amount to about IDR 5 million per vehicle (Reuters, 2022). One of the Indonesian startups, Spora EV, provides EV conversion for various vehicle types, including regular motorcycles, classic motorcycles, and classic cars.

In Kenya, Roam Electric, an EV conversion startup, fills the niche market for specialized vehicles and converts 4x4 vehicles for safari and tourism industries with specific routes and predictable range capacity (Jang et al., 2023). EV conversion is a positive development, given the high air pollution in urban centers like Nairobi (Jang et al., 2023). In addition, Kenya Power, the country's electricity operator, plans to convert 2,000 ICE vehicles by 2027 (Kanali, 2023).

In New Zealand, an electric truck conversion pilot for waste collection has been conducted since 2016 and exhibits the capability to handle daily operations with zero emissions (Primus Partners, 2024). In 2021, Waste Management New Zealand operated 27 electric trucks, of which 12 were converted from diesel.

In South Africa, Electric Powered Vehicles Africa, an EV conversion startup, converted 12 safari game-viewer vehicles to improve the sustainability of safari tours and to attract environmentally conscious visitors. The Mpumalanga Green Cluster Agency (MPGA, 2022) estimates that converting petrol or diesel-powered game-viewer vehicles would deliver around ZAR 150,000 fuel cost savings annually.

In Spain, EMT Madrid, TMB Barcelona, and EMT Valencia participate in the Electrobus Project, which aims to transform ICE buses into hybrid diesel-electric buses. The conversion of four hybrid buses exhibits a 16% fuel reduction compared to conventional buses, saving around EUR 4,500 per bus annually.

In the United States, established OEMs, such as Ford and General Motors, released official EV conversion kits for older models (Jang et al., 2023). Ford released conversion kits, allowing users to independently customize EVs (Doll, 2021).

Various countries have introduced supporting policies such as purchase subsidies enable the conversion of ICE to electric vehicles for end-users. Aside from vehicle incentives, France has also streamlined the certification of converted EVs[2]. Meanwhile, Indonesia complements government incentives with the provision of workshops on EV conversion across the country. The combined efforts of the country aim to increase the adoption of converted EVs, which stands at 178 units as of 12 May 2023.

Alongside government initiatives, start-up companies dedicated to advancing the EV conversion market have emerged in several countries. These start-up companies evaluate the viability of EV conversion across various market segments including public transport, tourism, and waste collection.

1.8. National Conversion Policies and Practices in Nepal

EV conversion has a significant potential in improving Nepal's environmental and socio-economic landscape. As of 2019, Nepal has a relatively low energy use per capita compared with the global average. (1530 kWh vs. global average of 20,841 kWh). Nepal mostly relies on biofuels, but petroleum considerably expanded its share (4.21% in 1990 vs. 17.52% in 2019) due to the increasing number of vehicles (Sharma et al, 2023). This demand increased the use of fossil fuels by 245% while energy from renewable sources and bioprocesses increased by 49% in the same period (1990 to 2019). These increasing demands for petroleum negatively impact the environment and national economy and are against the goals for sustainable development (Sharma et al, 2023). Supporting EV adoption and conversion promises numerous benefits for the country, including GHG emission reduction, quality of life improvement, socio-economic development, and climate change mitigation and adaptation (Krupa, 2019).

From experiences in China, United States, and Europe, it can be gathered that different policies can be implemented to mainstream electric mobility (Bathan-Baterina et al, 2020). Some policies include roadmaps and targets, Nationally Determined Contributions (NDCs), economic incentives, non-fiscal instruments, charging infrastructure deployment, product quality standards, registration or licensing, and institutional standards (Bathan-Baterina et al, 2020).

Nepal made several commitments to EVs alongside improving emissions and health through a variety of policy tools. Public sector stakeholders are engaged through interorganizational commitments listed in Table 10. Policies focus on environment and climate change, transportation, and fiscal matters. The first two use interventions for populations, while fiscal policies focus on target individuals.

When diesel three-wheelers were popular, they would release thick black smoke and were noisy (Dhakal, 2003). The registration of these vehicles was banned in 1992, and since the government did not provide any incentives to abandon these vehicles, it was not able to enforce it (Dhakal, 2003). Since the, those diesel three wheelers were converted to electric and named 'Safa Tempo'. In 1994, the government set emission standards; in 1995 the Ministry of Environment was formed, which passed the Environmental Protection Act two years later (Dhakal, 2003). In the next year

[2] In France, the certification process for converted EV now focuses on certifying the EV conversion kits rather than each individual vehicle.

the announcement of phasing-out non-complying vehicles were made, yet it was difficult to implement (Dhakal, 2003).

The government of Nepal recently amended the Motor Vehicle and Transport Management Act 2049 B.S. to allow the conversion of fuel-based vehicles into EVs. Initially, the Motor Vehicle and Transport Management Act prohibits vehicle modifications without prior approval. However, the Ministry of Physical Infrastructure and Transport (MoPIT) announced on March 29, 2022, that this rule would be suspended for three years which enables owner or operators to conduct vehicle modifications that will result to more energy-efficient and environmentally friendly vehicles (Dhakal & Shakya, 2022). Further, converted vehicles would receive tax exemptions according to EV rates, as they help reduce carbon emissions (Dhakal & Shakya, 2022). The permission for EV retrofitting and provision of tax exemptions aim to make vehicles more energy efficient and environmentally friendly, and to align with global trends in reducing carbon emissions. Experts suggest that converting existing fuel vehicles to EVs reduces the country's reliance on petroleum which reduces overseas import costs. Currently, EV conversion costs between Rs. 7 million and Rs. 12 million.

Despite the success of previous conversion of diesel three wheeler to electric (Safa Tempos), Nepal still lacks the standardized guidelines that will ensure the safety and performance of converted vehicles. Navigating the legal landscape of EV conversions can be complex. This process involves adhering to regulations including vehicle registration, safety and standards, insurance liabilities, and environmental regulations. Understanding the legal landscapes before starting the conversion journey is crucial for a safe and hassle-free experience. Moreover, certified inspection is required for post-conversion to verify compliance with regulatory and performance standards, particularly concerning critical components like the powertrain, brakes, and lighting systems. A strategy on vehicle conversion is being drafted by the Department of Transport Management (DoTM).

The government of Nepal has taken other steps towards cleaner transportation besides EV conversion. For instance, the government is considering reducing import duties to boost EV adoption. Further, in a landmark decision, the government of Nepal officially banned vehicles older than 20 years nationwide, effective March 15, 2018, to control pollution, reduce fuel consumption, ease traffic congestion (Nepali Sansar, 2018), address concerns caused by old and poorly maintained vehicles, and ensure a clean environment. The Department of Transport Management (DoTM) estimated that about 5,000 public vehicles would be affected (Shrestha, 2018). Their documents will not be renewed, and their route permits will be revoked. The ban was initially enforced in Kathmandu, drastically reducing the number of old vehicles on the road. While outlawing vehicles over 20 years is a positive step, environmental experts and transportation entrepreneurs believe a more holistic approach is needed; for example, vehicle conversion. Experts suggest that converting existing fuel vehicles to electric ones could save on overseas imports. The conversion process involves installing new electric components while retaining the vehicle's structure, with estimated costs ranging from Rs. 7 million to Rs. 12 million.

