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Opportunity to Use Solar Hybrid Mobile Cold Storage in India -A Critical Review

Surender Kumar
PhD Research Scholar, Mechanical Engineering Department, NIT, Jalandhar (PB), India
Dr. R.S Bharj
Associate Professor, Mechanical Engineering Department, NIT, Jalandhar (PB), India

ABSTRACT

India's automobile industry is one of the biggest in the world with an annual production at 23.96 million vehicles in FY 2015-16 accounting for around 7% of the country's GDP. The automobile industry comprises of two-three wheelers, passenger cars, multi-utility vehicles and commercial vehicles. Today, the environmental aspects of transport are very actual issues, primarily energy consumption and GHG production. The main problem facing the Indian transportation and power sector is the increasing prices of the fossil fuels. The swelling fuel prices have a direct effect upon the Indian GDP. As fossil fuels prices raise time to time, the search for alternative modes of transportation is required. Solar hybrid electric vehicle (SHEV's) transport is proving to be a complete new way to store and consume mass amounts of energy from the Indian power grid and solar. This paper focused on the importance of use of electric vehicle transport in India and infrastructure requirements for the same. Keeping in view of the technical performance and economic parameter, it demonstrates that this small-scale technology can contribute to solving problems of cooling like small area refrigeration including the transportable and small cold storage container with integrated PV energy supply systems.

Keywords:SHEV's (Solar hybrid electric vehicle), Transport demand, Green fuel, Economic impact

INTRODUCTION

Transport sector globally ishighlydependent onoilandIndia is no exception tothistrend.High dependence onoilisaconcern for India on account of three factors – energy security, local environment and climate change. As per the All India study report submitted to Petroleum Planning and Analysis Cell (PPAC), 70% of diesel and 99.6% petrol are consumed in the transport sector alone. Energy security concerns arise due to a very high dependence on imports which create uncertainties for prices and supplies [1-3].According to the Organization of the Petroleum Exporting Countries (OPEC), the demand for oil across the world will grow by 1.26 million barrels per day (mb/d) or 1.26 per cent in 2017 from 1.38 mb/d in 2016.India is expected to be one of the largest contributors to non-OECD (organization for economic cooperation and development) petroleum consumption growth globally. Total oil imports rose 4.24 per cent year-on-year to US$ 86.45 billion in 2016-17 [3-5]. India's oil consumption grew 8.3 per cent year-on-year to 212.7 million tons in 2016, as against the global growth of 1.5 per cent, thereby making it the third-largest oil consuming nation in the world. Rapid urbanization and accompanying motorization has created some of the most polluting cities in India. Thetopfourcities globally, according to$PM_{2.5}$, were Delhi, Patna, Gwalior and Raipur from India and the top 100 cities had from India (WHO, 2014). High levels of $PM_{2.5}$ and PM_{10}, much beyond national standard, is increasing morbidity. Fossil fuel combustion leads toCO_2emissions andaround 14%ofenergy related CO_2emissions areattributable to transport sector.Transport sector energy use and emissions are also highly related todevelopment patterns and investments in infrastructures [5-8].The low carbon scenarios also tend to focus only on improvements in efficiency of vehicles and less search on alternative modes of transportation. This paper draws attentions on hybrid electric vehicle usefor passenger andfreight transport.

