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COMMERCIAL AND TECHNOLOGICAL FEASIBILITY STUDY OF USING SOLAR E-RICKSHAW FOR SEMI-URBAN AREAS

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ABSTRACT

This research paper basically deals with improvement in the mode of transportation. Due to the extinction of non-renewable energy, we are focusing on making current transportation fuel free. The energy generation as well as utilization, both should be from renewable. Our objective in presenting this research paper is to improve and upgrade e-Rickshaw, which are currently in use, with solar PVs in semi-urban areas of India.

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INTRODUCTION

NDIA, as well as the whole world, are dwelling with problems of traffic congestion & emission and it is going to worse in coming years. The automobile industry is going through tremendous pressure of producing better and more environmentally sound vehicles. The government of India is seeking a way to increase public transport services which are eco-friendly as well as economy efficient (backed up by the renewable source of energy). In urban cities like Delhi, there exists public transport like Metro (Mass Transit System) which are somehow reducing traffic congestion problems but it lacks in first & last-mile connectivity. Today, Electric Vehicles (EVs) like e-Rickshaw serve as a Special Purpose Vehicle (SPVs), being used for first and last-mile connectivity as a means of public transport in many urban and semi-urban areas like Delhi and NCR. At present, India is highly dependent on non-renewable resources for its energy requirements.

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Thus, the EVs would not entirely benefit until and unless they use a renewable source of energy to power the battery bank. It is very clear that relying on a non-renewable source of energy like crude oil is not only hampering our health and environment but also causing a huge dent in our economy. National Electrical Mobility Plan (NEMMP) 2020 has set target of deploying 5 to 7 million EVs in India by 2020 of which it is targeted to have 4,00,000 Passenger Battery Electric Vehicles (BEVs) which will avoid 120 million barrels of oil & 4 million tons of CO_2 and hence lowering vehicular emission by 1.3% by 2020. NITI Aayog in collaboration with Colorado-based Rocky Mountain Institute report on Transformative Mobility Solutions says India can save as much as $60 billion in energy costs by 2030 and one gigatons of CO_2 emissions from 2017 to 2030 if it adopts more electric and shared vehicle. On basis of India's new green car policy, Govt. may consider doling out both fiscal & non-fiscal incentives and subsidies to push sales of EVs while discouraging the use of petrol and diesel-run vehicles. Tsinghua University, China studies says that the photovoltaic powered electric vehicle model has pollutant reduction

potentials of 99.8%, 99.7% and 100% for CO_2, SO_2, and nitrogen oxides, respectively, compared with a traditional gasoline-fueled car. Keeping in mind, Sustainability, Govt. policies & initiatives and research works, Solar e-Rickshaw (Emission free & Powered by renewable energy) is proposed in our paper for first and last-mile connectivity in semi-urban areas and will provide employment opportunities for lower middle-class people. Solar e-Rickshaw can be described as the application of solar PVs/energy to power & run wheels of e-Rickshaw. It has low maintenance, low running cost, is eco-friendly and non-polluting product and can be used for public mobility solutions in semi-urban areas. E-Rickshaws are ideal for electrification powered by solar PVs due to its low speeds and a relatively small distance covered in a day. Therefore, we are set out to make solar e-Rickshaw the example of environment consciousness & sustainable product in semi-urban areas of India with use of e-Rickshaw powered by Solar PVs. Although solar e-Rickshaw is costly to afford, Government fiscal & non-fiscal incentives and subsidies and daily earnings from solar e-Rickshaw can payback with a payback period of one to two years. This paper contains brief knowledge of technical, economic & social aspects of solar e-Rickshaw in semi-urban areas.

Literature Review

As time is passing by, society is observing a depletion in conventional sources of energy at a faster rate. To avoid the loss due to depletion, the main focus of study and researchers has now shifted to alternative energy like solar energy. A handsome amount of work has already been done, in this field, till now. Semi-urban and rural areas are going to be the major victims of this, as fossil fuels are depleting and its' prices are constantly increasing. Due to this, the price of electricity supplied to them is considerably higher when compared with alternative source electricity production. So there is an urgent need for a system which can provide them with electricity at cheaper rates. So, the government has decided to provide subsidized solar PV system. A photovoltaic (PV) module is a packaged, connected assembly of typically 6×10 photovoltaic solar cells. Photovoltaic modules constitute the photovoltaic array of a photovoltaic system that generates and supplies solar electricity in commercial and residential applications. Each module is rated by its DC output power under standard test conditions (STC), and typically ranges from 100 to 365 watts. The solar panel works on photo electric effect. They use light energy (photons) from the sun to generate electricity through the photovoltaic effect.