Policies in Nepal that successfully introduced e3W were made in an environment where the public supported interventions for air pollution; where vehicles in the area moved in a 15 to 20 km diameter and had top speeds of 30 to 35 km/hour which meant that e3W could be accepted and used; and were implemented due to the potential use of hydroelectric power (Dhakal, 2003).

Although public sector commitments are multisectoral, broad and clear regulations for the quality, energy efficiency, or safety of people using equipment are lacking (Sharma et al, 2023). This leads to the importation of low-quality, expensive, economically inefficient electrical appliances

(Sharma et al, 2023); and Nepal's importation of 5,107 EVs resulted in a revenue loss of NPR 13.6 billion for the entire financial year compared to ICE vehicles (Gauchan et al, 2024). Additionally, the opportunity cost for importing EVs in FY 2023-2024 cost NPR 18 billion (Gauchan et al, 2024). There is a need to strengthen EV policies so that the adoption of EVs can successfully meet targets such as those set under the Paris Agreement.

Table 10. Nepal's public sector stakeholders and corresponding policies for EVs

Institutions	Policy/source	Note	Reference
Policies on EV conversion			
DoTM	Unpublished report: 'Environment Friendly Transport Operation and Management Directory (2024); Environment Friendly Transport's Conversion Criteria (2024)	o Guidelines provided for customer requirements, EV designing, production and construction of system mounting blocks, drive train systems and battery pack installation, and test rides. o Additional requirements such as vehicle specification, certification, quality checks, speed, certification of spare parts, safety measures, skills, and inspection and testing of EVs are also provided. o A code of practice for vehicle conversion including sections on testing and checkables are included.	DoTM, 2024 (unpublished)
Policies on environment and climate change			
	National Climate Change Policy (2019)	encourages EVs, establishing and implementing a low-carbon emission strategy	Bist, 2023
	National Environment Policy (2019)	controls pollution, promote greenery, manage waste, promote clean vehicles like EVs	Bist, 2023
Policies on transportation			
	National Transport Policy (2001)	foster clean energy powered electric buses, trams, mass public transit vehicles	
	Environment-Friendly Transport Policy (2014)	e-mobility targets, increase EVs by 20% by the end of 2020, reduce GHG emissions, provide finance options for EV infrastructure development	Bist, 2023
Nepal Electricity Authority		preparing to provide electricity for EV charging at the rate of NRs. 8.90 (cheaper than normal electricity rates)	Mali et al 2022
	National Action Plan for Electric Mobility (2018)	comprehensive plan addressing barriers to EV promotion, policy and governance, infrastructure and markets, financing and resources, and data and monitoring	Bist, 2023
Fiscal policies			

	National budget (i.e., for 2021, 2022)	taxes favorable for EV sales, customs duties on EVs based on battery capacity	Bist, 2023
	Nepal custom duties for EVs	With a range from 10% to 80% based on capacity, these act as incentives which led to a surge in EV imports; and were implemented alongside lowered excise taxes and bank auto loans made easier	Gauchan et al, 2024
Other policies			
Electricity Regulatory Commission, Nepal Energy Efficiency Program, Energy efficiency and loss reduction department	They are regulatory governmental institutions	Maintain the quality and efficiency of the electricity supply	Sharma et al, 2023
	Constitution	right to a clean and healthy environment for all citizens	Bist, 2023
	NDC 2020	policy framework supporting EVs, with a goal of 90% private 60% public vehicles being electric by 2030	Bist, 2023
Nepal as signatory	Paris Agreement	created its NDC, a 14-target plan to address climate change which include aims to increase the share of EVs up to 20% from its 2010 level, decrease its transport sector's dependency on fossils by 50% in 2050, develop a hydro-powered rail network by 2040, and to decrease the rate of air pollution by 2025	Krupa, 2019
Energy Ministry, Nepal Electric Authority		Authorities over charging infrastructure; NEA also established 50 charging stations	Krupa, 2019; Mali et al, 2022

1.9. Opportunities for EV Conversion Promotion in Nepal

A study in Southeast Asia notes that technology alone is not a solution for mainstreaming electric mobility; governments must prioritize it in national and local plans, create policies to promote their use, prioritize upgrading old diesel vehicles, use clean sources of electricity, use fiscal incentives, innovate, regulate the fuel economy, formulate clear financial incentives that cannot be misinterpreted, use non-fiscal incentives, develop charging infrastructure, harmonize standards, letting those in the industry participate in the development of policies and targets, and utilize working groups (Bathan-Baterina et al, 2020). Besides those listed, below are identified opportunities in promoting EV conversion and strengthening its uptake (Table 11).

Table 11. Target areas and opportunities

Target Area	**Opportunities**

Planning, policymaking and governance	o Promote infrastructure sharing o Prioritize sustainable urban transport planning o Strengthen government support for sustainable transport through the development of stimulative policies and incentivization o Incentivize conversion of old, underperforming, high-polluting vehicles o Set targets for electric public transportation transition and digitization (e.g., e-ticket, route tracking) o Bolster engagement and collaborations between government bodies, private sector, academe, and the public
Energy	o Enhance energy security o Promote a clean, self-reliant energy future o Encourage nighttime charging to prevent electricity deficit o Redirect surplus hydro-power energy to EVs
Finance	o Improve the accessibility of financing schemes for converted EVs o Value chain sense for manufacturing in Nepal o Economic development o Conversion can reduce trade deficit
Research and development	o DoTM and other industry players, such as owners and workers of conversion companies and factories and members of organizations involved in vehicle conversion, must pursue continuous research and development. For example, they can create a working group to facilitate collaboration

1.10. Nepal's stakeholders in the EV conversion industries and financing

Nepal has public and private stakeholders such as EV companies, conversion tool kit suppliers, battery suppliers, and financing institutions. As governments consider electric mobility as a solution, many large automakers have made commitments to going all-electric, starting in 2025 (Bist, 2023). The number of companies, tool kit suppliers, and battery suppliers remain limited, considering the relatively small size of the retrofitting industry. Further, some banks in the country offer financing support for EV purchases but not for EV conversion.

