

Stanje električnih lahkih motornih vozil v Indiji: Raziskava

Status of Electric Light Motor Vehicles in India: A Study

Izvilleček

Indija je četrty največji proizvajalec lahkih motornih vozil na svetu. Trenutno se v Indiji letno proizvede 4 milijone lahkih motornih vozil z motorji z notranjim izgorevanjem (ICE). Indija je začela električna vozila proizvajati leta 2015 in njihovo proizvodnjo hitro povečuje. Električna lahka motorna vozila (ELMV), ki jih poganja električni motor z akumulatorskimi baterijami z motorjem z notranjim izgorevanjem (ICE) ali brez njega, ki so opremljena z menjalnikom kot tudi z diferencialom, so proizvajajo v velikem obsegu. Hibridno električno lahko motorno vozilo (HELMV) poganjata tako motor z notranjim izgorevanjem kot baterija. Pod sistemi HELMV so baterija, elektromotor, močnostna elektronika in prenos, napajalni sklopnik, motor z notranjim izgorevanjem. V tem prispevku so opredeljeni hibridno električno vozilo in njegovi pod sistemi ter obravnavani različni sistemi pogonskega sklopa, in sicer zaporedni, vzporedni, zaporedno-vzporedni in kompleksni. Poskušali smo tudi ugotoviti stanje proizvodnje vozil HELMV in njihovo rast v prihodnosti do leta 2030, prepoznane pod sisteme, primerne za indijsko avtomobilsko industrijo, skupaj s tehnično-gospodarsko analizo.

Ključne besede: lahka motorna vozila, hibridna električna lahka motorna vozila, motor z notranjim izgorevanjem, pogonski sistem, močnostna elektronika in tehnično-gospodarska analiza

Abstract

India is the fourth largest Light Motor Vehicle (LMV) manufacturer in the world. Presently production of 4 million LMVs has been produced annually using internal combustion engines (ICE). India has started the manufacturing of electric vehicles (EVs) since 2015 and has been increasing production rapidly. Electric Light Motor Vehicles (ELMV) driven by electric motors powered by rechargeable batteries with or without IC engine (ICE) coupled with transmission including differential have been widely manufactured. Hybrid Electric Light Motor Vehicle (HELMV) is propelled by both ICE and battery. HELMV sub-systems comprise of battery, electric motor, power electronics and transmission, power coupler, and ICE. In the present work hybrid electric vehicle and their sub-systems have been identified and different power train systems namely series, parallel, series-parallel, and complex are discussed. An attempt has also been made to find the status of HELMV manufacturing and its future growth by 2030AD, sub-systems identified as suitable to the Indian automobile industry along with techno-economic analysis.

Keywords: Light motor vehicle, Hybrid electric light motor vehicle, Internal combustion engine, Power train system, power electronics, and Techno-economic analysis.

1 Uvod

Prvi avtomobil v Indiji je vozil po tamkajšnjih cestah že leta 1897, prvi indijski avtomobil pa je leta 1942 izdelalo [1] podjetje Hindustan Motors v sodelovanju s podjetjem Morris Motors iz Združenega kraljestva. Indija je četrta največja proizvajalka lahkih motornih vozil na svetu z letno proizvodnjo 4 milijonov vozil, skupaj pa se v Indiji proizvede 30 milijonov vozil, ki jih poganjajo motorji z notranjim izgorevanjem (ICE). ICE proizvajajo toplogredne pline, ki predstavljajo 13 % CO₂. Električna vozila to težavo rešujejo. Električna vozila so bila razvita pred izumom vozil z motorjem z notranjim izgorevanjem (ICEV). Britanski izumitelj Robert Anderson je leta 1832 zasnoval in izdelal prvo električno vozilo, ki je postalo priljubljeno konec 19. stoletja [2]. Zaradi padca cen nafte in potrebe po daljši vozni razdalji so se na začetku 20. stoletja razvila vozila ICEV.