Various automobile companies are working on vehicles that can run on clean energy. One such example is The Solar Electric Vehicle Company running in the United States of America. This plant is producing 14 passenger enclosed shuttle and 23 passengers solar electric vehicle which can replace the traditional bus system in polluted cities such as Beijing and Delhi. Many other companies are also doing the study in this field such as Tesla. Photovoltaic (PV) cells contained in solar panels convert the sun's energy directly into electric energy. This electric energy is then transmitted as power for vehicle propulsion. Not only land vehicles are using solar to travel but nowadays airplanes are also powered using solar energy. Solar Impulse is first such plane which is powered by solar energy.
Various colleges and universities are also studying this field to improve people's lives and reduce people dependency on traditional fuels. In one of the papers, published by Delhi Technological University, mobile solar photovoltaics system is very useful in providing electricity. They have designed a system to meet the agricultural and household needs of a farmer by moving solar photovoltaic system. This kind of system is being designed in various college. An example for this is a solar powered vehicle designed by Industrial Design Center of IIT Mumbai.

Description of e-Rickshaw

E-Rickshaws have been becoming a mode of transport in semi-urban areas for first & last-mile connectivity to bus stands, metro stations, etc. since 2010 as an alternative to petrol/diesel/CNG auto-rickshaws & pulled rickshaws because of their low running cost and less human effort compared to pulled rickshaws. These are 3-wheelers pulled by an electric motor ranging from 650-1400 Watts for a route of less than 5 km.

Manufacturing, Design, Construction & Working Principle

Manufacturing of e-Rickshaws are done on customisation of drivers in an unorganized sector and final cost ranges from Rs. 1,00,000 to 1,50,000. These are mostly manufactured in China & India and only a few other countries. E-Rickshaws are built on M.S. (Mild Steel) Chassis which consists of 3-wheel with a differential at rear wheels. Body design varies from passenger segment to load carriers. These are designed to carry a weight ranging from 400Kg to 500Kg according to their type of operation. The working of e-Rickshaw is based on DC motor, battery & suspension system different from conventional auto-rickshaws. It uses a Brush Less DC motor ranging from 650-1400 Watts with a differential mechanism at rear wheels. The electrical system used in Indian cities is 48V. Some variants made in fiber are also in use due to their strength and durability, resulting in low maintenance. It consists of the controller unit.The battery used is mostly Lead acid/Li-ion battery with a life of 6-12 months. Deep discharge/cycle batteries designed for EVs are mostly used.

Major Parts and Components

Electric Motor: Brush Less Direct Current (BLDC) type 650-1400W & 48V (Input) motor is used. It is controlled via an electronic controller.

Electronic Motor Controller: The controller includes a manual or automatic switch turning the motor on/off, selecting forward or reverse motion, selecting and regulating speed, regulating or limiting torque and protecting against overloads. It is connected to battery pack and controller feeds the input to the motor, lamp, AC/DC converter and Speedometer/ Indicator.

Battery: Set of four 12V deep cycle lead acid/Li-ion batteries are used since the required voltage is 48V. These batteries are connected in series to the controller unit.

Differential: Chinese manufactured differential is used in e-Rickshaws which is connected to the electric motor and rear wheels.

Front Shock Absorbers: Helical Spring with dampener with hydraulic telescopic shock absorbers are used.

Rear Suspension: Leaf spring carriage spring with rear shocker

Brakes: Drum brakes, actuated internally, expanding shoe type are used. Brakes are mounted on the chassis (Pedal-brakes), so on pressing the pedal, the brakes will engage stopping the rear wheels.

Speedometer/Indicator: Speedometer generally used have analog dials. The one the left side indicates vehicle speed and one on the right side indicate battery charge level. It is connected to the controller unit.

Steering: Handle bar type steering is used.

Miscellaneous Spare parts: Centre locking, Alloy wheel, Rear light, Front glass, Front Indicator, Head light, Ignition switch, Charger, Converter, left-right switch, Tyre, Wirings, Throttle set etc.