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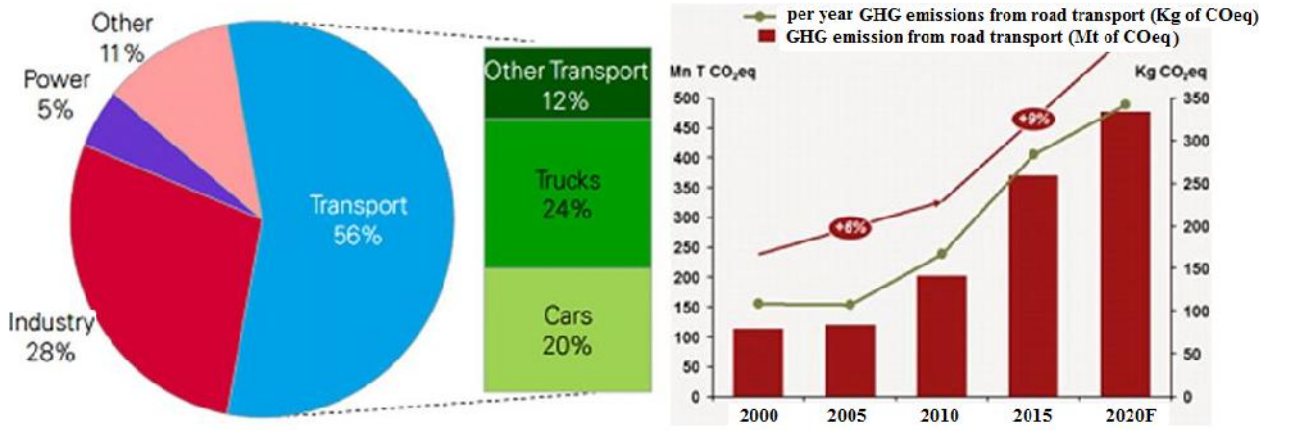

Fig. 1 Global oil demand and GHG emission from road transport in 2016 [10]

TRANSPORTATION SECTOR ENERGY CONSUMPTION

In the International Energy Outlook report 2016, transportation sector delivered energy consumption increases at an annual average rate of 1.4%, from 104 quadrillion British thermal units (Btu) in 2012 to 155 quadrillion Btu in 2040. Energy demand in transportationgrowth occurs almost entirely in regions outside of the organization for economic cooperation and development (Non-OECD), with transportation demand roughly flat in OECD regions—largely reflecting different expectations for economic growth in developing regions compared with developed regions.Transportation energy consumption (annual average growth) by OECD and non-OECD region is shown in figure 2 [8-10].

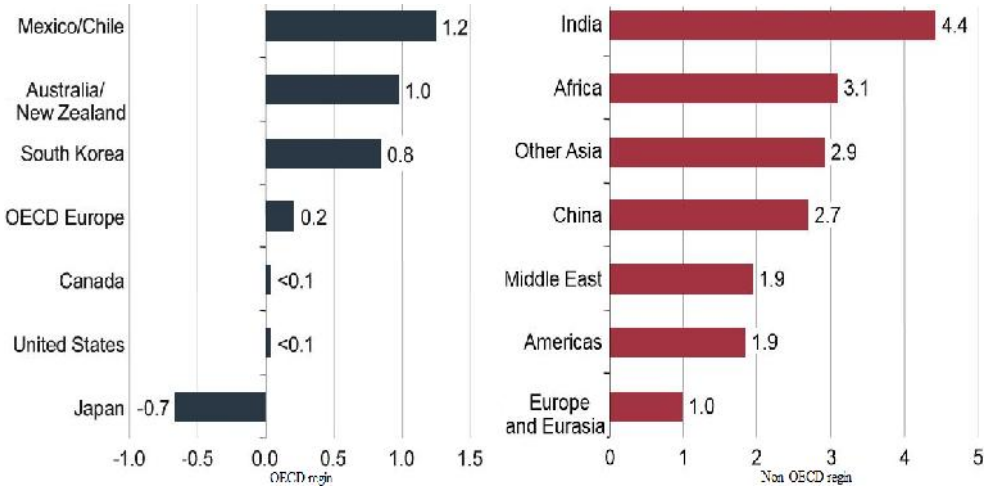

Fig. 2 Annual average growth in delivered transportation energy consumption by OECD& non- OECD region, 2012–40 (percent per year)

GHG PRODUCTION CALCULATION

Calculated energy is the mechanical work needed to move the vehicle. If is it transformed into units of MJ, it can be subsequently converted to total consumed energy. It means that the well-to-wheels principle is using factorse_w, g_w (EN 16 258:2012) or total energy efficiency η_T [11-14].