Table 12. Some of Nepal's private stakeholders

Companies		
Type	**Name of institution**	**Vehicle type conversion**
Private companies	Abhiyantriki Karmashala	E-Motorbike, E- 4 wheelers
	Ryan Energy	E-tempo, E- 4 wheelers
	Shree Eco Visionary	E-van, E-tempo
	Clean Energy International	E-tempo, E-motorbike, E-4 wheelers
Government/public	Sajha Yatayat	E-bus
Non-profit organization	National Innovation Center	E-jeep, E-nano car
Conversion tool kit suppliers		
Name of company	Products/company description	
Daraz Nepal	EV charging equipment, including e-bike geared DC motor	

Eco Drive Automobiles Private Limited	EV distributor and parts supplier offering equipment trading and related services
JAC E-T8: NEV Nepal, under the umbrella of Thee Go	Nepal's authorized distributor of JAC E-T8, an electric pickup truck model
Komaki EV Nepal	Authorized distributor of Komaki EVs, parts, and services, offering a range of EV-related products and services, including tool kits and spare parts
S.P Handicraft Export & Import	Bicycle shop that sells Electric Conversion Kits (ECKs), which turn normal bicycles electric
Ultimate Export & Import	Providing automotive tools and equipment, some of which are for EVs
Battery suppliers	
Name of company	**Products/company description**
Asian Batteries Pvt. Ltd.	Asian Batteries aims to become Nepal's most preferred power solution brand, providing excellent quality batteries. They offer a variety of batteries, including those for EVs.
Karacus Energy Pvt. Ltd	Karacus Energy specializes in EV lithium and customized battery solutions, and sells different batteries (i.e. 48V, 80AH/100AH/160AH EV batteries; 96V, 100AH/160AH/200AH EV batteries; 60.8V, 80AH/100AH EV batteries; 73.6V, 80AH/100AH EV batteries)
LOHUM	India's largest producer of sustainable energy transition and battery materials has partnered with several entities in Nepal's EV ecosystem. The collaboration includes associations with MG, Stellantis, Tata, Volkswagen, Suzuki, Renault, and Mahindra EV brands. The goal is to recycle around 200,000 batteries and produce battery materials over the next five years. LOHUM manages end-of-life batteries for most EV brands in Nepal, contributing to energy independence and environmental sustainability.
Financing institutions	
Nabil Bank, NMB Bank, Prabhu Bank, and Government Initiatives	These financing institutions provide some financial support for EVs, but no financing mechanisms for EV conversion

Lessons from the SOLUTIONSplus EV Conversion Pilot Projects in Nepal and Key Considerations for EV Conversion

1.11. Lessons from the SOLUTIONSplus EV Conversion Pilot Projects

This section elaborates on impact analysis of the pilot implementation of vehicle conversion for a bus and a mini truck and shed an important lesson on financial viability and environmental impacts, which was carried out under SOLUTIONSplus.[3]

4.1.1. Financial viability of pilot projects

The financial viability of vehicle conversion is crucial for both investors and operators involved in this transition. Investors seek assurance of profitability and return on investments, considering initial costs, ongoing maintenance expenses, and potential savings from reduced fuel consumption. On the other hand, operators evaluate upfront costs and investments against long-term benefits and regulatory compliance to ensure sustainable adoption of converted vehicles in their transport services and operations.

Determining the financial viability of these vehicle conversion pilots includes an assessment of key performance indicators to evaluate their profitability and cost-effectiveness. In the pilot projects, the metrics used to assess profitability are IRR, NPV, and payback period. Typically, the IRR and the NPV are required by funding institutions. However, the project's cost-effectiveness is assessed by calculating the cost-effectiveness ratio.

Investors who are interested in vehicle conversion should look for the following indicators to determine its financial viability: Investment cost, Residue value, Annual revenues, Annual operating and maintenance cost, Net pre-tax cash flow, Cumulative pre-tax cash flow, Depreciation, Book value, Taxable income, Income tax, Net after-tax cash flow, and Cumulative after- tax cash flow. Several local data and information were collected for the modelling or the assessment of finance KPI (Table 13).

Table 13. Data utilized to assess finance key performance indicators

Data category	**Specific data**
Propulsion	Battery type Battery Size (set) Number of Batteries
Capital Cost	Purchase price Charging infrastructure Training cost Expected useful life Residual value Depreciation Schedule
Operational Profile	Route Length of round trip Round trips per day Total distance per day Operating days per year Passengers per day Charging per day

[3] SOLUTIONSplus report on Impact assessment results: Baseline scenario and ex-ante assessment

Yearly operating cost	Route permit Vehicle road tax Technical inspection insurance Personnel cost Electricity cost Maintenance cost Income tax Yearly revenues

Bus conversion

Financial viability for bus conversion

Assumptions on the operation of converted bus

It is planned that once properly licensed, the converted e-bus will be operated on one of the current Sajha Yatayat routes from Lagankhel to Budhanilkantha with a roundtrip length of 32 km. After comparing a few operating schemes concerning daily operating hours and the corresponding charging time, it was decided to perform 3 roundtrips per day transporting a total of 366 passengers daily. This can be achieved with about 7 hours of overnight charging at the Sajha depot plus 1.5 hours of opportunity charging in one of the terminal stops of the route. The expected energy consumption is 0.56 kWh/km in the first year of operation, gradually increasing to 0.93 kWh/km by its tenth year, due to efficiency losses of the battery.

In Table 14, the converted bus is compared with two other alternatives of Sajha Yatayat: the purchase of a new e-bus and the purchase of a new diesel bus (like those in operation). The investment in the converted bus is considered 8 million NPR (for a single unit of conversion as a pilot project), while the new e-bus is 13 million NPR, and the new diesel bus is 4.9 million NPR. The 10% discount rate considered in the net present value (NPV) calculations, which is the opportunity cost of capital (return forgone by investing in the project) and reflects the return of a risk-free investment (long-term government bonds) plus the premium required for projects of similar risk. It appears that, with the current diesel fuel prices (mean price over the period of October 2022 to January 2023) and an average fuel consumption of 0,22 lt/km (Das, et al., 2022), the diesel bus remains the most profitable solution due to its low acquisition cost. The converted bus does not seem to be as profitable as the new e-bus, but it comes close, and the investment requirements are much lower. The taxation reduces profitability as expected and prolongs the payback period, which, however, remains shorter than the foreseen useful life of the vehicle of 10 years.

However, the project exhibits positive NPV at rates lower than the internal rate of return (IRR) of 8.81%. Additionally, a conversion cost of less than 8 million NPR produces a positive NPV, enhancing the significance of possible economies of scale at a later stage of the project.