Block Diagram

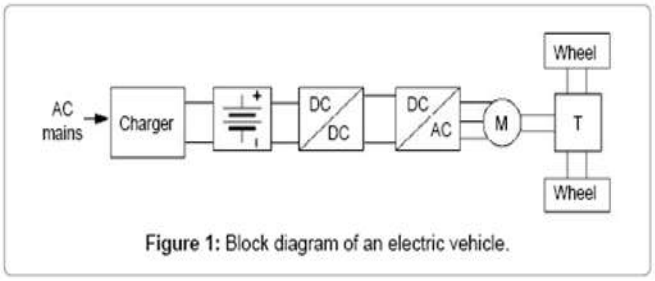


Figure 1: Block diagram of an electric vehicle.

Technical Specifications

S.No.	PARAMETER	SPECIFICATION
1.	Dimensions (l*b*h)	2870mm*1000mm*1760mm
2.	Seating Capacity	4+1+(40 Kg Luggage)
3.	Tyre Size	90*90*12, 3.75*12
4.	Battery Type	Exide/JPM/TRONTEK/Altimo
5.	Electricity Consumption/Charge	5-6 units
6.	Charging Time	8-10 hours
7.	Range per charge	*90 Km & above
8.	Battery dimensions (l*b*h)	400mm*180mm*205mm
9.	Differential length	970mm
10.	Motor Max Power	1140W & 48V
11.	Motor Type	BLDC
12.	Max. Speed	25 Km/hr
13.	Controller	24 Tubes 50A
14.	Charger	10-15 A
15.	Front Powerful Shocker	Helical Spring with dampener with hydraulic telescopic, shock absorber
16.	Rear Suspension	Leaf Spring Carriage Spring with Rear Shocker
17.	Brakes	Drum brakes actuated + Expanding Shoe Type, Combined
18.	Brake Shoe Thickness	50mm
19.	Drum Width	145mm
20.	Steering	Handle Bar Type
21.	System Voltage	12 V
22.	Performance	Excellent
23.	Rim	Alloy wheel/steel rim
24.	Rear Track	960mm
25.	Ground Clearance	135mm

Since the manufacturing of e-Rickshaw is done in an unorganized sector so there is no standardization of its parts. However, technical specifications of e-Rickshaw listed below are from Speego Vehicles Company Pvt. Ltd. (An ISO 9001:2015 Certified Company) in Delhi:

Courtesy: Speego Vehicles Company Pvt. Ltd. (An ISO 9001:2015 Certified Company)

Energy Requirement and Efficiency

Charging time for e-Rickshaw to its full is about 8-10 hours and Electricity consumption per charge is about 5-6 units or KWh. With the full charge, it covers a range of 90 Km and more i.e. Rs. 2-3 per Km and fare is Rs. 10 per passenger for 2Km in cities like Delhi. Detailed Earnings & Savings of e-Rickshaw drivers are described later in this paper. On comparing e-Rickshaw with other fuelled vehicle in semi-urban areas, it is found that e-Rickshaw stands at position one in mileage and cost. Hence, e-Rickshaw is currently the most efficient transport. We can imagine if electricity in e-Rickshaw is powered by Solar PVs which our paper presents then it will be a grace to society especially semi-urban areas.

Comparison of e-Rickshaw with other fueled vehicle

S.no.	Fuel type	Mileage (avg.)	Cost (avg.)	Rank
1.	CNG	21Km/Kg	Rs. 38/Kg	3
2.	LPG	21Km/Kg	Rs. 40/Kg	4
3.	Diesel	17Kmpl	Rs. 55/litre	5
4.	Petrol	15Kmpl	Rs. 65/litre	6
5.	Electricity(e-Rickshaw)	18Km/KWh	Rs. 10/KWh	2
6.	Solar e-Rickshaw	18Km/KWh	Rs. 1.30/KWh	1

Present Scenario of e-Rickshaw in semi-urban areas

In million plus population cities like Amritsar, Kanpur, and Delhi, e-rickshaw plays a major role as feeder services to public transport in metro cities, public transport in small & medium towns and mode of transport for tourists. All age group people travel by e-Rickshaw mostly for their work trip. Urban Mobility India Conference & Expo 2015 says 90% e-rickshaws on average carry more than 50 passengers per day. In areas like Kanpur, most of the e-rickshaws carry more than 80 passengers per day due to overloading and used as a public transport. In cities like Amritsar, 90% are occasional users (tourists) and in Kanpur & Delhi, there is 70:30 daily and occasional users respectively. In Delhi, 70% of e-Rickshaws are owned while other 30% are rented on average Rs. 300 per day.

Present e-Rickshaw Services

Laws: The Motor Vehicles (Amendment) Act, 2015

Regulatory bodies: RTO (Registration), Municipality (Infrastructure) & Traffic Police (Enforcement)

Route: Fixed by drivers (In Delhi, 236 roads are banned by authority). Travel distance less than 5 Km.