For the consumption of vehicles equipped by combustion engines is used following equation.

$$E_T = F_V * e_w = \left[\left(E_M * m_p\right) * \frac{1}{\rho_F}\right] * e_w [\text{MJ}]$$

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E_T -Total energy consumed by diesel vehicles [MJ]

F_V -Fuel consumption of vehicle [l , dm^3]

E_M -Mechanical energy consumed by the movement of the train (train dynamics software result) [kWh]

m_{Pe} -Vehicle engine specific fuel consumption [g/kWh]

ρ_F -Fuel (diesel) specific weight (density) [g/dm^3]

e_W-Energetic factor [MJ/dm3]

Calculation of GHG production through eq. by consumed amount of diesel fuel

$$G_T = F_V * g_w = \left[\left(E_M * m_p\right) * \frac{1}{\rho_F}\right] * g_w \text{ [gCO}_2\text{e]}$$

G_T -Total amount of emissions produced by diesel vehicles [gCO2e]

g_w -Emission factor for defined fuel [tCO_2e/MWh]

The basic units of MJ and gCO_2 were chosen for the calculation because they are the units declared in the standard.

ELECTRIC VEHICLE PRODUCTION WORLDWIDE

The Global EV Outlook report, published by the Electric Vehicles Initiative (EVI), estimates that the global EV stock in 2014 was more than 665000 vehicles, while the annual sales number for EVs was 113,000 in 2013. The report also concluded that overall EV sales are growing rapidly – 70% growth in 2013 and 53% growth in 2014. The percentage share of Battery Electric Vehicles (BEVs) in the total number of EVs sold is increasing every year – 49% in 2012, 54% in 2013 and 57% in 2014 (Clean Energy Ministerial, Electric Vehicles Initiative, and International Energy Agency 2013). China is currently operating 36,500 electric buses as compared with a negligible number of electric buses in India (Electric Vehicles Initiative and International Energy Agency 2015). The Indian market for electric vehicles is still nascent as the challenge is to augment charging infrastructure in big cities immediately to promote migration to electric vehicles. It has been projected that electric vehicles could account for close to 5% of the Indian car market, or 175,000 cars, by 2017, while the global market for the vehicles could reach about 20 million cars by 2020 [15-20].