Table 14. Comparison of converted bus to other alternatives

Parameter		Converted bus	New e-bus	New diesel bus
Size	Passenger capacity	50	60	70
Capital cost	Investment cost (NPR)	8.507.500	13.183.010	4.947.500
	Residual value (NPR)	1.180.000	3.896.681	1.482.000
Operational profile	Route	Lagankhel to Budhanilkantha		
	Round trips/day	3	4	4
	Passengers/day	366	579	684
Yearly operating cost	Total operating cost (NPR)	994.836 [1]	1.225.544 [3]	3.980.265
	* Personnel cost (NPR)	582.000	582.000	582.000
	* Electricity/fuel cost (NPR)	140.206 [2]	267.059 [4]	2.920.960
	* Maintenance cost (NPR)	234.030	334.328	418.705
	* Other (NPR)	38.600	42.157	58.600
Yearly revenues	Total revenues	2.267.004	3.586.326	4.236.696
Financial indicators (pre-tax)	NPV (@ 10% discount rate)	-452.308	2.412.601	5.276.148
	IRR	8,81%	13,75%	30,12%
	Payback period	6,83	5,68	3,15
Financial indicators (after-tax)	NPV (@ 10% discount rate)	-1.474.099	49.464	3.353.438
	IRR	6,02%	10,08%	23,02%
	Payback period	8,03	6,93	3,94
1 Reaching 1.088.306 in Year 10		3 Reaching 1.403.584 in Year 10		
2 Reaching 233.677 in Year 10		4 Reaching 445.099 in Year 10		

Production scale for bus conversion

The production cost of the bus conversion at a larger scale by a specialised workshop or manufacturer (vs. SOLUTIONSplus pilot's single unit) affects the profitability. Two changes in the conversion cost estimate are associated with this fact. First, conversion kits will be procured in larger quantities and a volume discount should be secured. In addition, economies of scale will result in lower production costs. In total, a 30% discount on the conversion cost is foreseen. Second, the manufacturer will have to earn a profit from this activity. A 10% profit has been added to the cost estimate as a result. With these adjustments, the investment cost becomes 6,545,000 NPR, while other figures remain unaltered. As shown in Table 15, the financial performance of the conversion is now very close to that of the new bus. Although the pre-tax IRR value is slightly better than the new bus one, the corresponding NPV is lower due to the difference in investment cost.

Table 15. Comparison of bus conversion to a new e-bus (Scaled production)

Financial indicators		Converted bus	New e-bus
Pre-tax	NPV (@ 10% discount rate)	1.502.692	2.412.601
	IRR	14,86%	13,75%
	Payback period	5,23	5,68
After-tax	NPV (@ 10% discount rate)	276.677	49.464
	IRR	10,92%	10,08%
	Payback period	6,30	6,93

Mini truck conversion

The conversion of a petrol-powered mini truck to electric was carried out by the local Nepali start-up Clean Energy International. The Tata Ace model, commonly used for inner-city businesses like transporting fruits, vegetables, furniture, and hardware, was chosen for the project. The demand for such cargo vehicles, particularly electric ones, is growing due to their lower operational costs.

Technical considerations for mini truck conversion

Technical considerations concern the conversion of a petrol-driven pick-up truck into electric, mainly through chassis repair, drive unit and battery replacement, and minimum bodywork. A 15 kWh lithium-iron-phosphate battery and a new drive train are installed on the old vehicle, built in 2007, which has a payload capacity of 750 kg (although the license is restricted to a maximum freight load of 500 kg). Key technical details of the converted mini truck are summarized below (Table 16).

Table 16. Key technical details of the converted mini truck

Parameters	**Specifications**
Drivetrain Top Speed	20 KW 60 km/hr
Battery pack Charging time	15 kWh 5 hours
Payload GVW	750 kg 1400 kg
Body dimension (l*b*h)	3.8m*1.5*1.845m

Investor's perspective for mini truck conversion

For an investor buying a converted mini truck from a manufacturer, the expected battery life restricts the useful life of the vehicle to 6 years, after which the initial investment of 1.93 million NPR will only be worth 150,000 NPR. The input values for its financial assessment appear in Table 17. The vehicle is expected to be operational for 330 days per year and perform daily an average of 3.5 paid trips of 20 km each. At an average charge of 1,500 NPR per trip, the yearly revenues are estimated at about 1.73 million NPR. Under these assumptions, the investment islucrative with a pre-tax NPV of almost 3.8 million NPR (at a 10% discount rate), an IRR of almost 64% and a payback period of less than 18 months (Table 18).

Table 17. Input values for assessing the converted pick-up truck (Investor's perspective)

Converted pick-up truck - Investor's perspective - Input values

Category	Parameter	Value	Units	Comments
General info	Year built	2007		
	Payload capacity	750	kg	Officially only 500 kg (bluebook)
Propulsion	Electric	LFP		
	Battery capacity	15	kWh	Only 80% (=12 kWh) can be used before recharging
Capital cost	Investment cost	1.927.000	NPR	(=sum(C8:C10))
	- Old vehicle	450.000	NPR	
	- Drive train	702.000	NPR	
	- Battery pack	775.000	NPR	
	Expected useful life	6	years	Based on the charging cycles of the battery
	Residual value	150.000	NPR	
	Depreciation schedule	10%		Per year
Operating profile	Average length of trip	20	km	
	Paid trips/day	3,5	trips/day	
	Total distance/day	70	km/day	(=C15*C14)
	Operating days/year	330	days/year	
Yearly operating	Total operating cost	437.270	NPR/year	(=sum(C19:C21)+C25+C29+C43)
	* Road tax, license renewal & insp.	24.000	NPR/year	
	* Insurance	11.000	NPR/year	
	* Personnel cost	297.300	NPR/year	(=(C22+C23)*12+C24)
	- Basic monthly salary	20.000	NPR/month	
	- Monthly allowance	4.000	NPR/month	
	- Yearly bonus	9.300	NPR/year	
	* Electricity cost	27.720	NPR/year	(=C16*C17*C26*C28)
	- Specific energy consumption	0,120	kWh/km	On the assumption of 100 km per 12 kWh
	- Battery efficiency	100,000	%	Average annual drop of 4%
	- Fuel price	10	NPR/kWh	Price applicable in registered charging stattions
	* Maintenance cost	40.750	NPR/year	(=sum(C30:C42))
	- Tires	10.000	NPR/year	
	- Brake shoes	12.000	NPR/year	
	- Dent paint	8.000	NPR/year	
	- Suspension	3.000	NPR/year	
	- Wiring	0	NPR/year	
	- Headlights, tail lights	4.000	NPR/year	
	- Differential crown gear	0	NPR/year	
	- Fuses	500	NPR/year	
	- Display system	2.500	NPR/year	
	- Throttle pedal	750	NPR/year	
	- Battery change	0	NPR/year	
	- Engine service	0	NPR/year	
	- Other maintenance costs	0	NPR/year	
	* Other	36.500	NPR/year	(=sum(C44:C46))
	- Vehicle parking	18.000	NPR/year	(=1.500 NPR per month)
	- Vehicle cleaning	18.000	NPR/year	(=1.500 NPR per month)
	- Driver's license	500	NPR/year	
Yearly revenues	Total revenues	1.732.500	NPR/year	(=C17*C15*C48)
	Charge per trip	1.500	NPR/trip	
Income tax	Income tax rate	25%		