Fare Structure: Flat fare for fixed routes (Rs. 5, 10, 20). About Rs. 50 for personalized services.

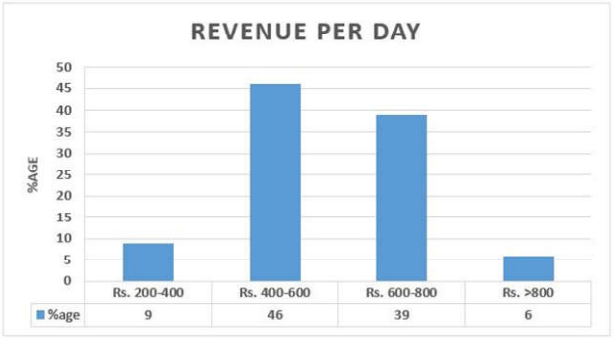
Infrastructure Facilities: No charging points. No Stands for Halts & Go. No parking areas.

Permit Issue: Only Delhi Govt. has a permit fee of Rs. 1,510 valid for five years and recognized 33 models & 20 dealers for

sale. No other cities have defined the structure yet. Cities like Amritsar charges similar permit fees as that of auto rickshaw.

Earnings & Savings per Month from e-Rickshaw

Average revenue earned by owned e-Rickshaws drivers is Rs. 15,000 per month whereas average revenue earned by rented drivers is Rs. 9,000 per month. High Operation & Maintenance (O&M) cost of Rs. 3,000 per month for owners as compared to rented vehicles. An average of additional Rs. 300 per month is spent by all drivers including expenses for charging, bribes to traffic police & parking in few areas. The income earned by the e-Rickshaw drivers in all cases is more than the minimum wage level, 2015 (Rs. 4,800 per month) specified by Govt. of India.



Reasons for using e-Rickshaw

User's Perspective: Users mostly prefer e-Rickshaw due to easy availability & accessibility and experience high level of comfort. Low fare, time savings, and travel in a small group are some other factors.

Other than this, first & last mile connectivity to bus stands, metro stations, etc. facilitates users to use e-Rickshaw. Most of the users felt e-Rickshaws provide good service and must be operational in urban & semi-urban areas. More than 30% of users wanted e-Rickshaw to be more safe and free from overloading.

Driver's Perspective: More than 50% of drivers are illiterate and e-Rickshaw is a good source of employment for them. It reduced pulling effort which was required in hand or cycle-rickshaw and hence effortless to drive. Fuel cost i.e. charging cost is very less as compared to other transport and running on small routes Frequent availability of passengers.

Engineer's Perspective: It is sustainable, eco-friendly and economical transport in semi-urban areas. Based on the comparison of the different fuelled vehicle, e-Rickshaw ranks position 1 in mileage and cost.

Government's Perspective: India's new green car policy, Govt. may consider doling out both fiscal & non-fiscal incentives and subsidies to push sales of EVs while discouraging the use of petrol and diesel-run vehicles. This action will increase modal share of e-Rickshaw in public transport.

Industry's Perspective: India is set to become the 3rd largest automotive market by 2020 and currently has one of the lowest vehicle penetration in the world making it a viable market for Electric Vehicle Manufacturers (EVMs). EV industry is at a nascent stage in India, comprising less than 1% of total vehicle sales, however, it has the potential to grow significantly in the coming years. EV sales are expected to grow at high double digit growth rates annually till 2020 due to Govt. green car policies and relaxation/subsidies on EVs.

Drawbacks of Present Scenario

- Absence of Policy/Regulatory framework for e-Rickshaw for permit issue, route rationalization, fare fixation
- No Infrastructure facility: Stands facilities, Halt & Go Stands, parking areas for the night, Availability of charging points 250m from junctions.
- Lack of specified schedules, performance/standards and Fixing & Revising fares.
- Lack of Institution governing e-rickshaws.
- Lack of financing: Cities like Kanpur, Amritsar lacks loan facilities for e-Rickshaws.

