JETIR.ORG ISSN: 2349-5162 | ESTD Year : 2014 | Monthly Issue
JOURNAL OF EMERGING TECHNOLOGIES AND INNOVATIVE RESEARCH (JETIR)
An International Scholarly Open Access, Peer-reviewed, Refereed Journal

ELECTRIC VEHICLES: A COMPUTATIONAL THEORY AND MARKET ANALYSIS

[1]Akshay S. Chobe, [2]Pooja S. Chobe
[1]Student, [2]Assistant Professor
[1]Department of mechanical engineering, Pune, India
[2] Department of electrical engineering, Sanjivani College of Engineering,
Kopargaon, India

Abstract: In many nations, despite the significant public subsidies and technological advancements, the market for electric vehicles is not growing at the predicted rate. One cause could be the absence of successful business concepts that would enable commercialization and widespread adoption of electric vehicles. Business models that worked well for conventional cars may not work well for electric vehicles due to technological constraints like reduced driving range, long charging cycles, and higher purchasing costs. However, a substantial body of scholarly literature on electric car business models has emerged in recent years. Nonetheless, these insights are fragmented and rarely address the company model in its entirety. We explore pertinent concepts about electric car business models and synthesize essential findings along with each business model feature in this literature review. The paper integrates insights from the scientific literature about EV business models all around the globe. This research develops various key insights along with the necessary quantifying elements regarding electric power. These propositions integrate knowledge on the electric vehicles (EV) market and the benchmarking of each component element in detail. Various batteries are classified according to different scenarios with their pros and cons, which motivates us to select the best outcome for the future service. Finally, a typical 2-wheeler motorcycle is taken into consideration for the purpose of the ideal calculation. The overall evaluation also contains a possible solution to prospective market threats, and in this way, our study gives a concise and complete assessment of current research while also indicating new avenues for future research for scholars**.**

Keywords **- Electric vehicle, EV batteries, Li-ion batteries, market analysis.**

I. INTRODUCTION

The automobile industry, which dates back more than a century, is preparing for change. Individual transportation habits have shifted due to the increase in the price of fossil fuels and the environmental impact of their emissions. The automotive industry slowly transitions away from internal combustion engines and moves toward electric vehicles (EVs).

Electric vehicles are powered by rechargeable batteries or some other form of portable power storage and are propelled by electric motors. These vehicles are more energy-efficient, transmit fewer greenhouse gases (GHGs), and operate at a lower noise level. Transportation contributes approximately one-fourth of total Greenhouse gas emissions. Vehicles are the primary source of Greenhouse gas emissions worldwide, accounting for 25.9 percent of emissions in China, 13.87 percent in the United States, and 7.45 percent in India.

The electric vehicle is a battery-operated and motor-driven vehicle which especially designed for reducing the excessive use of fossil fuels. Attributed to the fact that it is battery powered, it produces no pollution. A typical electric vehicle requires a couple of rechargeable batteries. The amount of time an electric vehicle can operate on a single charge is highly dependent on the type, rating, and capacity of its battery. The most common batteries advertise a run time of approximately eight hours and a distance of approximately 20-30 miles before needing to be recharged. Certain individuals are hesitant to purchase an electric vehicle due to concerns about battery damage scenarios, which can be costly, and battery recharging techniques, which are pretty time-consuming. Given the current state of the fuel markets, EV batteries are the most efficient way to power automobiles, and further research will undoubtedly alleviate the current difficulties associated with battery charging. So here is some work proposed related to the selection criterion of Battery cells.

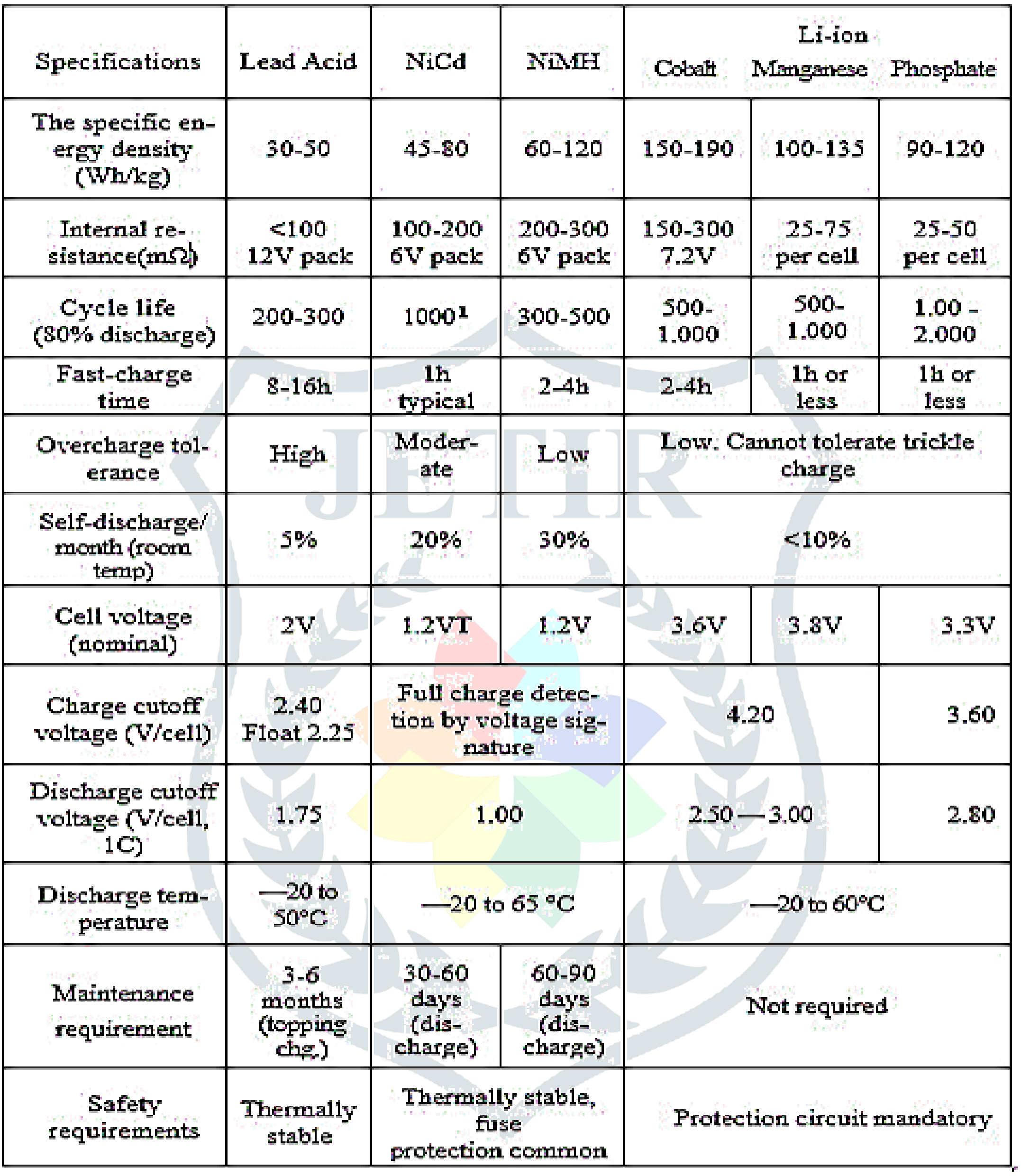
II. SELECTION OF THE BATTERY CELL

There are many battery sources available for electric vehicles in the market in the current scenario, so we are considering various compositions for battery benchmarking.