Table 18. Financial indicators for the converted pick-up truck (Investor's perspective)

Converted pick-up truck - Inspector's perspective - Calculations							
Discount rate	10%						
	Y0	Y1	Y2	Y3	Y4	Y5	Y6
Year	2022	2023	2024	2025	2026	2027	2028
Investment	-1.927.000						
Residual value							150.000
Annual revenues		1.732.500	1.732.500	1.732.500	1.732.500	1.732.500	1.732.500
Annual operating & maintenance costs		-438.425	-439.628	-440.881	-442.187	-443.547	-444.963
Net pre-tax cash flow	-1.927.000	1.294.075	1.292.872	1.291.619	1.290.313	1.288.953	1.437.537
Cumulative pre-tax cash flow	-1.927.000	-632.925	659.947	1.951.565	3.241.879	4.530.832	5.968.369
Year	0	1	2	3	4	5	6
Pre-tax NPV	3.781.425						
Pre-tax IRR	63,87%						
Pre-tax payback (years)	1,49						
Depreciation		-177.700	-159.930	-143.937	-129.543	-116.589	-104.930
Book value		1.749.300	1.589.370	1.445.433	1.315.890	1.199.301	1.094.371
Taxable income		1.116.375	1.132.942	1.147.682	1.160.770	1.172.364	238.236
Income tax		-279.094	-283.235	-286.920	-290.192	-293.091	-59.559
Net after-tax cash flow	-1.927.000	1.014.981	1.009.636	1.004.698	1.000.121	995.862	1.377.978
Cumulative after-tax cash flow	-1.927.000	-912.019	97.618	1.102.316	2.102.437	3.098.299	4.476.276
Year	0	1	2	3	4	5	6
After-tax NPV	2.664.246						
After-tax IRR	48,29%						
After-tax payback (years)	1,90						

Operator's perspective for mini truck conversion

For operators considering converting mini trucks, it is assumed that the second-hand price is 450,000 NPR and the employment of the vehicle is six years. Under an operating profile identical to that of Table 17, the conversion is expected to generate almost 3.5 million NPR, a return equivalent to an IRR of 198% (Table 19).

Table 19. Profitability of an existing pick-up truck before conversion (operator's perspective)

Existing pick-up truck - Operator's perspective - BEFORE - Calculations							
Discount rate	10%						
	Y0	Y1	Y2	Y3	Y4	Y5	Y6
Year	2022	2023	2024	2025	2026	2027	2028
Investment	-450.000						
Residual value							100.000
Annual revenues		1.732.500	1.732.500	1.732.500	1.732.500	1.732.500	1.732.500
Annual operating & maintenance costs		-839.793	-839.793	-839.793	-839.793	-839.793	-839.793
Net pre-tax cash flow	-450.000	892.707	892.707	892.707	892.707	892.707	992.707
Cumulative pre-tax cash flow	-450.000	442.707	1.335.415	2.228.122	3.120.829	4.013.537	5.006.244
Year	0	1	2	3	4	5	6
Pre-tax NPV	3.494.421						
Pre-tax IRR	198,16%						
Pre-tax payback (years)	0,50						
Depreciation		-35.000	-31.500	-28.350	-25.515	-22.964	-20.667
Book value		415.000	383.500	355.150	329.635	306.672	286.004
Taxable income		857.707	861.207	864.357	867.192	869.744	686.036
Income tax		-214.427	-215.302	-216.089	-216.798	-217.436	-171.509
Net after-tax cash flow	-450.000	678.281	677.406	676.618	675.909	675.271	821.198
Cumulative after-tax cash flow	-450.000	228.281	905.686	1.582.304	2.258.213	2.933.485	3.754.683
Year	0	1	2	3	4	5	6
After-tax NPV	2.579.302						
After-tax IRR	150,20%						
After-tax payback (years)	0,66						

When the NPVs of Table 19 enter the financial assessment of Table 17 as an additional cost (foregone profit), accompanied by a simultaneous reduction of total investment by the market price of the vehicle that now does not have to be purchased, the overall profitability of the conversion project is achieved. Given that the 3.5 million NPR of the previous operation has already been internalized, the NPV of Table 20 is an additional expected profit. Thus, the conversion project is still meaningful despite the enormous profits of the existing operation.

It is worth mentioning that although the second-hand price of the existing vehicle influences the profitability of the project from the investor's perspective (a higher price reduces expected profits), it has no effect on the project's profits from the operator's perspective, as it now constitutes an internal variable.

Table 20. Overall profitability of the conversion project (operator's perspective)

Converted pick-up truck - Operator's perspective - AFTER - Calculations							
Discount rate	10%						
	Y0	Y1	Y2	Y3	Y4	Y5	Y6
Year	2022	2023	2024	2025	2026	2027	2028
Investment	-4.971.421						
Residual value							150.000
Annual revenues		1.732.500	1.732.500	1.732.500	1.732.500	1.732.500	1.732.500
Annual operating & maintenance costs		-438.425	-439.628	-440.881	-442.187	-443.547	-444.963
Net pre-tax cash flow	-4.971.421	1.294.075	1.292.872	1.291.619	1.290.313	1.288.953	1.437.537
Cumulative pre-tax cash flow	-4.971.421	-3.677.346	-2.384.474	-1.092.855	197.458	1.486.411	2.923.948
Year	0	1	2	3	4	5	6
Pre-tax NPV	737.004						
Pre-tax IRR	14,86%						
Pre-tax payback (years)	3,85						
Investment adjustment due to tax	-4.056.302						
Depreciation		-161.300	-145.170	-130.653	-117.588	-105.829	-95.246
Book value		1.601.704	1.456.534	1.325.880	1.208.292	1.102.463	1.007.217
Taxable income		1.132.775	1.147.701	1.160.965	1.172.725	1.183.124	335.074
Income tax		-283.194	-286.925	-290.241	-293.181	-295.781	-83.768
Net after-tax cash flow	-4.056.302	1.010.881	1.005.947	1.001.377	997.132	993.172	1.353.768
Cumulative after-tax cash flow	-4.056.302	-3.045.420	-2.039.474	-1.038.097	-40.965	952.208	2.305.976
Year	0	1	2	3	4	5	6
After-tax NPV	508.295						
After-tax IRR	14,03%						
After-tax payback (years)	4,04						

4.1.2. Environmental impacts of EV conversion

Assessing the environmental impacts of EV conversion

Assessing the potential impacts of reducing GHG emissions is crucial when converting ICE vehicles. This evaluation reveals environmental benefits, such as reducing carbon dioxide and other pollutants, leading to improved air quality and public health. Understanding broader benefits like reduced noise pollution and enhanced energy efficiency also helps stakeholders decide on transitioning to EVs. Accurately measuring and assessing these impacts supports policymakers in Nepal to prioritize and incentivize the adoption of EVs. It provides knowledge and evidence to help the country in achieving its NDCs and mitigating climate change.