Earnings per month

Description	Earning per day (rs.)	Rent per day (rs.)	Total earning per month (rs.)
Income in case of owned e-rickshaws on less-profitable routes	200-400	-	6,000-12,000
Income in case of owned e-rickshaws on average profitable routes	400-600	-	12,000-18,000
Income in case of owned e-rickshaws on profitable routes like bus stands, metro station, railway stations, market areas	600-800	-	18,000-24,000
Income in case of rented e-rickshaws on average profitable routes	400-600	300	3,000-9,000
Income in case of rented e-rickshaws on profitable routes like bus stands, metro station, railway stations, market areas	600-800	300	9,000-15,000

Savings per month

Description	Avg. Earnings per month (rs.)	Avg. O&m cost per month (rs.)	Avg. Other expenses per month (rs.)	Total savings per month (rs.)
Income in case of owned e-rickshaws on less-profitable routes	9,000	3,000	300	5,700
Income in case of owned e-rickshaws on average profitable routes	15,000	3,000	300	11,700
Income in case of owned e-rickshaws on profitable routes like bus stands, metro station, railway stations, market areas	21,000	3,000	300	17,700
Income in case of rented e-rickshaws on average profitable routes	6,000	500	300	5,200
Income in case of rented e-rickshaws on profitable routes like bus stands, metro station, railway stations, market areas	12,000	500	300	11,200

MATERIALS AND METHODS

In designing of this solar e-rickshaw, basically, the work has been done on providing the power supply for charging to the e-rickshaw by attachment of solar panels over its roof.

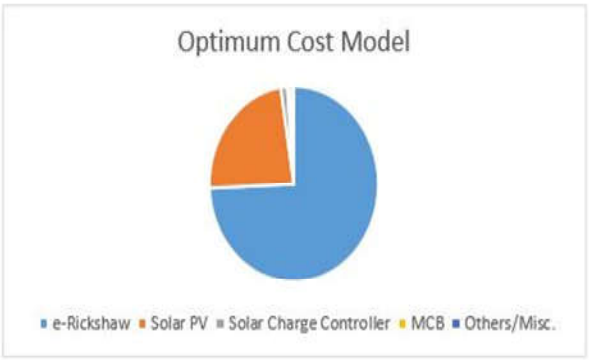
The basic things that were kept under observations were choosing panels and equipment in such a way that they won't increase the size of the roof, it should be economical and should be light in weight. It is basically light weight because it is a passenger vehicle and the maximum load is attained from it only, so other parts should be light in weight. The basic design of E-rickshaw will be same but alterations have been done in setting and adjusting the solar panels over the roof and adjusting its wiring and circuits accordingly.

After proper research and analysis, the result suggested that the design should be carried forward with three solar panels adjusted over the roof of the solar rickshaw. They are placed in such a manner that all the axis of panels (passing horizontally) will be kept at x-axis and the roof axis (passing horizontally) will be kept at the y-axis. This is done in this manner so that three panels can be adjusted properly to it. They all will be placed adjacent to each other. Panels are mounted on the roof properly and an option for rotating them manually at and a particular angle is also provided. It is rotated manually to avoid the issues like the weight of the motor and the power supply need for the motor to work. Their mounting is explained properly in the fabrication part. All the other components like solar charge converter, fuses and battery will be kept inside the compartment, which is placed below the passenger seat. The decision for choosing 250 watts three panels instead of 300 watts, is that the weight of the 250-watt panels is coming less and this is solving the excessive weight problem. The price of 300-watt panels is more and by neglecting it, we can economize our product. The problem for the accommodation of these panels is also solved by using 250-watt panels, as their length size is less than the 300 watts one. So, all the conditions asked are fulfilled by choosing this one. The power produced by these panels will completely charge the battery in 8hrs. So once a fully charged battery is used in starting the first run then there will be no need of charging the battery again by external output.
The advantage of using this system in semi-urban areas will be that it will easily charge the system while vehicle will be standing ideal. For this, a switch will be provided at the steering of the vehicle, when it is ideal mode the battery will be getting charged and when in working mode, batteries will be discharging. So by this method at the end of the day, the battery of this rickshaw will be completely charged and next day they can easily make their conveyance properly.

Fabrication

During the fabrication of this system, the points to be considered are: the attachment of solar panels is done in such a manner that they don't fall or break during mobility of vehicle, second thing to be considered is that the panels can be rotated manually by the driver according to the sun rays while vehicle is standing ideal, all the other components should be placed so that they do not create any irritation to the passengers and the drivers. The comfortability of both the rider and the passengers is kept at high priority. Firstly, the attachment of solar panel is done on the roof. Prime roofing is done with Aqua proof profile sheet. Then two metal bars (act as chassis of the roof) are welded on the roof corners, where the panels are actually mounted upon. On these rods, the panel's attachments are screwed and then on these attachments panels are fixed using bolts. The attachments are mounted in such a manner that the panel after placement face towards the south, as it is the best position.