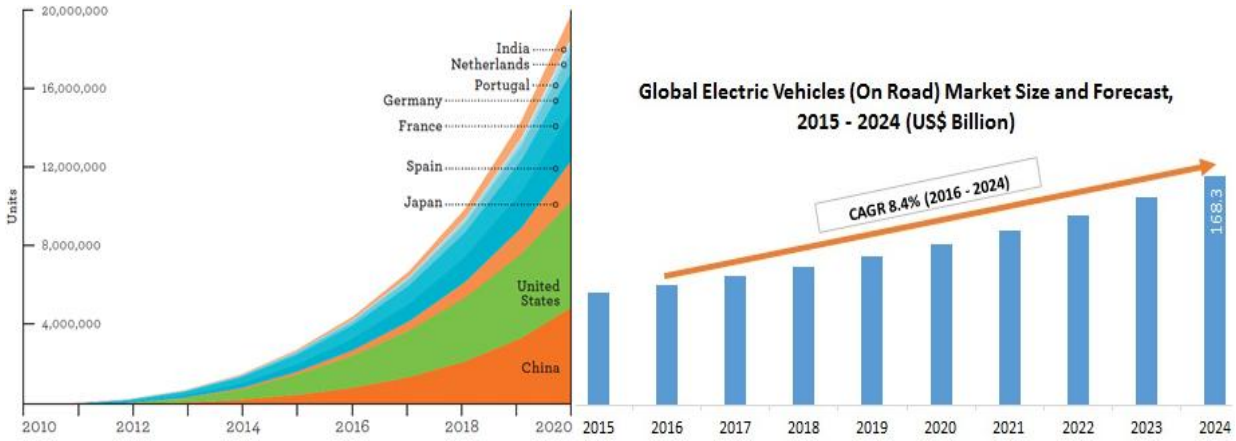

Fig. 3 Global electric vehicle production and market size

GREEN TRANSPORTATIONREQUIREMENT IN INDIA

Transpiration is one of the most significant human requests in this century. Average number of trips and the average traveled distance per man is constantly rising everywhere. Mobility is becoming a very important element of human existence which has very harmful effect on the environment by noise, vibration, accidents, area's needs, congestions and energy intensity [21-24]. Entering energy is converted in to the movement of

vehicles which provide the required transfer of goods and people in country. Thus, the transport depends on the supply of energy. Today transportation is largely dependent on oil, as the vast commons of vehicles are driven engines combusting petroleum products - hydrocarbon fuels [25-28]. Railway transport is representative mode of transportation where most railway vehicles are now powered by electric traction motors, so the rate of dependence on oil is minor than previous modes. But the fact is that in most countries the electricity is produced through petroleum products like coal [29]. All of these are non-renewable natural resources and their stocks have steadily decayed. In a price-conscious economy such as India's, the shift towards green vehicles will be slow unless spurred by government mandates. Manufacturers are placing greater faith in dual-fuel technologies than in battery-powered alternatives because the necessary support infrastructure, such as recharge stations, is not yet in place for the widespread adoption of the latter. Use of public transport in India has waned as private vehicle ownership has boomed, but increasing strain on the road infrastructure in major cities. Risk factor subcategories in green transport corridors are shown in figure 4.