During the pilot project implementation, the team assessed the environmental impacts of EV conversion by calculating GHG, PM2.5, and NOx emissions using mileage data (e.g., VKT), fuel consumption, and well-to-wheel (WTT) emission factors. The team also used the UNEP EMOB calculation sheets as a reference in calculating the emissions.

Assumptions in the emissions calculation of converted EV vehicles

With the assumption that along the Lagankhel-Budanilkantha route in Kathmandu, similar to an existing diesel bus of Sajha Yatayat that travels 128 km daily (=4 trips of 32 km each), on average, and an average deployment of 326 days per year (=27.17 days per month), the annual mileage of a bus on this route amounts to 41,728 km. Das et al. (2022) estimate that on average, the specific fuel consumption of such a bus in Kathmandu is 0.22 lt/km, leading to an annual consumption of 9,180 lt of diesel oil. This figure must be adjusted to reflect differences in transport work (due to size and round trips) performed by a demo and a diesel bus. Based on Sajha Yatayat statistics, a diesel bus on the Lagankhel-Budanilkantha route serves 684 passengers daily. Assuming the same utilization rate, the demo vehicle will serve 366 passengers per day, resulting in an adjustment factor of 0.5351, i.e. fuel consumption of the converted bus in Kathmandu is 0.112 lt/km. The application of this factor to the fuel consumption estimated above leads to an amount of 4,912 lt of diesel oil annually . The tank-to-wheel (TtW) CO2 emission factor of diesel oil is 2,582 gr/lt (Das et al., 2022). According to the e-Mob calculator of UNEP, the well-to-tank (WtT) CO2 emission factor of diesel oil is 500 gr/lt, resulting in a well-to-wheel (WTW) factor of 3,082 gr/lt .

GHG emission assumptions

The adjusted annual fuel consumption estimated above then results in 15.14 tons of CO2 emissions per year. Under the assumption that all electricity used by the converted e-bus will be generated exclusively through renewable sources [5], the figure of 15.14 tons per year will be the expected gain in GHG due to the conversion (. For the mini truck conversion, it was found that one unit of the converted vehicle is expected to save 5.78 tonnes of CO2 emissions per year.

NOx emission assumptions

According to ARAI (2007), the average NOx emission factor for heavy commercial diesel buses in India built in the period 2000-2006 is estimated at 9.02 gr/km. Assuming an average fuel efficiency for medium-sized buses in this country of 4.55 km/L (Karali et al., 2019), this estimate is transformed into 40.98 gr/lt. The application of this factor on the adjusted annual fuel consumption estimated above results in a figure of 201.30 kg of NOx emissions abated annually per unit of converted bus. For the mini truck conversion, it was found that one unit of the converted truck is expected to save 26.49 kg of NOx emissions annually.

PM2.5 emission assumptions

For e-buses, the $PM_{2.5}$ emissions factor[6] for this type of fuel and vehicle is 10.62 gr/lt (Das et al., 2022). The mass of abated $PM_{2.5}$ emissions annually per unit of converted bus then becomes 52 kg . For converted mini trucks, the mass of abated PM2.5 emissions annually per unit of the converted pick-up truck is 36.42 kg.

Calculated environmental impacts of EV conversion

The converted truck will replace an existing pick-up truck in the latter's daily operations. Under the assumption that all electricity used by the converted vehicle will be generated exclusively through renewable sources, the emissions of the pick-up truck reflect the emissions abated.

Converted EV GHG emissions

The tank-to-wheel (TtW) CO2 emission factor of diesel oil is 2,582 gr/lt (Das et al., 2022). According to the e-Mob calculator of UNEP, the W23T CO2 emission factor of diesel oil is 500 gr/lt, resulting in a WTW factor of 3,082 gr/lt.

The adjusted annual fuel consumption estimated above results in 15.14 tons of CO2 emissions per year. Under the assumption that all electricity used by the converted e-bus will be generated exclusively through renewable sources, the figure of 15.14 tons per year will be the expected gain in GHG due to the conversion. For converted mini trucks, one unit of the converted vehicle is expected to save 5.78 tonnes of CO2 emissions per year.

Converted EV NOx emissions

According to ARAI (2007), the average NOx emission factor for heavy commercial diesel buses in India built in the period 2000-2006 is estimated at 9.02 gr/km. Assuming an average fuel efficiency for medium-sized buses in this country of 4.55 km/lt (Karali et al., 2019), this estimate is transformed into 40.98 gr/lt. The application of this factor on the adjusted annual fuel consumption estimated above results in a figure of 201.30 kg of NOx emissions abated annually per unit of converted bus . For converted mini trucks, one unit of the converted truck is expected to save 26.49 kg of NOx emissions annually.

Converted EV PM2.5 emissions

Similarly, the PM2.5 emissions factor for this type of fuel and vehicle (bus) is 10.62 gr/lt (Das et al., 2022). The mass of abated PM2.5 emissions annually per unit of converted bus then becomes 52 kg . For converted mini trucks, the mass of abated PM2.5 emissions annually per unit of the converted pick-up truck is 36.42 kg.

1.12. Key Considerations for EV Conversion from the SOLUTIONSplus Pilot Projects

This section elaborates on the processes and highlights key considerations involved in the pilot implementation of vehicle conversion for a bus and a mini truck which was launched in April 2024. Considerations from the lessons learned are supplemented by relevant literature.

Expert team composition

Prior to the SOLUTIONSplus project pilot implementation, an expert team conducted thorough assessments to determine the technical feasibility of converting these units. This team consisted of mechanical engineers from Abhiyantriki Karmashala and Sajha Yatayat and EV technicians from Sajha Yatayat for bus conversion and additionally team members from Clean Energy International for mini truck conversion. Although their skills and experience are primarily with ICE vehicles, they have practical hands-on experience working with EVs, even if they do not necessarily have formal degree qualifications. This team of local experts played an integral role across all project phases, from initial planning and design to fabrication and operations.

Selection of vehicles for conversion

When selecting a vehicle for EV conversion, factors are considered based on user needs and objectives. In the SOLUTIONSplus project, which aimed to reduce the environmental impact of urban transport vehicles, key considerations included vehicles' high decarbonization potential, local conditions and context, and strategic local partnerships to facilitate implementation. The high decarbonization potential of the vehicles was a critical factor in the vehicle selection for the pilot demonstration in Kathmandu. The SOLUTIONSplus project focused on diesel buses and mini trucks since it recognizes their significant contribution to GHG emissions in Nepal. Within the road transport sector, buses rank as the second-highest contributors to GHG emissions, while pick-ups are the third highest. Addressing emissions from these key contributors has a high potential impact on reducing GHG emissions from the transport sector.