2 Pregled literature

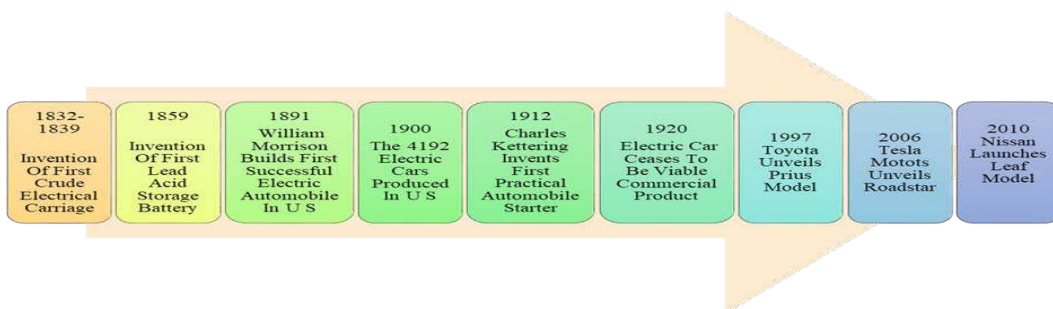
Zgodovinski razvoj električnih lahkih motornih vozil [3] je prikazan na Sliki 1. Priljubljenost električnih vozil je začela upadati zaradi izuma električnega avtomobilskega zaganjalnika, ki ga je leta

1 Introduction

The first car in India that plied on Indian roads was as early as 1897 and the first car was manufactured [1] by Hindustan Motors, in collaboration with Morris Motors, UK in 1942 AD. India is the fourth largest LMV producer in the world with an annual production of 4 million and cumulative plied vehicles of 30 million which are operated by internal combustion engines (ICE). The ICEs produce greenhouse gases which account for 13% of CO₂. Electric vehicles address this problem. Electric vehicles were developed before the invention of internal combustion engine (ICEV) vehicles. The British inventor Robert Anderson designed and manufactured the first electric vehicle in 1832 AD which later became popular at the end of the 19th century [2]. Due to the fallout of oil prices and the need for longer drive distances ICEVs were evolved at the beginning of the 20th century.

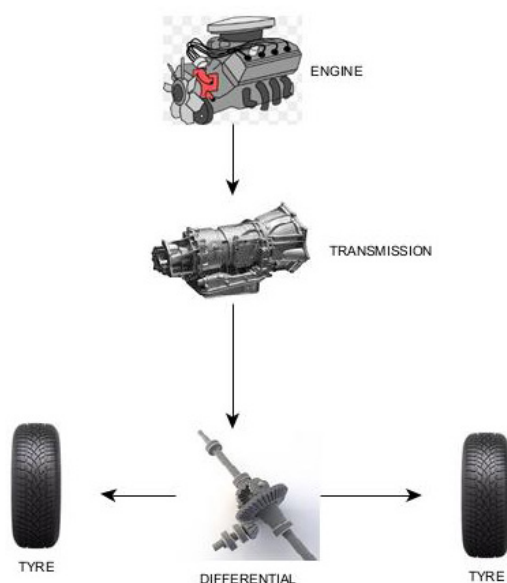
2 Literature Review

The historical development of electric light motor vehicles [3] is depicted in Figure 1. The decline of electric vehicles started due to the invention of the electric automobile starter by Charles Kettering in 1912 AD.



Slika 1. Zgodovinski razvoj električnih lahkih motornih vozil

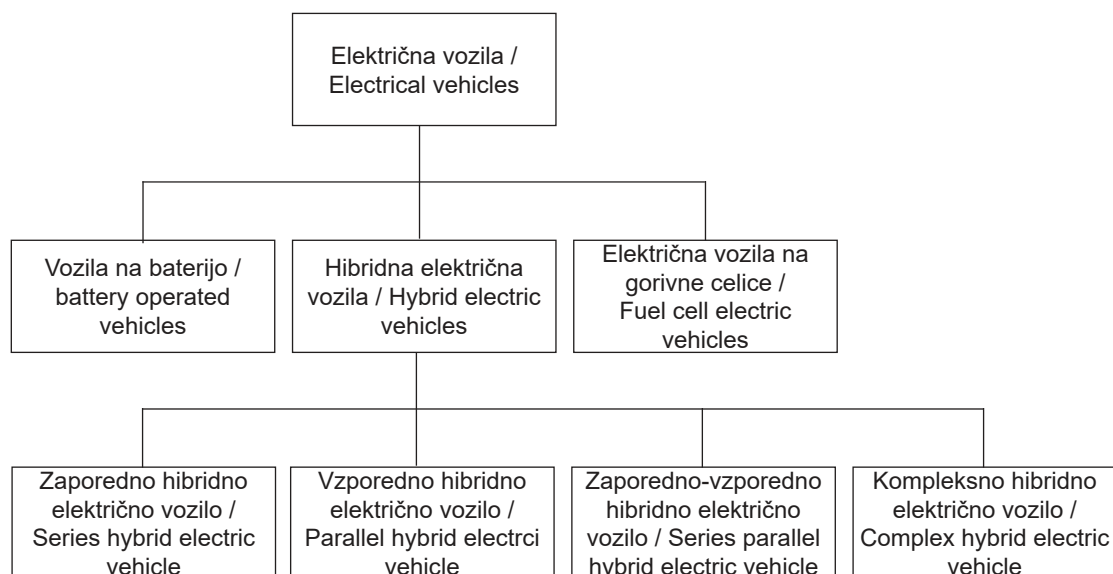
Figure1. Historical Development of Electric LMV