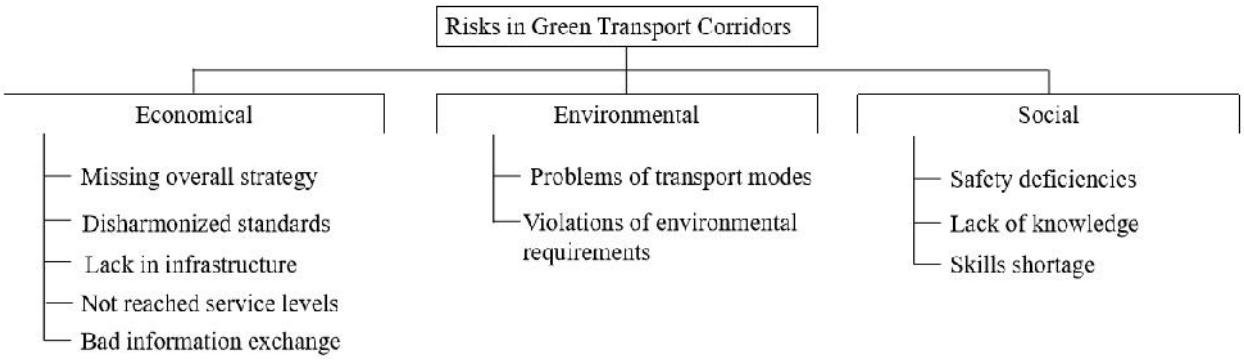

Fig. 4 Main and subcategories of arising risks in Green Transport Corridors

SOLAR HYBRID ELECTRIC VEHICLE

SHEV's are growing in popularity due to increasing governmental guidelines on industries and public opinion to reduce greenhouse gas emissions and move toward green technologies in transportation sector. Therefore, many automotive companies have already started to expand their production to capitalize on the growing electric vehicle market [30]. SHEV's offer numerous advantages over carbon footprint fuel based vehicles such as; more efficient motors, low emissions, less dependence on fossil fuels, energy storage for grid surplus and vehicle-to-grid capability for supporting grid during peak times. Electric vehicles can come in many types such as all-Battery Electric Vehicles (BEVs) and Plug- In/Hybrid Electric Vehicles (HEVs/PHEVs) which combine battery powered electric motor thrust with conventional fuel based IC engines (for long range cruising). The final BEVs with plug in technology type are currently the most popular. These types are expected to be charged in public or corporate car parks, electric charging stations and at a customer's sites. Therefore, an electric vehicle network complete with charging stations and infrastructure to support residential PEV charging is necessary for future. Typical PEV battery capabilities presently range from a few kWhs to over 50 kWh. In order to charge these batteries in a time period similar to filling the tank of a fuel based car, it is estimated that most PEVs will have multiple charging ways allowing slow to rapid charging. Lithium-ion batteries are presenting promise with their lightweight, energy dense and rapid recharge capability [31].

The SHEV's can be further split up into the following categories:

- **On road highway speed vehicles**

This type electric vehicle is capable of driving on all public roads and highways. Performance of these on road vehicles is similar to IC Engine vehicles.

- **City electric vehicles traditionally**

These BEVs that are capable of driving on most public roads, but generally are not driven on highways. Top speed is typically limited to 55 mph.

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- **Neighborhood electric vehicles**

These BEVs also known as low speed vehicles are operating on public streets posted at 35 mph or less speed.

- **Commercial On-Road Highway Speed Vehicles**

There are a number of commercial electric vehicles, including commercial trucks and buses. These vehicles are found as both BEVs and PHEVs.

FREIGHT TRANSPORT ON ROAD NETWORK IN INDIA

India has invested heavily in developing its road network over the last 25 years. India has the second largest road network of 5.4 million kilometers in the world. This road network transports more than 60 per cent of all goods in the country and 85 per cent of India's total passenger traffic. The Indian roads carry almost 90 per cent of the country's passenger traffic and around 65 per cent of its freight. In the BAU scenario, it is estimated that the share of road in total freight traffic would decline to 65% in 2016-17 and then further to 55 % in 2021-22 and 50% in 2031-32 (NTDPC, 2014) [10]. Road transport is the most significant as compare to rail because it could provide door to door service. The freight transport industry has been growing at rate of 8.5% per annum. Road freight vehicles are a key enabler of global economic activity and play an essential role in delivering all types of goods or commodities from their points of production to the factories and industries that use or transform them, or to their final points of sale. Transport industry plays a vital role in the development of economic of a nation.Transport sector accounts for 6.4% share in India's Gross Domestic Product (GDP).However, Road Transport has emerged as a dominant segment in India's transportation sector with a share of 4.8% in India's GDP as shown in figure 5. Road based freight mobility in India is mainly driven by the agricultural and industrial sector of the economy. HCVs are more common for transporting goods for longer distances. LCVs are finding more popularity as a carriage mode for navigating through the compact urban centers and also rural areas.The transportation industry in India is evolving rapidly and it is the interplay of infrastructure, technology and new types of service providers that will define whether the industry is able to help its customers reduce their transport costs and provide effective services (which are also growing). Changing government strategies on taxation and regulation of service providers are going to play asignificant role in this process. Coordination across various government agencies requires support from multiple ministries and is a road block for multi modal transport in India [8-13].