2.1 Battery benchmarking

There are several battery parameters to consider. Some parameters are more critical than others depending on the application for which the battery is used. For example, the energy density of a modern battery for a general car is irrelevant since the battery is a minor fraction of the overall battery weight, so this parameter will normally not be specified for a conventional car battery. However, since the battery weight is a significant portion of the overall vehicle weight in electric vehicle applications, the energy densities will be given.

Table 1. Benchmarking of various batteries



Specifications	Lead Acid	NiCd	NiMH	Li-ion		
				Cobalt	Manganese	Phosphate
The specific energy density (Wh/kg)	30-50	45-80	60-120	150-190	100-135	90-120
Internal resistance(mΩ)	<100 12V pack	100-200 6V pack	200-300 6V pack	150-300 7.2V	25-75 per cell	25-50 per cell
Cycle life (80% discharge)	200-300	1000[1]	300-500	500-1.000	500-1.000	1.00 - 2.000
Fast-charge time	8-16h	1h typical	2-4h	2-4h	1h or less	1h or less
Overcharge tolerance	High	Moderate	Low	Low. Cannot tolerate trickle charge		
Self-discharge/ month (room temp)	5%	20%	30%	<10%		
Cell voltage (nominal)	2V	1.2VT	1.2V	3.6V	3.8V	3.3V
Charge cutoff voltage (V/cell)	2.40 Float 2.25	Full charge detection by voltage signature		4.20		3.60
Discharge cutoff voltage (V/cell, 1C)	1.75	1.00		2.50—3.00		2.80
Discharge temperature	—20 to 50°C	—20 to 65 °C		—20 to 60°C		
Maintenance requirement	3-6 months (topping chg.)	30-60 days (discharge)	60-90 days (discharge)	Not required		
Safety requirements	Thermally stable	Thermally stable, fuse protection common		Protection circuit mandatory		

2.2 Why Lithium-ion batteries?

Lithium-ion batteries, in fact, have a higher energy density than other types of batteries; they are now used in the majority of portable consumer electronic devices, including mobile phones, laptop computers, digital cameras, and electric and hybrid vehicles. Additionally, they feature a high power-to-weight ratio, high efficiency at elevated temperatures, and a low self-discharge rate. While the majority of lithium-ion battery components are recyclable, the industry is still facing material recovery costs. While lithium-ion batteries are used in today's PHEVs and EVs, they use a different chemistry than batteries used in consumer electronics. There is ongoing research and development aimed at lowering their relatively high cost, extending their useful life, and addressing safety concerns about overheating.

2.3 Raw available materials for a Li-ion Battery

Lithium, manganese, cobalt, and graphite are all important raw ingredients in the production of Li-ion batteries (LIBs). As the number of electric vehicles on the road grows, so does the demand for lithium-ion battery cell production for vehicles. This project will look into the relationship between raw materials and the renewable energy supply chain. We look at cobalt and lithium, two important raw materials needed to make cathode sheets and electrolytes, two important Li-ion battery components.

III. SUPPLY MANAGEMENT CHAIN

3.1 Market of Lithium & Demand for the production of EV li-ion batteries

Lithium metal is usually recovered from a brine solution or a hard rock (spodumene). The shallow brine beneath Bolivia's Salar de Uyuni is thought to have the country's largest lithium reserve, with estimates ranging from half to more than half of the total. Lithium is collected from subsurface salar brine by digging and pumping liquids to evaporation ponds. Lithium is recovered from the ore via hard rock lithium recovery. Australia had the majority of spodumene reserves in 2018, whereas Chile, Argentina, and China controlled the majority of lithium brine reserves. Mining (from brine or spodumene), beneficiation, and processing into lithium carbonate are all part of the supply chain. Battery precursors are made from refined lithium carbonate by manufacturers of cathode active material and electrolytes. Lithium carbonate and lithium hydroxide are both utilised in the production of LIB cells, however the former has been employed more commonly due to the higher expense of processing lithium hydroxide. However, most Li-ion battery materials used in electric vehicles, such as nickel cobalt aluminium (NCA) and nickel manganese cobalt (NMC), require lithium hydroxide; as the customer base of LIB electric vehicles develops, more lithium hydroxide will be required. Lithium carbonate is commonly used as a base for lithium hydroxide, which necessitates an extra processing step and hence raises the price.

3.2 Market of Cobalt & Demand for the production of EV li-ion batteries

The cobalt supply chain comprises three major components: mining, mineral processing to create concentrates, and refining (through metal and chemical refineries). Manufacturers of cathode active materials source chemicals (battery precursors) from chemical refineries. Cobalt is frequently extracted as a byproduct of the copper or nickel mining processes. Between 2018 and 2021, 68% of cobalt extracted was a byproduct of copper extraction, 30% of cobalt extracted was a byproduct of nickel extraction, and only 2% was extracted from primary cobalt mines. The Central African Copperbelt, which spans nations such as the Democratic Republic of the Congo, the Central African Republic, and Zambia, is home to the majority of cobalt resources.

Reduced copper and nickel prices contributed to a reduction in cobalt output. Metal oversupply and economic slowdowns in emerging markets like China were cited as reasons for the declines. (The majority of countries experienced a decline in cobalt demand over this period, but the DRC remained unaffected. This could be partly explained by the DRC's vast cobalt reserves, which enable it to operate financially even when cobalt prices are low, and the participation of artisanal miners ready to accept lower cobalt prices.

Between 2018 and 2021, the DRC extracted around 54% of the country's cobalt. (See Figure 1.) The majority of the country's revenue-generating mines are owned by Chinese companies. Chinese firms active in the DRC include China Molybdenum Co., Ltd., Jinchuan Group, Shalina Resource, Zhejiang Huayou Cobalt, Wanbao Mining, and Nanjin Hanrui Cobalt. Similarly, China generated around 46 percent of refined cobalt globally over the same period. China's interest in cobalt mining and refining stems from its dominance in the production of LDV LIBs and its commitment to supply chain security.

The demand for lithium-ion batteries for electric vehicles increased by 192 percent between 2018 and 2021, from 11,000 to 32,000 MWh. Electric vehicles boosted their share of global cobalt consumption from 1.4 percent to 5% of total mine output at the same time. China remained the world's greatest producer of cobalt in 2018, which is needed to build cathode effective materials for lithium-ion batteries used in electric vehicles. Cobalt is also used extensively in Japan, South Korea, and Belgium. Between 2018 and 2021, cobalt usage in EVs declined somewhat in Japan, South Korea, and Belgium, but it climbed dramatically in China. Cobalt usage in China may have increased as a result of increased domestic and global demand for electric vehicles.

3.4 Indonesia the key for the nickel metal

EVs will require a large amount of nickel by the mid-2020s, even though the battery sector's proportion of nickel demand is significantly smaller than other metals. Due to the low nickel price, any project development has been hampered, and with lead times of up to ten years, the investment must be made immediately. While high-nickel ternary batteries will increase nickel demand, our long-term shortfalls are becoming more manageable as cobalt needs. Much of growth is attributable to Indonesia's expanding capacity to serve both the stainless steel and rising battery markets.