Slika 2. Pod sistemi lahkega motornega vozila

Figure 2. LMV Sub Systems

During the 1920s the electric car ceases to be a commercially viable product and its downfall is necessitated by a number of factors including the desire for longer distances and readily availability of fuel with limited horsepower and lack of infrastructure facility for battery charging. Again in 1997 AD Toyota launched Pirus new model of electric vehicle that sold 18,000 units and followed by Tesla Motors launched Roadstar in 2006 AD. Later Nissan Company introduced its new electric car namely 'The Leaf' capable of achieving a maximum speed of 140 kmph and can travel 160 km on a full charge. In 2015 India also launched electric light motor vehicles of three wheelers and four wheelers category. Tata Motors is the largest electric car manufacturer followed by M G Motors and cumulative sales of 0.42 million units.



Slika 3. Pod sistemi električnega lahkega motornega vozila

Figure 3. ELMV Sub Systems

1912 izumil Charles Kettering. V dvajsetih letih 20. stoletja električni avtomobil ni več komercialno uporaben izdelek, njegov propad pa je posledica številnih dejavnikov, med drugim želje po daljših potovanjih in dobri dostopnosti goriva kot tudi omejene moči ter pomanjkanja infrastrukture za polnjenje akumulatorjev. Leta 1997 je podjetje Toyota ponovno predstavilo nov model električnega vozila Pirus in prodalo 18.000 enot, leta 2006 pa je podjetje Tesla Motors predstavilo vozilo Roadstar. Nato je podjetje Nissan predstavilo svoj novi električni avtomobil Leaf, ki lahko doseže največjo hitrost 140 km/h in s polnim polnjenjem prevozi 160 km. Leta 2015 je Indija začela proizvajati tudi električna lahka motorna vozila, in sicer iz kategorije trikolesnikov in štirikolesnikov. Podjetje Tata Motors je največji proizvajalec električnih avtomobilov, sledi mu podjetje M G Motors, njuna skupna prodaja pa znaša 0,42 milijona enot.

3 Motorji z notranjim izgorevanjem in njihovi podsistemi za lahka motorna vozila

Sistem lahkega motornega vozila [4] je sestavljen iz šasije, motorja, električnega sistema, pogonskega sistema, sistema vzmetenja, zavornega sistema in karoserije. To je prikazano na Sliki 2. Šasija obsega motor, pogonski sistem, sistem vzmetenja, krmilni sistem in zavore.

4. Električna lahka motorna vozila in njihovi podsistemi

Razvrstitev električnih lahkih motornih vozil je prikazana na Sliki 3.

3 Internal Combustion Engines and Its Sub-Systems for Light Motor Vehicles

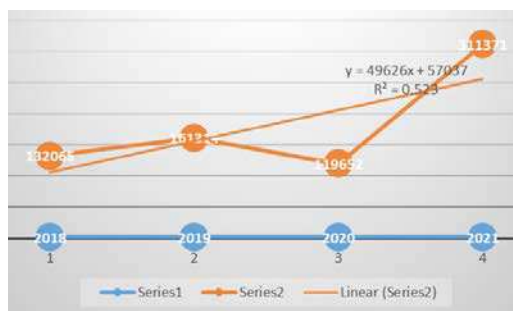
Light Motor Vehicle (LMV) system [4] consists of a chassis, engine, electrical system, transmission system, suspension system, brake system, and body. It is shown in Fig. 2. The chassis houses an engine, transmission system, suspension system, steering system, and brakes.

4 Electric Light Motor Vehicle and Its Sub-Systems

The classification of ELMVs is shown in Fig. 3.