After this, the wires from the panels, are drawn to setup, under the passenger seat, inside an insulated casing. These wires connect panels to MPPT charge controller. This controller then connected with a relay in between pass to battery charge controller. This battery charge controller is then connected to the battery. There is a relay placed between battery and motor drive (basically dc to ac inverter). Then this drive is connected to BLDC motor. Both these relays are controlled by an MCB switch, which is placed at steering of driver, when this MCB switch is on then charging of battery will take place (at that time the relay connected between battery and drive will cut off the connection) and when this MCB switched off then discharging of battery will take place (at that time the relay connected between MPPT charge controller and Battery charge controller will cut off the connection) i.e. power will be drawn by motors.

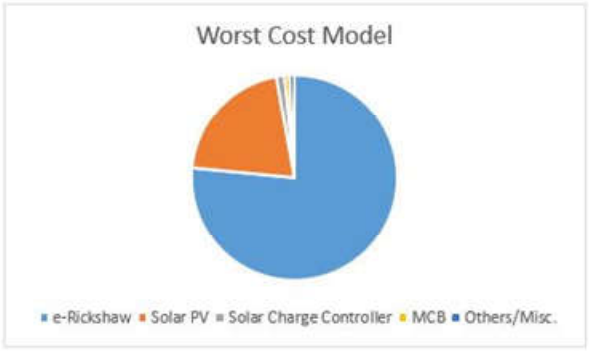


All the other circuit will remain the same as basic e-rickshaw design. And no further attachments need to be done because keeping the design simple will improve its efficiency and don't affect its load carrying capability.

Cost estimation of Solar e-Rickshaw

The cost of Solar e-Rickshaw is estimated using different tools & techniques such as Expert judgement, Analogous estimating, Three-point estimates (Best case, optimum case, worst case), spreadsheets and statistical tools.

Expert Judgement: Project mentor Dr. J P Kesari and expert from Zun Roof Solar, Vikram Solar have been consulted while preparing the cost estimation.



Analogous Estimating: Analogy has been used in the cost estimation from previous project and data.

Three-point Estimates: For 3-point estimates (Best, Optimum, and Worst), separate estimates are made for cost and brand. The proposed model requires an e-rickshaw, 3 units 250W Solar PV, Solar charge controller (MPPT type), MCBs and wires.

Table for cost estimation

S.No.	Equipment/ Component	Quantity	Cost (in INR)			Brand (with Specifications)		
			Best	Optimum	Worst	Best	Optimum	Worst
1.	e-Rickshaw	1	1,60,000	1,20,000	1,00,000	Mayuri	Sarthi	Baba
2.	Solar Panels	3*250W	48,000	37,500	27,000	Vikram Solar	Su-kam	Solar Power
3.	Solar charge Controller	1 (MPPT type)	2200	2000	1700	Su-kam	-	-
4.	MCBs	-	-	-	-	-	-	-
5.	Wires	-	-	-	-	-	-	-
Total			2,10,200+	1,59,500+	1,28,700+	-	-	-

Pie Chart Comparison

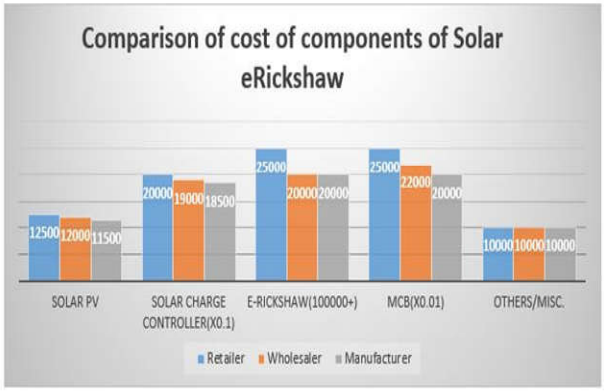
Cost Comparison-Retailer, Wholesaler & Manufacturer

For the comparison of the cost of components required for Solar e-Rickshaw, various retailers, wholesalers & manufacturers were contacted. Based on the discussion, a bar graph has been plotted between cost from retailer, wholesaler & manufacturer for different components.

Solar PV 250W: Based on discussion with 10 Retailers, 5 wholesalers & 5 manufacturers, the comparison shows Retailer price Rs. 12,500 | Wholesaler price Rs. 12,000 | Manufacturer Rs. 11,500.