3.5 Demand for graphite and business

The foundations of graphite haven't changed much. Despite the enormous magnitude of demand, we do not anticipate any supply-side issues in natural graphite flake due to the expanding supply from East Africa. Given the possible disruption of needle coke feedstock as the conclusion of the new IMO 2020 regulations with the expansion in China's steel sector, synthetic graphite poses a greater problem.

3.6 Manganese a key component of NMC batteries

The steel industry dominates the manganese business, which is unlikely to alter no matter how many electric vehicles are on the road. While a consistent supply of manganese sulfate will be critical for NMC battery manufacturers, we do not anticipate any supply-side concerns.

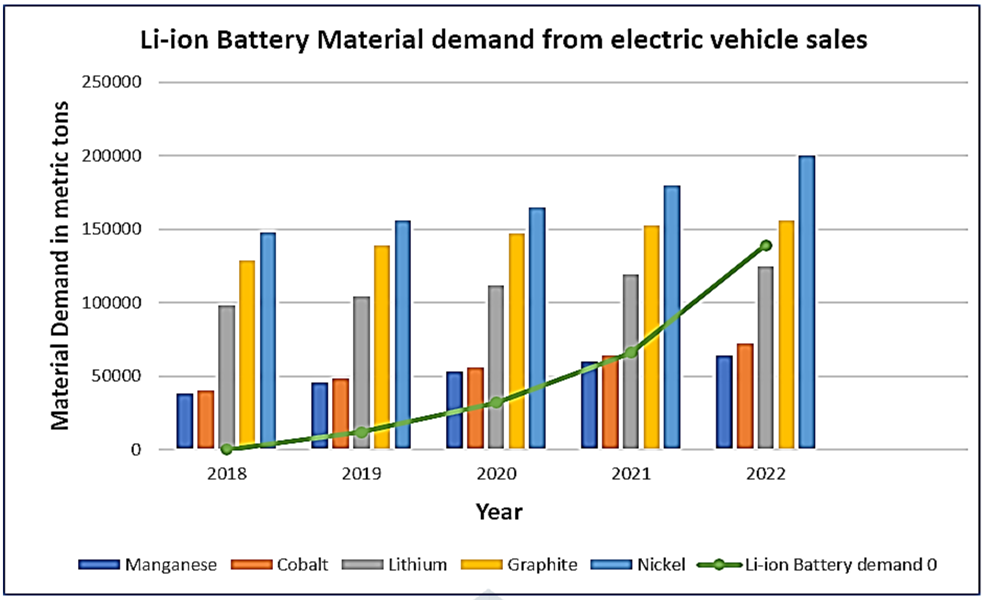


Fig. 1. Li-ion battery material demand from electric vehicle sales from the year 2018-2022.

IV. BATTERY PARAMETERS

The rechargeable battery business exclusively focuses on the electric vehicle sector (including pure EVs and hybrids). Other industry areas such as energy storage and the decrease in battery prices due to increased economies of scale are projected to gain from battery technology improvements focused toward EVs.

Batteries come in various sizes and shapes, ranging from tiny cells used in hearing aids and wristwatches to small, thin cells used in smartphones to large lead-acid batteries used in cars and trucks. In the past, the only way to increase a battery's performance was to increase its size. This made it difficult for engineers to design a battery that could be used in various applications. However, this has changed with the introduction of new technologies such as lithium-ion and lithium polymer batteries. The battery is an electrochemical device that converts chemical energy into electrical energy. It has several parameters that describe its performance in a given application.

The lithium-ion battery industry's expected expansion will place a growing strain on the supply chain for battery materials, both for the cathode (lithium, cobalt, nickel, and manganese) and the anode (lithium, cobalt, nickel, and manganese) (graphite). Capacity increases are on pace to guarantee that there is enough supply to fulfil the lithium market's needs through the end of the decade. Following parameters are taken into consideration while choosing an appropriate li-ion battery for specific use:

4.1 Specific power

Several batteries have a high energy density but a low specific power, which indicates they can store a large quantity of energy but quickly supply a little amount of power. This signifies that vehicles can travel large distances at a low pace in terms of transportation. However, high-specific-power batteries often have a poor energy density due to the quick depletion of accessible energy by high discharge currents (e.g., high acceleration)

Nevertheless, high-specific-power batteries often have a poor energy density due to the quick depletion of accessible energy by high discharge currents (e.g., high acceleration)

4.2 Specific energy

Specific energy, often known as energy density, is the amount of energy per unit mass. It's also known as gravimetric energy density or simply energy density, though energy density refers to the amount of energy per unit volume. The joule per kilogram (J/kg) is the SI unit for specific energy.

4.3 Safety

One of the most important factors to consider when selecting a battery pack for an electric vehicle is safety. A single positive incidence in the media might shift public opinion against this kind of vehicle. When steam engines burst and fuel tanks burst into flames 100 years ago, there were similar anxieties. A thermal runaway battery is the main problem. While well-designed safety circuits and sturdy enclosures nearly remove this risk, a severe disaster is still conceivable. Additionally, when a battery is used incorrectly or as it matures, it must be secure.

4.4 Life span

The term "life span" refers to the number of cycles a person has completed and how long they have lived. The majority of EV batteries have a guarantee of eight to ten years or 160,000 kilometres (100,000 miles). Ageing-related capacity loss is difficult to regulate, especially in hot regions. Automobile manufacturers are oblivious to the ageing process of batteries under a range of customer and environmental circumstances. EV manufacturers increase the size of the batteries to compensate for power loss, allowing for some degeneration during the battery's guaranteed service life.

4.5 Performance

Performance is closely tied to the battery's level of charge, whether driving the EV in blistering summer heat or frigid winter weather. Batteries are temperature sensitive and need climate control, unlike an IC motor, which can function over a broad temperature range. The energy necessary to regulate the battery temperature as well as heat and cool the cabin comes from the battery in autos that operate solely on batteries.

4.6 Cost

A big drawback is the cost. There is no certainty that the battery will reach BCG's stated goal price of $250–400 per kWh. Complicating things further is the demand for safety security loops, battery management systems for stability, temperature control for longevity, and an 8–10-year guarantee. The cost of the battery by itself is comparable to the cost of a regular automobile, thereby doubling the EV's cost.

V. VARIOUS LITHIUM-ION BATTERIES BENCHMARKING

There is no perfect candidate for electric powertrains; lithium-ion continues to be a viable option. Li-nickel-manganese-cobalt (NMC), Li-phosphate, and Li-manganese stand out as superior candidates. Although it was previously believed that the standard Li-cobalt battery used in consumer goods was insufficiently robust, the Tesla Roadster and Smart Fortwo ED are powered by this high energy density "computer battery."

The Figure below compares batteries based on their protection, specific energy, also known as energy density or capacity; specific power, or the ability to deliver a high current on demand; efficiency, or the ability to operate in extreme heat and cold; life period, which includes both cycle life and calendar life; and cost. The graph does not include charge times. All batteries used in EV powertrains can be charged relatively quickly if an appropriate electrical power outlet is available. For most users, a few hours of charging is sufficient; super-fast charging is an exception.