5 Status of Electric Vehicles

The Forecast of Electric Vehicles [5] is presented in Table 1 and presented graphically in Fig. 4 and the cost break-up of major EV sub-systems is shown in Fig. 5.



Slika 4. Stanje električnih vozil

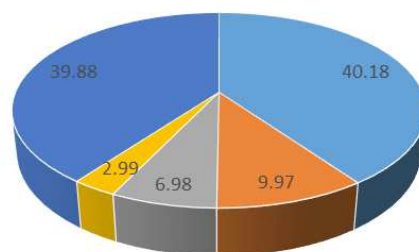
Figure 4. Status of Electric vehicles

5 Stanje električnih vozil

Napoved za električna vozila [5] je predstavljena v Preglednici 1, grafični prikaz je na Sliki 4, razčlenitev stroškov glavnih podsistemov električnih vozil pa je prikazana na Sliki 5.

6 Hibridno električno vozilo

Hibridno električno vozilo (HEV) [7] poganja motor z notranjim izgorevanjem in električni pogonski sistem, prikazan je na Sliki 6. HEV deluje na podlagi električnega pogonskega sistema, čeprav je potreba po moči majhna. Hibridno vozilo sestavlja pet glavnih delov: akumulator, motor z notranjim izgorevanjem (ICE), generator, naprava za delitev moči in elektromotor. Elektromotor pridobiva energijo iz naprave za shranjevanje energije, ki se v hibridnem avtomobilu imenuje akumulator. Ko vozilo potrebuje večjo hitrost, HEV preklopi na ICE. Akumulatorji se polnijo prek ICE; v vozilih HEV se za pridobivanje energije uporablja regenerativno zaviranje. Pogon z motorjem z notranjim izgorevanjem deluje tako, da motor kot generator proizvede nekaj energije in jo shrani v akumulatorju.



- BATTERY
- ELECTRIC DRIVE
- POWER ELECTRONICS
- VEHICLE INTERFACE
- NON POWER TRAIN COMPONENTS

Slika 5. Odstotek stroškov sistemov električnih vozil

Figure 5. Percentage of Cost of EV Systems

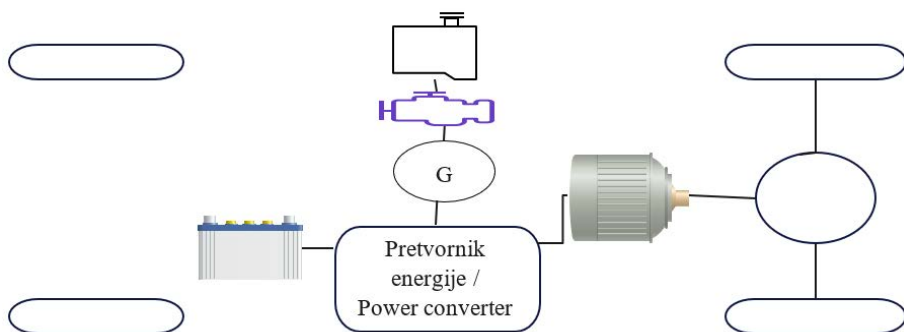
6 Hybrid Electric Vehicle

Hybrid Electric Vehicle (HEV) [7] is propelled by both an ICE and an electrical power train to power the vehicle and it is shown in Fig. 6. An HEV utilizes the electric propulsion system although the demand for power is low. Five main parts make up the hybrid vehicle which include the battery, internal combustion engine (ICE), generator, power split device, and electric motor. The electric motor derived energy from energy storage devices called batteries in a hybrid car. The HEV switches to the ICE when the vehicle needs higher speed. The batteries are