GLOBAL REFRIGERATED ROAD TRANSPORTATION MARKET

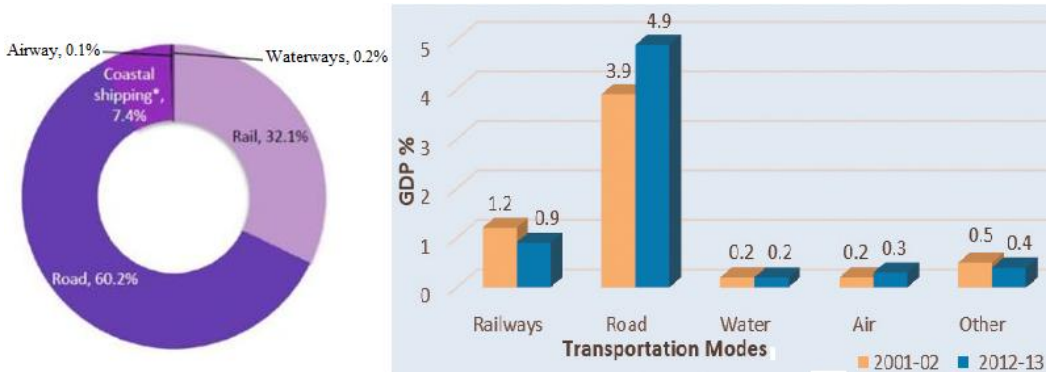

Fig. 5 total freight transport by various modes and its GDP

The global refrigerated road transportation market will grow at a CAGR of more than 26% between 2017 and 2021. Global losses in the food industry total more than $750 billion annually. Moreover, over $260 billion of annual bio-pharma products sales are dependent on cold chain. According to United Nations environment program (UNEP) and world resources institute (WRI) about one-third of the food produced are wasted every year. Fruits and vegetables had wasted about 25% at the production level. Demand for refrigerated road transportation across worldwide is increasing due to growing awareness among farmers and harvesters about

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the benefits of cold chain. Manufacturers are increasingly refrigerated trucks for delivery process to offer high-quality products. Increasing demand for frozen foods has propelled suppliers to equip their refrigerated units with multi-temperature systems to keep the food at the adequate temperature during transportation. But most of refrigerated trucks operated with IC engine and give highly environmental pollution. One of the latest developments in the market is the rapid move towards sustainable refrigeration units to reduce environmental impact and carbon footprint refrigeration [10, 16].

ROAD TRANSPORT OF PERISHABLE PRODUCTSIN INDIA

India is one of the world's largest consumers of food and the third largest producer of agriculture, according to 2015 Top Markets Report on Cold Chain by International Trade Administration. But due to fledgling cold supply chain there is a heavy loss of foodand other resources nearly 30-40 percent. These losses have been stated to be as high as US$8 to 15 billion per annum from the agriculture sector alone. There is a necessity to develop cold chain transport sector to avoid these problems. Cold supply chain involves the transportation of temperature-sensitive products. The cold chain industry has been rising at a CAGR of 20% for the last three years in 2014 to 2017. The cold chain market in India is estimated to reach Rs 624 billion (US$13 billion) by 2017. Many of products transported via different mode of transportation are perishable in their nature. Perishable products (such as agricultural products, meat, fish, shellfish, pharmaceutical products, etc.) are sensitive to a wide range of different factors, which include but are not limited to temperature, barometric pressure, humidity, air composition and transportation time [19, 20]. The demand for perishable products has been continuously growing.India also holds the distinction of being the largest producer of milk in the world and boats of having the largest livestock population. The food processing sector comprises two sectors-Primary (packaged fruits and vegetables, milk, etc., constituting around 62% in value) and Value added (processed fruits and vegetables, juices, jam & jelly etc. constituting around 38% share in the total processed food).According to Indian Brand Equity Foundation (IBEF), the food processing industry accounts for 32% of India's total food industry and 13% of Indian exports. In cold supply chain the former uses refrigerated trucks and containers transport of perishable products.Refrigerated trucks are required for maintain quality standards to ensure longer shelf life and selling value of products.But in India, most of refrigerated trucks operated with IC engine and give highly environmental pollution [23-25]. Thus our country requiressolar hybrid refrigerated electric vehicle for small and medium distance (5-70 km) for perishable products (light and medium weight freight) in ruler and urban areas.Indian government is one of the driving forces in developing solar hybrid refrigerated electric vehicle for transfer perishable product in cold chain industry and supports private participation through various subsidy schemes and grants. Temperature effect on self-life of perishable products is shown in table 1.