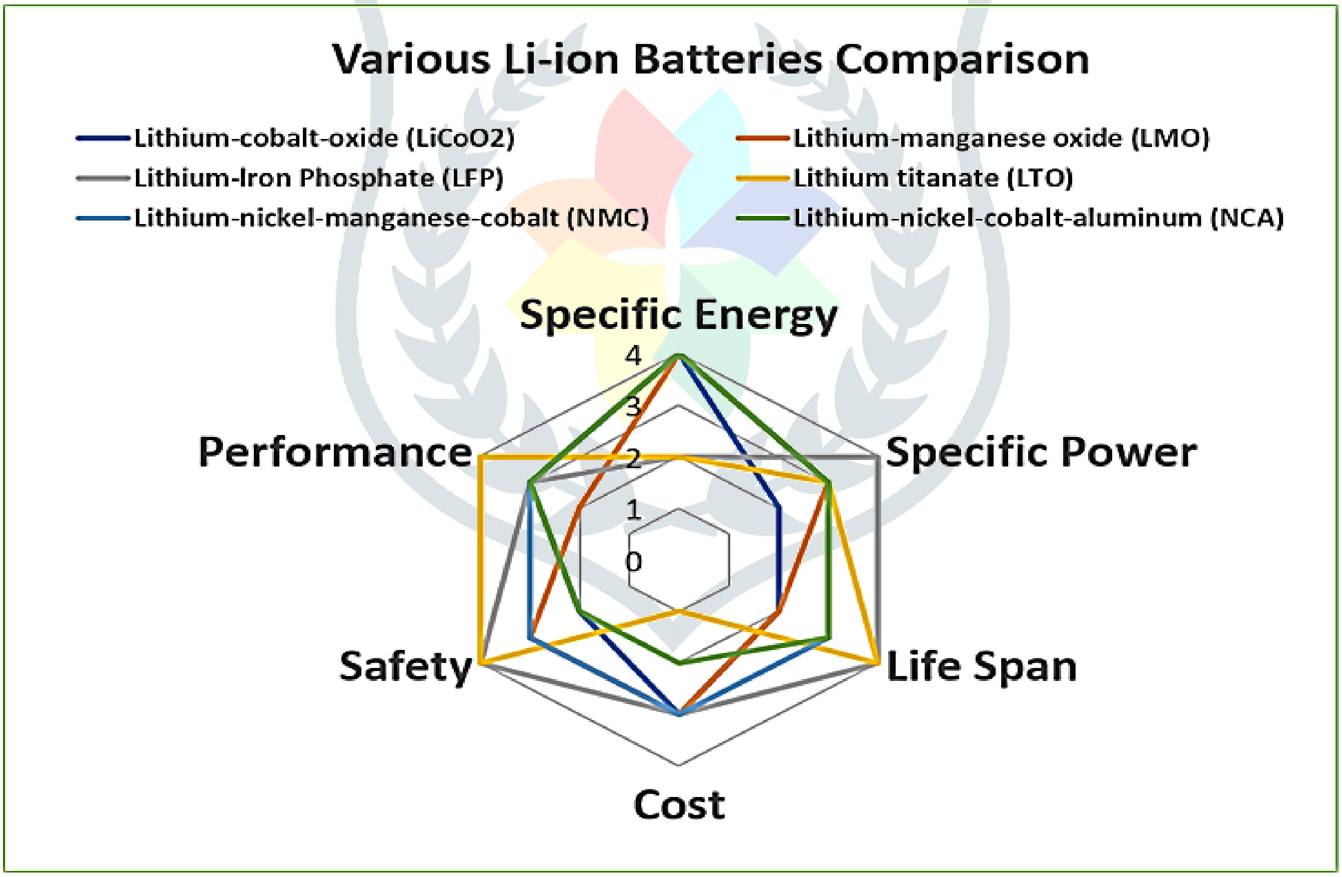
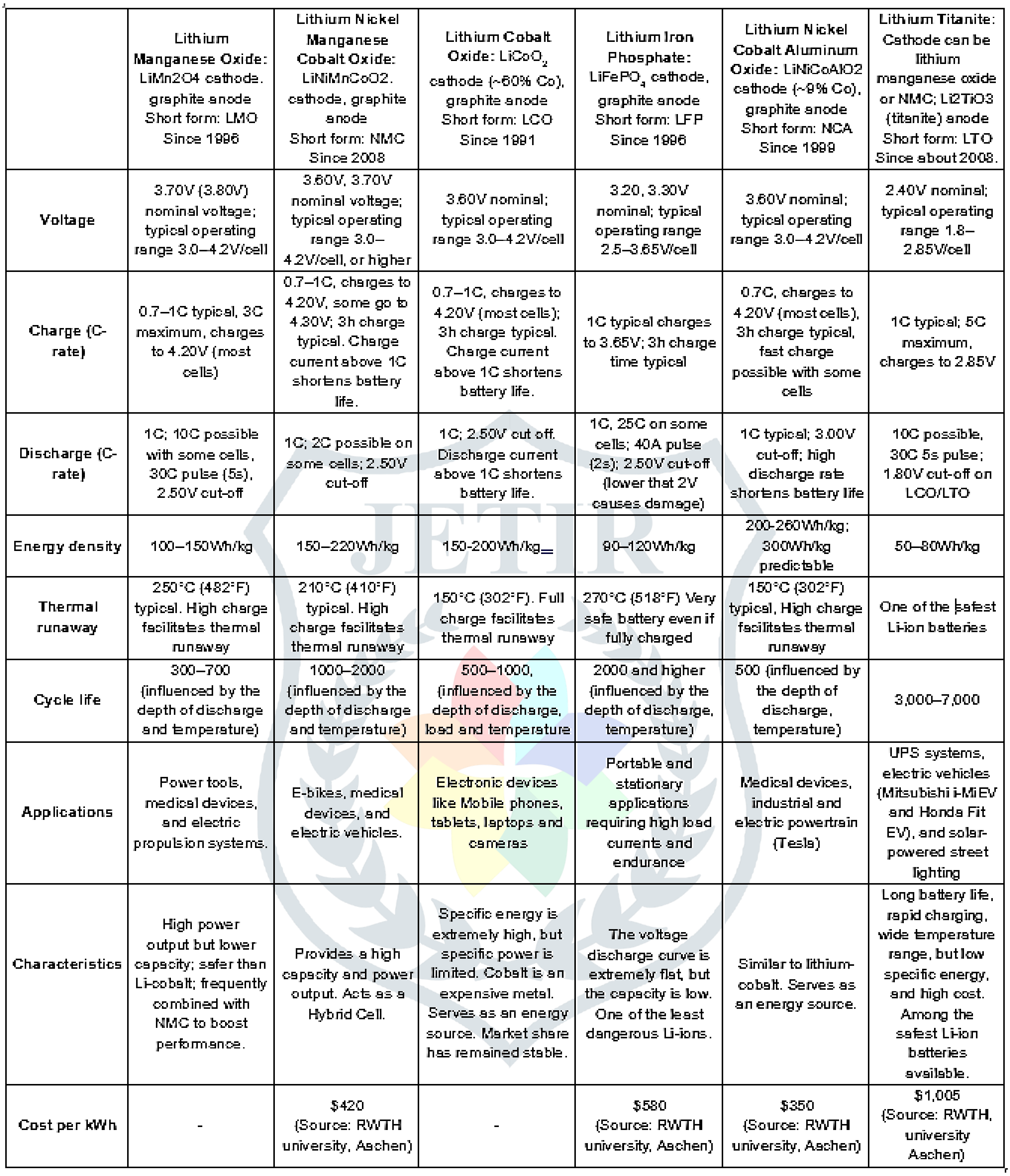


Fig.2. Assessment radar chart for several Li-ion types of batteries used in electric vehicles based on their specific power, safety, performance, life expectancy, specific energy (capacity), and cost (the outer hexagon is most desirable).