Preglednica 1. Napoved števila električnih vozil v Indiji 2022–2030

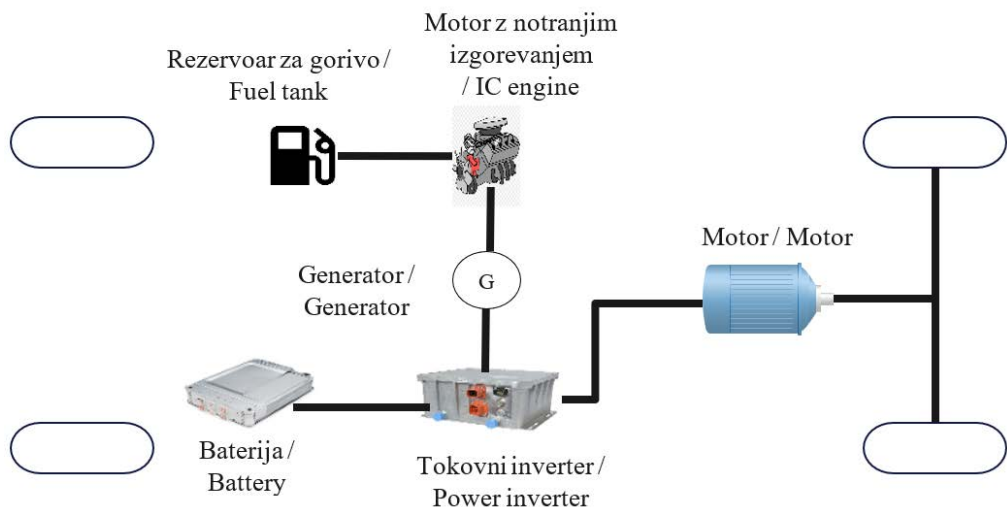
Table 1. Forecast of EVs in India 2022-2030

Leto / Year	2 W	3 W	4 W	6 W	Vsa električna vozila / all EVs
Enačba napovedi / Forecast Equation	$Y = 31688X - 47896$	$Y = 22558X - 15418$	$Y = 681,39X^2 - 4547,4 + 6385,5$	$Y = 36,887X^2 - 217,14X + 252,37$	$Y = 55946X - 67450$
Leto / FY 2025	300672	232720	38812	2327	547956
Leto / FY 2030	459112	345510	108062	6221	827686



Slika 6. Deli hibridnega lahkega motornega vozila

Figure 6. Parts of a hybrid Light Motor vehicle



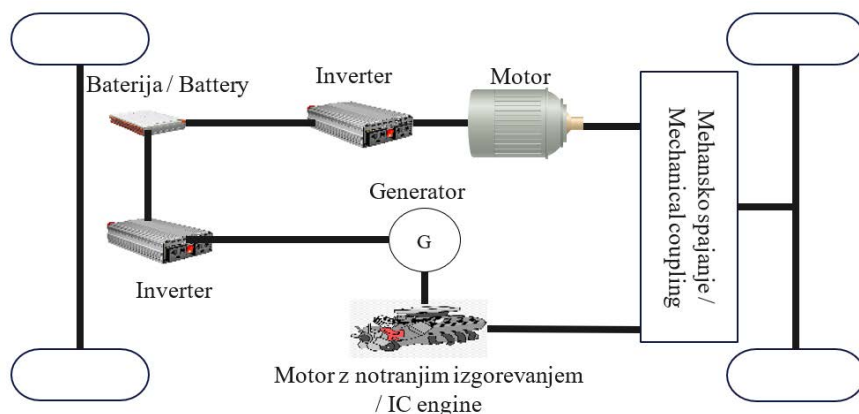
Slika 7. Zaporedno hibridno električno vozilo

Figure 7. Series Hybrid Electric Vehicle

6.1 Zaporedno hibridno električno vozilo

Zaporedno hibridno vozilo je podobno baterijskemu električnemu vozilu (BEV), ki je prikazano na Sliki 7. Motor z notranjim izgorevanjem poganja električni generator, namesto da bi neposredno poganjal kolesa.

charged by ICE; the regenerative braking is used in HEVs to recover energy. The propulsion of ICE works as the motor as a generator to produce some power and store it in the battery.



Slika 8. Zaporedno-vzporedno hibridno električno vozilo

Figure 8. Series Parallel Hybrid Electric Vehicle

Preglednica 3. Tehnično-gospodarska analiza podsistemov električnih vozil v letih 2020 in 2030

Table 3. Techno-Economic Analysis of EV sub-systems in 2020 and 2030AD

Podsistemi električnih vozil / EV Sub-systems	Odstotek deleža v stroških leta 2022 / Percentage of Share in Cost in 2022	Stroški v letu 2022 (v INR) / Cost in 2022 i(n INR)	Odstotek deleža v stroških v letu 2030 / Percentage of Share in Cost in 2030	Stroški v letu 2030 (v INR) / Cost in 2030 (in INR)
Paket baterij / Battery pack	40,18	5,59,806	18	1,78,707
Električni pogon / Electric drive	9,97	1,38,875	9,97	1,38,875
Napajalna elektronika / Power electronics	6,98	97,212	6,98	97,212
Vmesnik vozila / Vehicle interface	2,99	41,662	2,99	41,662
Brez pogonskega sistema / Non-Power Train	39,88	5,55,550	39,88	5,55,550
Stroški električnega avtomobila (v INR) / Cost of an electric car (in INR)		13,93,106		10,12,000

Generator polni akumulator in napaja elektromotor, ki poganja vozilo. Kadar je potrebna večja moč, motor črpa električno energijo iz akumulatorja in generatorja.