Local conditions and context will be an important consideration for selecting vehicles. With the pilot's country context, the government prohibited vehicles older than 20 years on roads, potentially leading to a significant number of vehicles scrappage. These vehicles provide an opportunity for EV conversion, offering potential economic benefits through replication. Notably, EV conversion of heavy-duty petroleum vehicles (i.e., buses) has not yet been undertaken in Nepal. As such, the SOLUTIONSplus project aims to demonstrate the viability of EV conversion through two pilot demonstration projects, focusing on diesel buses and mini trucks.

Among various pick-up/mini truck models, the TATA Ace[4] was selected for EV conversion. Due to its affordability, the TATA Ace continues to dominate the light-duty cargo vehicle market in the country. With many of these models nearing the end of their usable lifespan, there is a significant opportunity for EV conversion and replication.

Other considerations for selecting vehicles relate to ease of implementation of EV conversion. This pertains to strategically working with local partners with existing fleet and has ample technical capacities and expertise to conduct the vehicle conversion. The pilot demonstration partnered with Sahja Yatayat, a public transport bus operator in Nepal. Although their technicians are more well-versed with working on conventional ICE vehicles, they have slight familiarity with vehicle conversion. To address this skills and expertise gap, the SOLUTIONS project facilitated mentorship and training opportunities for the local team through partnership with European industry partners with expertise and knowledge. In this case, the Kathmandu pilot demonstration partnered with PEM Motion which provided technical assistance to the local team in implementing EV conversion.

However, the conversion of these vehicles to electric poses significant challenges. Regulations from the Province of Bagmati in Nepal restrict the conversion of buses to electric only for those that are less than seven years of age. This regulation poses challenges since the main objective of EV conversion is to extend the operational life of the vehicle and avoid vehicle scrappage. In addition, these buses remain in good operating condition after seven years, which makes it impractical for operators to convert their vehicles.

[4] Considered as a mini truck by the SolutionsPlus Project

Lessons from vehicle conversion steps

Step 1

As units neared the end of operational life, the team evaluated whether these vehicles had functional components. Afterwards, the power transmission system was analyzed, given that some have complex systems that could pose challenges during conversion. Success of the first step can be attributed to several key factors. Notably, the proper facilities from Sajha Yatayat and the technical guidance from the SOLUTIONSplus consortium made it possible for the team. However, as the inspection requires some vehicle parts to be in good physical condition, this may pose a potential challenge especially with vehicles that are at the end of their usable life. These old-age vehicles will inevitably show signs of wear and tear.

Overall, much planning is needed before and during inspection because it is worth considering a consumer's needs which must be built around, such as charging infrastructures, domestic charging, mass charging, AC charging, and DC charging options (Tiwari et al., 2022). Besides considering consumer needs, planning and inspecting must be done for safety such as addressing electrical risks and chemical leaks (Nishana et al., 2022). These challenges occur when the consequences of changes in vehicles not initially designed to be electric are not considered, which leads to structural damage (Nishana et al., 2022).

Step 2

In the pilot, success was attributed to the practical technical experience of the local technicians and the availability of the equipment needed. The local technicians dismantled the engine from the chassis along with the engine equipment (e.g., radiator, alternator). In addition, the fuel tank, exhaust, and gear lever were removed. At this stage, the previous practical experience of the technicians and engineers enabled them to successfully remove the vehicle's components accordingly. In addition, all the necessary tools and parts were readily available, ensuring a smooth removal process.

Step 3

Unlike step 2, where the hands-on experience of the local technicians was helpful, this required more advanced technical expertise. Despite the practical experience of the local team, this step proved challenging due to unfamiliarity with the technology and process. The team faced several challenges with integrating the technology into the vehicles. As the technology is still in its pilot, the team lacked adequate formal training for the conversion and faced difficulties in dealing with unexpected outcomes. The team also faced challenges with resources including the lack of insulated tools for heavy energy works.

For the actual conversion of the vehicle, the team suggests providing adequate capacity building for the engineers and technicians who will be involved in EV conversion. This can be in the form of knowledge transfer and exchange, opportunities for formal education and training to obtain technical qualifications, and close mentorship and coaching. This equips them with the knowledge to understand the new technology, learn about the latest research and development for the technology, and improve their skills to conduct the activity. In addition, the study emphasizes the importance of acquiring the proper tools and equipment for the activity.

Step 4

During the pilot, converted mini truck received permit and was tested on ground. However, the challenges in obtaining required permits prior to regular operation for converted bus hindered the conduct of technical tests on the roads. According to local partner Sajha Yatayat, proper on-road testing could not be done due to legal constraint in Nepal such as the absence of directives for conversion and usage of converted vehicles in roads yet. Although the DoTM provides a permit for this, it only applies to applications for scientific research purposes only.

Since the converted bus was not tested on the road (until the preparation of this paper), it is difficult to determine their actual performance. Nevertheless, the local team tested the converted vehicles inside Sajha Yatayat's premises. During the technical test, the vehicles provided a smooth and jerk-free driving experience. In addition, the team experienced good pick-up and speeds.

After EV conversion, all components, installation, and wiring need to be rechecked. Below are specific considerations for the fourth step (PEM motion, 2024).

Preparation
Lift the drive wheel (front and rear) off the ground, then charge the battery (verify charger and wiring function).

Power On
Release the charging plug and turn the key on while on neutral with the parking brake engaged. Next, slowly press the accelerator and observe the motor for any abnormal behaviors, such as no rotation, twisted rotation, or abrupt movements. These indicate that the motor controller (MC) needs tuning. Perform tuning if the controller has these abnormal behaviors or add a necessary component for tuning.

Motor and transmission test
If the motor shaft rotates normally, test the clutch and transmission. Shift gears and release the clutch, noting any issues during gear shifts, and tune the clutch if needed. Test and tune all components like the vacuum pump, electro-hydraulic power steering (EHPS) or electric power steering (EPS), air conditioner, and battery management system if a lithium battery is used.

Test drive
For the test drive, first lower the vehicle, ensuring the wheels are free. Next, shift into gear and slowly press the accelerator. Test the vehicle under various conditions, including motor response, hilly roads, heavy loads, and braking. If tests are satisfactory, vehicle conversion is complete.