Additionally, table 2 omits self-discharge, another critical battery characteristic to remember. While Li-ion batteries generally have a low self-discharge rate, this characteristic can be overlooked when the battery is brand new. However, when exposed to heat pockets, ageing accelerates the self-discharge of the affected cells, posing management challenges. Li-phosphate has a greater self-discharge rate than the other EV battery candidates. The following is a concise overview of the most critical characteristics of an electric vehicle's battery. Li-ion Can be classified on the basis of several criteria such as shapes, sizes, and composition, some of these are categorized below:

Table 2. Comparison of various Li-ion battery Compositions



	Lithium Manganese Oxide: LiMn2O4 cathode. graphite anode Short form: LMO Since 1996	Lithium Nickel Manganese Cobalt Oxide: LiNiMnCoO2. cathode, graphite anode Short form: NMC Since 2008	Lithium Cobalt Oxide: $LiCoO_2$ cathode (~60% Co), graphite anode Short form: LCO Since 1991	Lithium Iron Phosphate: $LiFePO_4$ cathode, graphite anode Short form: LFP Since 1996	Lithium Nickel Cobalt Aluminum Oxide: LiNiCoAlO2 cathode (~9% Co), graphite anode Short form: NCA Since 1999	Lithium Titanite: Cathode can be lithium manganese oxide or NMC; Li2TiO3 (titanite) anode Short form: LTO Since about 2008.
Voltage	3.70V (3.80V) nominal voltage; typical operating range 3.0–4.2V/cell	3.60V, 3.70V nominal voltage; typical operating range 3.0–4.2V/cell, or higher	3.60V nominal; typical operating range 3.0–4.2V/cell	3.20, 3.30V nominal; typical operating range 2.5–3.65V/cell	3.60V nominal; typical operating range 3.0–4.2V/cell	2.40V nominal; typical operating range 1.8–2.85V/cell
Charge (C-rate)	0.7–1C typical, 3C maximum, charges to 4.20V (most cells)	0.7–1C, charges to 4.20V, some go to 4.30V; 3h charge typical. Charge current above 1C shortens battery life.	0.7–1C, charges to 4.20V (most cells); 3h charge typical. Charge current above 1C shortens battery life.	1C typical charges to 3.65V; 3h charge time typical	0.7C, charges to 4.20V (most cells), 3h charge typical, fast charge possible with some cells	1C typical; 5C maximum, charges to 2.85V
Discharge (C-rate)	1C; 10C possible with some cells, 30C pulse (5s), 2.50V cut-off	1C; 2C possible on some cells; 2.50V cut-off	1C; 2.50V cut off. Discharge current above 1C shortens battery life.	1C, 25C on some cells; 40A pulse (2s); 2.50V cut-off (lower that 2V causes damage)	1C typical; 3.00V cut-off; high discharge rate shortens battery life	10C possible, 30C 5s pulse; 1.80V cut-off on LCO/LTO
Energy density	100–150Wh/kg	150–220Wh/kg	150-200Wh/kg	90–120Wh/kg	200-260Wh/kg; 300Wh/kg predictable	50–80Wh/kg
Thermal runaway	250°C (482°F) typical. High charge facilitates thermal runaway	210°C (410°F) typical. High charge facilitates thermal runaway	150°C (302°F). Full charge facilitates thermal runaway	270°C (518°F) Very safe battery even if fully charged	150°C (302°F) typical, High charge facilitates thermal runaway	One of the safest Li-ion batteries
Cycle life	300–700 (influenced by the depth of discharge and temperature)	1000–2000 (influenced by the depth of discharge and temperature)	500–1000, (influenced by the depth of discharge, load and temperature	2000 and higher (influenced by the depth of discharge, temperature)	500 (influenced by the depth of discharge, temperature)	3,000–7,000
Applications	Power tools, medical devices, and electric propulsion systems.	E-bikes, medical devices, and electric vehicles.	Electronic devices like Mobile phones, tablets, laptops and cameras	Portable and stationary applications requiring high load currents and endurance	Medical devices, industrial and electric powertrain (Tesla)	UPS systems, electric vehicles (Mitsubishi i-MiEV and Honda Fit EV), and solar-powered street lighting
Characteristics	High power output but lower capacity; safer than Li-cobalt; frequently combined with NMC to boost performance.	Provides a high capacity and power output. Acts as a Hybrid Cell.	Specific energy is extremely high, but specific power is limited. Cobalt is an expensive metal. Serves as an energy source. Market share has remained stable.	The voltage discharge curve is extremely flat, but the capacity is low. One of the least dangerous Li-ions.	Similar to lithium-cobalt. Serves as an energy source.	Long battery life, rapid charging, wide temperature range, but low specific energy, and high cost. Among the safest Li-ion batteries available.
Cost per kWh	-	$420 (Source: RWTH university, Aachen)	-	$580 (Source: RWTH university, Aachen)	$350 (Source: RWTH university, Aachen)	$1,005 (Source: RWTH, university Aachen)

VI. LI-ION BATTERY MANUFACTURERS

6.1 Manufacturing of Lithium-ion Batteries in India: Current Situation

Lithium-ion batteries are the most expensive component of an electric vehicle, accounting for between 40% and 50% of the total cost. With the growing adoption of electric vehicles in our transportation system, the demand for Li-ion batteries for EV applications is expected to soar. Apart from electric vehicles, other applications such as the integration of renewable energy into the grid will drive Li-ion battery demand. According to government estimates, India will require a minimum of 10 GWh of lithium-ion batteries by 2022, approximately 60 GWh by 2025, and 120 GWh by 2030. The following is a list of top manufacturers in India.

- Amara Raja batteries (AMARON)
- Luminous
- Panasonic India
- TDS- Lithium-ion batteries, Gujrat
- Exide Industries
- Tata Chemicals
- Amperex Technology limited
- Li Energy

6.2 Economics

The market for lithium-ion battery recycling is big and rising, thanks in large part to electric vehicles. Many other lithium-ion batteries are recycled, including those from phones and power tools, but EV batteries account for the vast majority.

The recycling market was predicted to be worth $1.5 billion in 2019. In 2020, 460,000 metric tons of lithium-ion batteries are expected to be recycled, which is a considerable quantity compared to prior years. The recycling market is anticipated to reach $12.2 billion by 2025. After that, it is expected to expand at an annual pace of 8%. To put it in context, lead-acid batteries are in equilibrium in the world; the number of batteries manufactured equals the number of batteries returned for recycling. Only new vehicle sales drive market growth, and EVs are likely to take over in the next decade.

Although Tesla is striving for it, most EV batteries will not have a second life. Some of Tesla's batteries are examined, verified to be functioning, and then repurposed for use in electric vehicles. They may return and pass tests, but they aren't good enough to be put into an automobile. These could be converted for home power storage.

EV batteries have a substantially longer lifespan than lead-acid batteries (two to four years for LAB vs an estimated ten years for LIB). The number of batteries returned for recycling vs the amount produced will be out of balance for a long time. It will take till the EV market reaches a lowest and eight to ten years have passed for the old batteries to resurface.