Solar Charge Controller: 5 of each retailer, wholesaler & manufacturer were contacted. Taking multiplier 0.1 on bar-graph, the cost comes out to be Retailer price Rs. 2000 Wholesaler price Rs. 1900 | Manufacturer Rs. 1850.

e-Rickshaw: 5 of each retailer, wholesaler & manufacturer were contacted. Taking base price Rs. 1, 00,000, cost comes out to be Retailer price Rs. 1, 25,000 | Wholesaler price Rs. 1, 20,000 | Manufacturer Rs. 1, 20,000.



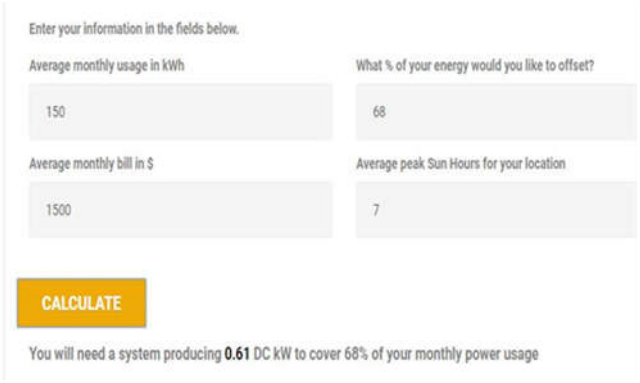
MCBs- To be found

Others- If required

Payback Period

Consideration

With Solar Panels (All in Rupees)



Cost of E Rickshaw = 1, 00,000/-
Cost of Solar Panels = 27,000/-
MPPT = 1,700/-
Others = 1,500/-
Attachments = 1,500/-
Total Cost = 1, 31,700/-

Without Panels (All in Rupees)
Cost of E Rickshaw = 1, 00,000/-
Others = 1,500/-

Calculations

Cost of Electricity for Charging (per day) = Rs.10 * 5 unit = Rs.50

Cost of Electricity for Charging (per year) = Rs. 50* 365 = Rs.18, 250

Payback period = 28,700/18,250 = 1.6 Years

Cost of Production of Electricity

Cost of Solar PV = Rs.27, 000/-
Cost of Mounting attachments = Rs.1, 500/-
MPPT = Rs.1, 700/-
Miscellaneous and others = Rs.1, 500/-
Total Cost of the proposed system = Rs.31, 700/-
Daily usage of e-Rickshaw (in kWh) = 5
Monthly usage of e-Rickshaw (in kWh) = 5*30 = 150
Yearly usage of e-Rickshaw (in kWh) = 5*365 = 1825
Average Sun hours for Delhi = 7 hours

A system of 0.75 kW Solar PVs will produce 80% of rated power i.e. 0.80*0.75=0.6 DC kWh

So, this system will cover around 68% to 70% of monthly usage of e-Rickshaw i.e. system will produce 0.7*5= **3.5 kWh**

Financial benefits

While considering life of Solar PV as 20 years

Years	Per Year (In kWh)	Total (In kWh)	Rated Capacity
1-5	3.5*365=1277.5	1277.5*=6387.5	100%
6-10	0.92*3.5*365=1175.3	1175.3=7555.5	92%
11-15	0.85*3.5*365=1085.875	1085.875=5429.375	85%
15-20	0.75*3.5*365=958.125	958.125=4790.625	75%

Total kWh (For 20 years) = 24, 163 Units
Total cost of production per unit = 31,700/24,163 = Rs.1.31
= Rs. 1.30

With all above considerations, the cost of electricity generated for e-Rickshaw while considering a time span for 20 years will be Rupees 1.30 per unit or kWh.

Environmental benefits

This system will able to eliminate 11290 Ibs or 5121.05 Kgs of CO_2 per year and is equivalent to planting 16 trees every year.

Conclusion

By the research and study done by us on making e-Rickshaw powered by solar energy revealed that Solar e-Rickshaw is a feasible mode of transport for first and last mile connectivity in semi-urban areas. As e-Rickshaws are already in use for covering short distances, so we decided to make it more efficient and eco-friendly. This is more environmentally friendly and is much better alternative fuel vehicle. Our economic feasibility states that the optimum cost of a single unit of Solar e-Rickshaw found is Rs. 1, 31,700 and Calculation reveals that the payback period of this system is around 1.3 years & the cost of production of a single unit of electricity for a span of 20 years comes out to be Rs. 1.3(One Rupee & Thirty Paise). Also, the average revenue earned by owned drivers is Rs. 15,000 and average revenue earned by rented drivers is Rs. 9,000. The overall study reveals that in all cases income earned by drivers is more than minimum wage level, 2015 (Rs. 4,800) specified by Govt. of India. Solar e-Rickshaw is found to be technically feasible than many vehicles on the road as it is noise free, cheaper and most efficient of all another type. These rickshaws are a replacement for other fuelled vehicle. A parking shed with a roof made up of Solar PVs and charging units (Plug-in Electric vehicle) will be grace for the owners of Solar e-Rickshaw and enhance technical feasibility. Solar e-Rickshaw is also socially feasible as it ensures the employment of drivers and low cost & noise-free rides also motivate users to use these rickshaws for their short distances.