Table 1Temperature effect on self-life of perishable products

Food product	At optimum cold temperature	Optimum temperature + 10°C	Optimum temperature + 20°C	Optimum temperature + 30°C
Fresh fish	10 days at 0°C	4 to 5 days at 10°C	1 to 2 days at 20°C	A few hours at 30°C
Milk	2 weeks at 0°C	7 days at 10°C	2 to 3 days at 20°C	A few hours at 30°C
Fresh green vegetables	1 month at 0°C	2 weeks at 10°C	1 week at 20°C	Less than 2 days at 30°C
Potatoes	5 to 10 months at 4 to 12 °C	Less than 2 months at 22 °C°	Less than 1 month at 32 °C	Less than 2 weeks at 42 °C
Mangoes	2 to 3 weeks at 13°C	1 week at 23°C	4 days at 33°C	2 days at 43°C
Apples	3 to 6 months at -1°C	2 months at 10°C	1 month at 20°C	A few weeks at 30°C

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India has 27,000 milk tankers which work on IC engine, but these are not temperature controlled vehicle. Making proper use of all of India's cold storage capacity would require 600,000 refrigerated trucks. But in current 30,000 IC engine operated refrigerated trucks are available.According to industry estimates, approximately 104 million metric tons of perishable produce is transported in India between cities each year. About 100 million metric tons moves via non-refrigerated mode and only four million metric tons is transported by refrigerated vehicles. It has been observed that majority of the refrigerated vehicles (80%) are utilized for milk and milk products transportation. It is very clear that the high cost of transportation is a major challenge for refrigerated vehicles market.In India, at present, only 3.5% of perishable goods are transported in refrigerated trucks. As compared to this, the comparable figures are 75% for China and 85% in the US.There for transport sector innovations that include energy efficiency and usage of renewable energies may improve adoption of cost effective pollution free transport, reduce wastage and stabilize prices in market.By using solar panels in battery operated electric vehicle will achieved higher efficiency of refrigerated electric vehicle.

Fig. 6 Electric vehicle for freight and perishable products (mini mobile cold storage)

CHALLENGES FOR SHEV's IMPLEMENTATION IN INDIA

- The SHEV's technology since its inception sets a main problem of enlarged cost as a result of which it finds lower acceptance in the majority of middle class income group of Indian population
- The increase in charging station necessity is bound to be extremely high which comes with its own problems.
- The battery charging times for all vehicles are few hours, thus this leads to a lower acceptance as compared to the conventional fueled vehicles.
- The increase in demand-generation gap which is already quite high in the Indian power sector is bound to worsen if there is an increase in the use of SHEV's.
- Considering the Indian population the amount of load of power system will be extremely high during the peak load periods.
- Battery life is few years and we demanding efficient solar panels at lower cost for SHEV's.

CONCLUSION

It found that electric vehicles are making unexpectedly fast progress in all over world. The main purpose of this research paper was focused on opportunity to use solar hybrid electric vehicle for transport perishable Products in India. Fossil fuels based vehicles was one of the main source of environmental pollution. SHEV's had potential to change the face of market due to their lower petroleum consumption and toxic emissions. But it was not preferred because of their niche pricing. Some of them require immediate attention that can support in mitigating the potential challenges and provide impetus to supply chain of perishable Products sector. The initial cost of SHEV's seemed high but the operating costs of this system were reduced due to operating lower power consumption on the long run. SHEV's was specially designing to reduce both wastage and deterioration of perishable products during transportation in ruler and urban areas. It can suitably be used in many rural regions for freight and passenger transportation up to 60 km. SHEV's will be more reliable,

efficient and effective during the summer season when electricity demand is more because it work on both type of power source either on solar or grid electricity. The modern Indian transport policies must be instituted; to promote cost-effective strategies, to mitigate emissions, to encourage various operating modes and to minimize other adverse environmental effects. Therefore the final outcome of this research paper was focused toward saving transportation cost in cold storage by using solar hybrid electric vehicle.

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