VII. Batteries used in various Vehicles

Battery electric power is used to power electric cars and motorcycles. There are many different types of batteries on the marketplace currently. Lithium-ion batteries, solid-state batteries, nickel-metal hydride batteries, lead-acid batteries, and ultra capacitors are just a few examples. Lithium-ion batteries, but at the other hand, are the most efficient and popular. Lithium-ion batteries are currently employed in the majority of electric vehicles due to their high energy density per unit mass when compared to other kinds of electrical energy storage. They also have a high power-to-weight ratio, excellent high-temperature performance, and a low rate of self-discharge. The majority of lithium-ion battery elements can be recycled. Lithium-ion batteries are used in the majority of todays modern electric vehicles, albeit their chemistry differs from that of consumer gadgets. There still is ongoing research and development to lower their relatively expensive cost, increase their usable life, and address overheating safety concerns. Although the phrase "lithium-ion" can apply to a range of chemistries, it all boils down to a charging and discharging battery with a lithium-ion cathode and a graphite anode. Two lithium-ion chemistries that are commonly utilised are Nickel Manganese Cobalt (NMC) and Lithium Iron Phosphate (LIP) (LFP). From electric vehicles to residential batteries to grid-scale applications, lithium-ion batteries are employed in a wide range of applications. The names of some of the electric car manufacturing businesses, as well as the storage technologies used by them, are mentioned below to determine how the Li-ion batteries are leading the market:

Table 3. EV OEMs

Country Name	Company Name	Vehicle model	Battery technology Used
India	Revolt Motors	Revolt RV400(2 wheeler)	Li-ion
USA	GM	Chevy-Volt	Li-ion
		Saturn Vue Hybrid	NiMH
USA	Ford	Escape, Fusion, MKZ HEV	NiMH
India	Ampere	Magnus (2 wheeler)	Li-ion
Japan	Okinawa	i-Praise (2 wheeler)	Li-ion
India	Hero	Hero electric (2 wheeler)	Li-ion
Germany	BMW	X6	NiMH
India	Ather Energy	Ather 450X (2 wheeler)	Li-ion
Japan	Toyota	Prius, Loom	NiMH
Japan	Honda	Civic, Insight	NiMH
Germany	Daimler Benz	MLASO, 5400	NiMH
USA	Tesla	Roadster (2009)	Li-ion
Norway	Think	Think EV	Li-ion, Sodium/Metal Chloride
Japan	Nissan	Altima	NiMH

VIII. CALCULATIONS

Now, let us consider a typical 2-wheeler model which has to achieve the speed of 80kmph with two persons of average weight 70kg each, are sitting on it. Keeping criteria of standard conditions, the following calculations can be performed:

Required speed	80 kmph = 80*(1000/3600) = 22.22 m/s
Kerb weight (weight ofbike)	110 Kg
Gross weight (kerb weight + Rider weight)	110 kg+70 kg+70 kg = 250 kg

1. **Tyre specs** = 130/70 R-17
2. **Tyre rim diameter (wheel diameter)** = 17 (inch) *25.4 = 432mm
3. **Tyre width=** 130 mm
4. **Tyre width** = 130 mm
5. **Tyre height**=130*70%=130*0.70= 91mm
6. **Tyre diameter**=432+91+91= 614mm
7. **Tyre radius**=614/2= 307mm
8. **Tyre circumference/linear wheel travel**= 2*π*r = 2*3.14*307 = 1928mm = 2m
9. **Diameter of wheel rim =** 17 inch = 0.4318 m
10. **Diameter of wheel =** Dia. of rim + (Height of tire*2) = 0.4318+ 0.091*2 = 0.6138m

1. **Bike frontage width with rider (approx.)** = 715mm
2. **Bike height (approx.)** = 1115mm
3. **Bike height with rider(approx.)** = (1115+400) mm
4. **Bike frontage area**= 715*(1115+400) = 1 m^2

Rpm required at wheel = Speed (in m/min) / Tyre circumference =(22.22*60)/2 = 666.6 RPM =667 RPM

Force Calculation:

Mass (m)	250 kg
Gravitational Constant (g)	9.81 m/s^2
Velocity (V)	22.22 m/s
Air Density	1.2 kg/m^3
Air drag	0.82
Frontal Area (A)	1 m2
Primary Acceleration (S_1)	0 km/h
Secondary Acceleration (S_2)	80km/h
Time interval for acceleration (t)	15 seconds

Total Force (Ft)= Rolling Force (Fr)[@ wheels due to friction between surface]]+ Drag force(Fd)[force due to air resistance]+ Acceleration force (Fa) [force required for high acceleration] + Gradient Force(Fg)[vehicle climbing on slope]

1. **Rolling Force (Fr)= mg*coefficient of rolling resistance (C_r)** = 250*9.81*0.008 = 19.62 $kg.m/s^2$ = 20 $kg.m/s^2$ = 20N
(Since C_r=0.08 from Table. 4)

2. **Drag Force (Fd) = 0.5 * Air Density * coefficient of drag force (C_d) * A_f * V^2** = 0.5*1.2*0.7*0.9*22.22*22.22 = 186.62 kg m/ s^2 = 187 N
(Since A_f=0.7 and C_d=0.9 from Table. 5)

3. **Acceleration Force (Fa)= m*a**= 250*(S_2-S_1)/ t = 250*((80-0) / 15) * (1000/3600)= 250 * 1.48148= 370.370 $kg.m/s^2$ = 371 N

4. **Gradient Force (Fg)= ±M × g × sin θ =** 180×9.81×sin (5)= 250*9.81*0.0872 = 213.7494 kg.m /s2= 214 N

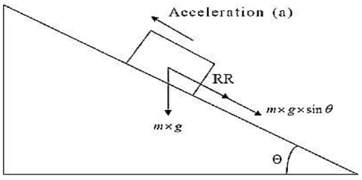


Fig. 3. A Vehicle's Free Body Diagram as it moves up an Inclined Surface.

5. **Total Force (Ft)= Fr + Fd + Fa + Fg** = Fr + Fd = 20 + 187 = 207 kg.m/s2
[We don't need high acceleration for an 80 km bike and we don't need that much power for hill climbing for EV considering regular gradient.]

Power (P) = Ft * V = 207*22.22 = 4599.54 w = 4.6 Kw

Torque (T) = P*60 / (2*π*N) = (4600*60) / (2*3.14*667)= 65.8906 Nm = 66 Nm

Motor selection:

Standard Motor Specifications:

BLDC Motor Standard Speed	3000 RPM
Required Speed at Wheel	667 RPM
Reduction Ratio	3000:667 = 4.5:1
Motor power	1500 Watt
Required Torque	66 Nm

P = 2*π*N*T/60
T = P*60/(2*π*N) = 1500*60/(2*3.14*1000) = 14.32Nm = 15Nm

[BLDC Motor already has higher torque hence we consider a lower RPM of about 1000]

Torque on Wheel at 1000 RPM = T*4.5 = 15*4.5 = 67.5 = 68Nm

Calculations for Battery:

Obtained Battery power	1500w
Required Voltage	48v

Battery Capacity (in Wh) = Motor Power*hr = 1500*1 = 1500 Wh = 1500Wh * 1.20 = 1800 Wh
[Out of the full battery, 80% should be in use and 20% should remain in the case for reserve.]