Conclusion and Ways Forward

This policy paper attained its four goals. First, it overviewed EV conversion policies and practices in Nepal and other countries. A review of EV conversion policies worldwide showed that different countries extend varying levels and forms of support to encourage EV conversion. In Nepal, regulations prohibiting vehicle modifications have been relaxed recently for changes leading to a more energy-efficient and environmentally friendly vehicle. In comparison, other countries like France and Indonesia provide subsidies for retrofitting vehicles. At the same time, Spain has set a clear target of converting their ICE buses to hybrid diesel-electric buses through the Electrobus Project. Vehicle conversion startups have emerged in several countries due to the growing interest in EV conversion worldwide.

Second, this policy paper subsequently discussed the EV conversion process using insights from the SOLUTIONSplus pilot bus conversion project and mini truck conversion in Kathmandu. Examining the EV conversion process showed that it constitutes four main steps: initial inspection, thermal elements removal, technology integration, and technical tests and verification. Conversion kits simplify the conversion process, although the components vary depending on the vehicle type. Smaller 2W and 3W require fewer parts than relatively larger vehicles. The required electric motor specifications and number of batteries depend on the vehicle's size and usage. EV conversion involves multiple stakeholders, including conversion companies, conversion tool kit suppliers, battery suppliers, and financing institutions. However, Nepal's retrofitting industry is relatively small.

Third, this policy paper analyzed the advantages of EV conversion and the barriers to and opportunities for its widespread adoption. EV conversion generates environmental and socio-economic advantages, thus fostering green mobility. It mitigates land and air pollution since it reduces vehicle scrappage and a vehicle's carbon footprint. At the same time, it stimulates the growth of local economies, particularly through business and job creation (especially for women). EV conversion also makes e-mobility more accessible and affordable, given that converting an ICE vehicle to an EV requires less capital than purchasing a brand-new EV. However, the retrofitting industry faces multiple barriers, including policy and regulatory, technical, institutional, social, economic, and knowledge-related barriers. Nonetheless, several opportunities exist to promote EV conversion, especially through improvements in planning, policymaking, governance, energy security, financing, and research.

Fourth, the policy paper detailed the essential processes and considerations in converting buses and mini trucks to electric, drawing from insights gained during the SOLUTIONSplus pilot demonstrations. The policy paper emphasized that the financial viability for investors and operators, the environmental impacts, and the ease of implementation must be considered in vehicle selection for EV conversion. The paper also presented the lessons learned across the four major steps of vehicle conversion, highlighting successes, challenges faced, and recommendations for ensuring successful replication.

The initial inspection was crucial to assess the vehicles suitability for conversion while prioritizing consumer safety and needs. Once deemed suitable for conversion, non-essential components were removed to accommodate the integration of the new technology. The integration involved motor chassis assembly, shaft coupling, mounting installation, electrical component placement, and, most importantly, the battery placement. Following the EV conversion, technical tests and verification were performed to assess the converted vehicle's performance. In summary, the pilot demonstration's success was greatly influenced by having the proper facilities, tools, and equipment, together with the previous team experiences and guidance from experts. In addition, to sustain the ongoing success and ensure the project's replication, capacity building and training must be provided for EV conversion technicians and engineers to equip them with the necessary knowledge and skills for the conversion. Additionally, permits for the commercial operations of the converted EVs must be obtained to benchmark their performance against other vehicle types.

Upon review of the existing policies and practices in Nepal, the policy paper determined that the country has already established technical regulations and incentives aimed at promoting EV conversion. Owners considering the conversion of their existing vehicles must obtain verification from the transport office. In addition, the government provides incentives through annual vehicle and road tax exemption for up to 5 years to encourage EV conversion. However, the financial viability assessment conducted during the pilot project revealed that EV conversion remains economically challenging for single unit. For comparison, purchasing a new diesel bus still remains more profitable than converting an existing bus to electric due to lower acquisition costs.

To garner greater public interest, the government could enhance its efforts by introducing additional financing schemes and incentives (i.e., subsidies and tax exemptions). Examples from countries like France, Germany, and Indonesia, where substantial subsidies have significantly reduced EV conversion costs, could serve as models for Nepal.

Further, there is a need to enhance and consolidate the currently fragmented policies and strategies in the country. For instance, Bagmati Province's policy that restricts EV conversion to those that are no older than seven years poses challenges for owners and operators. Many vehicles within this age range are still in excellent operational condition. However, one of the primary goals of vehicle conversion is reducing the scrappage of older vehicles. Therefore, the regional government could reconsider this policy and eliminate the age restriction to align with the core objectives of vehicle conversion.

Moreover, the national government amended the Motor Vehicle and Transport Management Act 2049 B.S. to allow owners to convert their vehicles to more energy efficient modes (e.g., electric) for a three-year period. Considering that the pilot project is the first attempt at heavy-duty vehicle conversion, the government could consider extending the three-year exemption to allow further research and development. This extension could allow the government to create a dedicated task force comprised of members from the government, industry, and the academe to formulate clear targets and guidelines for vehicle conversion, including testing and maintenance protocols and commercial operation.

The pilot project also highlights the need to provide adequate capacity building and training for personnel involved in EV conversion. To address the technical gaps, the policy paper recommends the government to collaborate closely with organizations (e.g., NGOs, academe, among others) to facilitate mentorship, training opportunities, knowledge transfer, and technical assistance. By doing so, Nepal can enhance local capacity to bolster vehicle and vehicle parts manufacturing capabilities.

Collaboration with different organizations could also be essential in mainstreaming and effectively communicating the advantages of EV conversion. Pilot projects usually assess the technical, economic, and environmental feasibility of EV conversion which provides data on the performance, reliability, emissions, and profitability. For instance, this paper highlights the environmental benefits of vehicle conversion such as reduced tailpipe emissions and avoidance of vehicle scrappage. In addition, highlighting successful case studies EV conversion projects can inspire stakeholders to consider similar initiatives.

Governments and their partners, including NGOs and academic institutions, can disseminate these benefits through various channels. These may include publishing reports, leveraging social media platforms, and through active community engagement using workshop, trainings, and public consultations. Active communication and engagement are pivotal in fostering broader acceptance and adoption of EV conversion initiatives across different sectors.

As a way forward, this policy paper recommends continuing the technical, economic, and environmental assessment of public transport vehicles (e.g., buses, and mini trucks) beyond the pilot phase. As discussed earlier, addressing the emissions from these public transport vehicles has a significant potential in reducing emissions in the country. In addition, estimates show that Nepal has a total of 5,000 public vehicles that are more than 20 years old, which will eventually be de-registered. As such, EV conversion is a valuable option to reduce vehicle scrappage. To continue the work on this sector, the government could revisit their permitting guidelines to enable on-road tests to accurately assess the technical capability of the converted vehicles.

Continued focus on this sector will enable the personnel involved in the conversion efforts to continuously increase their technical capabilities with guidance from experts. Notably, despite having limited prior experience in EV conversion, these individuals navigated the conversion process and implemented the necessary steps successfully. Lastly, this policy paper strongly recommends the development of a national guideline for vehicle conversion.

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