Way forward and future works

Since our study was based on sustainable transport system for masses in tropical countries with growing economies like India due to a surge in the no. of vehicles across major cities. These cities seldom have an efficient mass transit system, forcing people to operate private vehicles. This problem is compounded by the social stigma, where people view operating a private vehicle as a sign of prosperity, while public transport is viewed as being used by the lower echelons of the society.

In coming future, we look forward to

- Design Solar Halt & Go Stand for these rickshaws like Bus stand which will use Off grid & On grid Solar Charging Station.
- Feasibility study of Mass Transit system equipped with Solar energy which will state how more efficient and clean system can be.
- Design Solar Charging Station like conventional fuel stations

Moreover, we expect from government to

- Promote fiscal & non-fiscal incentives and subsidies to push sales of renewable energy powered vehicle and discourage conventional fuelled vehicle.
- Roll out public transport based on renewable energy.
- Awareness of sustainable program among citizens to encourage people to use public transport and provide first & last mile connectivity.

In next one to two decades, we can imagine whole India run on renewable energy and we look forward that India will be a role model country for countries with growing economies in Renewable Energy based Transport.

REFERENCES

8th Global Summit Vibrant Gujarat 2017. Manufacturing of Electric vehicles: Two wheelers/Three wheelers/ Passengers Cars. Government of Gujarat

8th Urban Mobility India Conference & Expo 2015. Improving and upgrading electric rickshaws in Indian cities. Institute of Urban Transport India

ADB Open Innovation Forum, Manila 2015. Electric Vehicles in India: Policies, Opportunities, and Current Scenario. National Institute of Urban Affairs

Available Online: http://www.internationaltransportforum.org/Updates/index.html

Dr. J.P. Kesari and Rajat Sharma 2015. Design and Development of Solar Electric Vehicles at Delhi Technological University. IJISET - International Journal of Innovative Science, Engineering & Technology, Vol. 2 Issue 3, March 2015. http://ijiset.com/articlesv2/articlesv2s3.html ISSN 2348 – 7968

KPMG India 2010. Indian Automotive Industry

KPMG International 2013. Tax and incentives for Renewable energy

NASA. Surface Meteorology and Solar energy. Available Online: https://eosweb.larc.nasa.gov/sse/

Sehgal Lakshey, Prasath Arun R.and Rehalia Arvind, 2015. Proposal of Integral Mounted Solar Charging and External Solar Charging Station for an Electric Rickshaw in Delhi. American Journal of Renewable and Sustainable Energy Vol. 1, No. 3, pp.86-89

Singh Manoj et al (NITI Aayog), Marshall Abramczyk et al (RMI) 2017. India Leaps Ahead: Transformative Mobility Solutions for all. NITI Aayog, India-Rocky Mountain Institute, America. Available Online: http://niti.gov.in/writereaddata/files/document_publication/RMI_India_Report_web.pdf https://www.rmi.org/insights/reports/transformative_mobility_solutions_india

Tang, J. et al 2014. Economic analysis of photovoltaic electricity supply for an electric vehicle fleet in Shenzhen, China. International Journal of Sustainable Transportation 8, 202-204

Tarun Saxena, J P Kesari and Sudhir Y Kumar 2017. Solar Energy is the Path For India's Rural Prosperity: A Mobile Solar PV Application, Proceedings of International

Conference on Renewable Energy and Smart Grids Technology, ISBN 978-93-86432-07-0, Feb 24-25, 2017, Mody University, Laxmangarh, Rajasthan.

Technical Specification e-Rickshaw. Speego Vehicles Company Pvt. Ltd. (An ISO 9001:2015 Certified Company)

World Bank Study on Sustainable Transportation. Available Online: http://www.web.worldbank.com

Ye Bin, et al 2015. Feasibility study of a Solar-powered Electric Vehicle Charging Station Model. MDPI Energies 8, 13265-13283

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