Current (in Ah) = Battery capacity/ voltage = 1800w.hr / 48v = 37.5 Ah

Battery charger Selection:

Charging Time (t)	5 Hours
Battery Capacity	1800 Wh
Voltage (V)	48V

Charger Power required (P) = battery capacity / t = 1800 / 5 = 360 w
Current rating of the charger = P/V = 360/48 = 7.5A

[According to the above calculation, a 48v, 37.5Ah battery requires a 48v, 7.5A charger to charge it in 5 hours.]

Hence, we can determine the approximate values for calculations of various electric vehicles.

Table 4. Coefficient of friction (C_f)

0.001-	Wheels of Railroad steel on steel rail
0.001	Cycle tire running on wooden track
0.002	Cycle running on concrete.
0.004	Cycle running on an asphalt road.
0.008	Cycle tire running on rough paved
0.006-0.01	Truck tire on asphalt
0.01-0.015	Car tire on concrete road
0.02	Car tire on a tar or an asphalt road
0.02	Car tire on newly gravel-rolled road
0.03	Car tire on cobbles-large won
0.04-0.08	Car tires on the solid sand, gravel loose worn, soil medium-hard
0.2-0.4	Car tire on loose sand

Table 5. Coefficient of drag (C_d) and Frontal area (A_f)

Vehicles	C_D	A_f
Motorcycle with a rider	0.5-0.7	0.9
Open convertible vehicle	0.5-0.7	1.75
Limousine car	0.2-0.41	1.73-2
Coach	0.4-0.82	6-10
Truck without the trailer	0.45-0.82	6-10
Truck with the trailer	0.55-1.12	6-10
Articulated vehicle	0.52-0.92	6-10

IX. FUTURE SCOPE

9.1 The Environmental Impacts of Lithium-Ion Batteries

It is considered that lithium-ion batteries containing nickel and cobalt cathodes have a significant environmental influence, including resource depletion, contributing to global warming, ecological damage, and bad health impacts.

Activists raised awareness about a dangerous chemical discharge at the Ganzizhou Rongda Lithium mine in 2016, which wreaked havoc on the local ecosystem and resulted in dead fish floating in the Liqi river. Following the third incident in seven years, witnesses reported dead cows and yaks running downstream from the mine. The mine was closed after the second tragedy in 2013, but reopened in 2016 to fulfil the increasing demands for cellphones and electric car batteries. Immediately following the reopening, residents noted an increase in fish mortality.

Cobalt is an integral part in lithium-ion batteries. Due to the ecologically and socially irresponsible mining of lithium-ion batteries, they cannot be considered a legitimate alternative to fossil fuels. Despite these worries, many think lithium-ion batteries will be necessary to the global energy sector's decarbonization. Tesla's Model S is powered by around 12 kg of lithium-ion batteries, and world consumption for battery-powered vehicles is growing as they gain popularity. The concern is that the power sector may be substituting one approach for another more ecologically destructive. While substituting 'clean' energy powered by lithium-ion batteries minimizes the carbon emissions related to non-renewable energy, it does so at the price of the environmental effect connected with getting the huge amounts of lithium necessary as demand climbs rapidly. According to scientists, we are on the edge of a mineral disaster that will have a negative impact on the ecosystem.

9.2 Is Excessive Lithium Use Harmful to the Environment?

A report by the Friends of the Earth Europe charity outlined the negative impacts of lithium extraction and use. It noted that the mining and processing of lithium cause damage to ecosystems, land, and water. In addition, the process requires toxic chemicals, which can harm local communities and food production. In the report, Vice President Akira Yoshino admitted that lithium is a necessary ingredient for future electric vehicles, but the environmental consequences of excessive lithium mining and use are too large to justify its high price.

Despite the fact that lithium mining and processing produces no hazardous waste, it is still an issue. The traditional methods of extraction and processing of lithium use hydrochloric acid, which can leak into waterways. These chemicals are also released into the environment during disposal. In Nevada, researchers found that the lithium mines were having a negative impact on fish 150 miles downstream. This is why it is so important to find alternative energy sources that do not contain lithium.

Furthermore, excessive lithium mining causes significant amounts of waste, which may be harmful to the environment. The process involves leaking chemicals into waterways and using toxic chemicals during the process. In fact, there is a risk that the waste from this industry could leak into the environment. As a result, excessive lithium use is not suitable for the environment. It is also harmful to human health and can be toxic.

Moreover, excessive lithium mining releases toxic chemicals into the environment. These chemicals are released during the processing of lithium. Besides, there is a considerable risk of spilling waste into the water. In fact, a Nevada study showed that the chemical contamination of the seawater was affecting fish that lived up to 150 miles downstream of the mining operation. This could potentially harm humans and the environment.

As of 2015, the Environmental Protection Agency affirmed that excessive lithium-ion batteries do not pose a threat to human health. However, the fact remains that the excessive use of lithium-ion batteries causes significant environmental harm. Not only are they a source of pollution, but they also have adverse effects on the environment. Affected populations are already concerned about the risks affecting the climate.

The environmental impact of lithium-ion batteries is not fully understood. The manufacturer of lithium-ion batteries is secretive about its lithium content. After it is used, the lithium-ion batteries are disposed of in landfills. The discarded cells often contain metals that leach into the environment. They can also contain ionic fluids that can leach into the environment.

9.3 A Possible Solution to the threat in the future

While lithium is not the most concerning aspect of clean energy's future, it remains a significant environmental concern that jeopardizes the transition from non-renewables to renewables. Fortunately, scientists are investigating ways to mitigate the environmental impact of lithium extraction. Recent research indicates that scientists may eventually synthesize lithium from seawater.

The world's oceans contain approximately 180 billion tons of lithium. Due to the deficient concentrations of lithium in the earth's crust, current methods of extraction are highly energy-intensive. Prior to developing an environmentally responsible and sustainable method for extracting lithium from seawater, a less energy-intensive method must be developed. Research is currently being conducted, and it is hoped that a solution will be discovered in the next few years.

X. RECYCLING AND REUSE

10.1 Recycling of lithium-ion batteries

To diminish the world's dependency on the previously mentioned natural substance delivering nations, fostering a hearty reusing foundation will turn out to be progressively essential later on. Processes for recuperating natural substances from little lithium-particle batteries, for example, those found in phones, have been executed to some extent. Nonetheless, vehicle batteries are essentially bigger, heavier, and all the more remarkable, confounding the course of industrialization. The Libero research project at RWTH Aachen University, in collaboration with Vinnova, Sweden's development agency, is set aside by the German Federal Ministry of Economics and Energy (BMWi) as part of the Central Innovation Program for SMEs. The Swedish-German partnership is promoting a robust, versatile, and waste-free battery reusing technique. It consists of two industry partners and two analysts from each country. The project, which began in 2019, is tasked with setting up an office capable of reusing 25,000 tonnes of battery mass per year. Fortum, a Finnish organization that is to some extent state-possessed, has effectively fostered an interaction for reusing lithium-particle batteries from electric vehicles.

Umicore is a market leader in the reuse of commercial batteries. The interactions of the organisation are divided into two categories: pyrometallurgical and hydrometallurgical. A cobalt, nickel, and copper combination, as well as a slag portion, are framed after the underlying heated treatment stage. In the subsequent hydrometallurgical phase of the interaction, the metals are recovered. The first Umicore reuse office has a yearly limit of 7000 tonnes of battery mass, or about 35,000 electric vehicle batteries.