6.1 Series Hybrid EV

A series hybrid is like a battery electric vehicle (BEV) as shown in Fig.7. Here,

6.2 Zaporedno-vzporedno hibridno električno vozilo

Vozilo lahko poganja samo bencinski motor, električni motor ali oba pretvornika energije, ki delujeta skupaj, kar je prikazano na Sliki 8. Razporeditev moči med motorjem in električnim motorjem je zasnovana tako, da lahko motor v največji meri deluje v optimalnem območju delovanja.

7 Tehnično-gospodarska analiza električnega vozila

Stroški različnih podsistemov električnih vozil, kot so baterija (40,18 %), močnostna elektronika (9 %), vmesnik vozila (2,99 %) in drugi podsistemi (39,88 %), so predstavljeni v Preglednici 3. Prikazana je tudi ocena stroškov do leta 2030. Stroški se bodo do leta 2030 po vsej verjetnosti močno zmanjšali.

8 Sklepi

Napovedi pravijo, da bo proizvodnja električnih vozil do leta 2030 znašala približno 1 milijon vozil. Hibridna električna lahka motorna vozila (ELMV), ki jih poganjajo tako ICE kot baterije, so primernejša za indijski sektor lahkih motornih vozil. V tem prispevku so opredeljeni hibridno vozilo in njegovi podsistemi ter različni sistemi pogonskih sklopov, in sicer zaporedni, zaporedno-vzporedni. Tehnično-gospodarska analiza kaže, da se bodo stroški baterij do leta 2030 verjetno zmanjšali s 40 % na 18 % stroškov električnega vozila. Opredeljeni podsistemi ELMV, primerni za indijske razmere, skupaj s tehnično-gospodarskimi dejavniki. Stroški električnih vozil se bodo do leta 2030 močno znižali. Uvedba in uporaba električnih vozil bo prispevala k zmanjšanju toplogrednih

the combustion engine drives an electric generator instead of directly driving the wheels. The generator both charges a battery and powers an electric motor that moves the vehicle. When large amounts of power are required, the motor draws electricity from both the battery and the generator.

6.2 Series-Parallel Hybrid EV

The vehicle can be powered by the gasoline engine working alone, the electric motor by itself, or by both energy converters working together and is shown in Fig. 8. Power distribution between the engine and motor is designed so that the engine can run in its optimum operating range as much as possible.

7 Techno Economic Analysis of Electric Vehicles

The cost of various EV sub-systems like a battery (40.18%), power electronics (9%), vehicle interface (2.99%), and non-powertrain (39.88%) is presented in Table 3. Cost estimation by 2030 is also shown. The costs are likely to reduce drastically by 2030 AD.

8 Conclusions

The Forecast for production of EVs will be around 1 million vehicles by 2030 AD. Hybrid Electric Light Motor Vehicle (ELMV) propelled by both ICE and battery are more suitable for the Indian LMV sector. In the present work hybrid vehicle and their sub-systems were identified and different power train systems namely series, and series parallel are discussed Techno Economic

plinov in izzivov, s katerimi se soočajo avtomobilski proizvajalci.

9 Zahvala

Avtorji se iskreno zahvaljujejo Severo-vzhodnemu regionalnemu inštitutu za znanost in tehnologijo (velja za univerzo), Nirjuli, Itanagar, Arunachal Pradesh, Indija, za potrebno pomoč pri tem prispevku in gospe Mirjam Jan-Blažič, predsednici Društva livarjev Slovenije ter 62. mednarodnemu livarskemu posvetovanju v Sloveniji, ker so nam omogočili predstavitev prispevka na konferenci.

Analysis shows that battery cost is likely to reduce from 40% to 18% of the cost of the EV by 2030 battery. ELMV subsystems were identified suitable to Indian conditions along with technoeconomic factors. The cost of EVs will significantly be expected to reduce by 2030AD. The introduction and use of EVs will address in reduction of the greenhouse gases problem and challenges faced by Auto Manufacturers.

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