In mid-2021, Volkswagen began work at a pilot factory in Salzgitter, Germany, to reuse high-voltage vehicle batteries. Lithium, nickel, manganese, and cobalt will all be recovered 100 percent, while aluminium, copper, and plastic will be recovered 90 percent. The system is currently capable of reusing up to 3600 battery frameworks every year, compared to 1500 tonnes of battery mass.Be that as it may, as utilized batteries become accessible, the framework can be increased to deal with more enormous volumes. Volkswagen claims that the reusing system kills the requirement for impact heater purifying, which would consume a lot of energy. Utilized battery frameworks at the plant are profoundly released and dismantled. Destroying individual parts makes pulverize, which is then dried. Aluminum, copper, and polymers are produced as a result of the interaction, but the most important result is afine dark mixture containing the key battery natural components lithium, nickel, manganese, cobalt, and graphite. After that, Volkswagen's experienced partners discretize and treat the individual components using hydrometallurgical procedures that include water and chemicals.

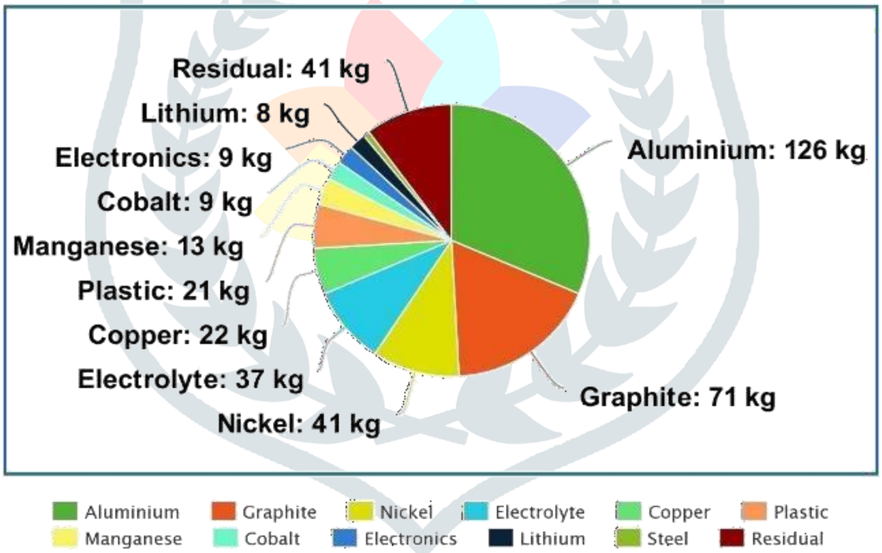


Fig. 4. The proportion of recyclable materials as a percentage of weight [kg] (based on a 400 kg overall battery mass) (source:Volkswagen)

10.2 Second-life approach

Old vehicle batteries can be reused in stationary applications for a long time before they need to be recycled. There is currently no empirical evidence on the quantity of batteries that would meet the secondary use requirements in terms of remaining storage capacity and service life. The second-life notion is mostly limited to applications that need the use of older, lower-energy-density batteries. Furthermore, concerns of uniformity and warranties must be addressed.

Increased failure and replacement rates are expected, according to Fraunhofer ISI, implying that the high levels of reliability required of decentralised battery storage systems for residential structures, for example, cannot be assured. The number of cells required, as well as the cost of the batteries, would grow due to the required levels of redundancy. Only a small percentage of outdated traction batteries can be recycled, according to Fraunhofer ISI.

REFERENCES

[1] E. Braco, I. S. Martín, A. Berrueta, P. Sanchis and A. Ursúa, "Experimental Assessment of First- and Second-Life Electric Vehicle Batteries: Performance, Capacity Dispersion, and Ag-ing," in IEEE Transactions on Industry Applications, vol. 57, no. 4, pp. 4107-4117, July-Aug. 2021, doi: 10.1109/TIA.2021.3075180.

[2] M. Świerczyński, D. I. Stroe, A. Stan, R. Teodorescu and D. U. Sauer, "Selection and Performance-Degradation Modeling of LiMO$_{2}$/Li$_{4}$Ti$_{5}$O $_{12}$ and LiFePO $_{4}$/C Battery Cells as Suitable Energy Storage Systems for Grid Integration With Wind Power Plants: An Example for the Primary Frequency Regulation Service," in IEEE Transactions on Sustainable Energy, vol. 5, no. 1, pp. 90-101, Jan. 2014, doi: 10.1109/TSTE.2013.2273989.

[3] S. R. Bonu and D. S. Panigrahi, "Recollection and Recycling of Automotive Lithium Ion Batteries in India," 2019 IEEE Trans-portation Electrification Conference (ITEC-India), 2019, pp. 1-5, doi: 10.1109/ITEC-India48457. 2019.ITECINDIA2019-47.

[4] “Summary and Comparison of Battery Characteristics” https://www.pveducation.org/pvcdrom/battery-characteristics/summary-and-comparison-of-battery-characteristics

[5] “Supply chain of raw materials used in the manufacturing of light-duty vehicle lithium-ion batteries.” Tsisilile Igogo, Debra Sandor, Ahmad Mayyas, and Jill Engel-Cox https://www.nrel.gov/docs/fy19osti/73374.pdf

[6] Isidor Buchmann is the founder and CEO of Cadex Electronics Inc. “Batteries in a Portable World - A Handbook on Recharge-able Batteries for Non-Engineers"

[7] Battery Raw Materials - Where from and Where to? Journal: MTZ worldwide > Issue 10/2021 Author: Richard Backhaus

[8] Service, R., 2020. Seawater could provide nearly unlimited amounts of critical battery material. Science. 13 JUL 2020 BY ROBERT F. SERVICE

[9] The spiralling environmental cost of our lithium battery addic-tion. Amit Katwala. Wired. 05.08.2018

[10] W. -C. Lih, J. -H. Yen, F. -H. Shieh and Y. -M. Liao, "Second Use of Retired Lithium-ion Battery Packs from Electric Vehi-cles: Technological Challenges, Cost Analysis and Optimal Business Model," 2012 International Symposium on Computer, Consumer and Control, 2012, pp. 381-384, doi: 10.1109/IS3C.2012.103.

[11] Nagasree Garapatia, Benjamin M. Adamsb,c, Jeffrey M. Biel-ickid,e, Philipp Schaedlea, Jimmy B. Randolphb,f, Thomas H. Kuehnc, Martin O. Saara,b,f “A Hybrid Geothermal Energy Conversion Technology - A Potential Solution for Production of Electricity from Shallow Geothermal Resources” Peer-review under responsibility of the organizing committee of GHGT-13. doi: 10.1016/j.egypro.2017.03.1852

[12] Lelie, Markus, Thomas Braun, Marcus Knips, Hannes Nord-mann, Florian Ringbeck, Hendrik Zappen, and Dirk U. Sauer. 2018. "Battery Management System Hardware Concepts: An Overview" Applied Sciences 8, no. 4: 534. https://doi.org/10.3390/app8040534.

[13] JEON, YoonCheol, GunGoo LEE, TaeYong KIM, SangWon BYUN, ChoongHo LEE, KyeongBeom CHEONG, HanYong LEE, SooSeok CHOI, KiHo KIM, and Jun SONU. 2007. "De-velopment of Battery Pack Design for High Power Li-Ion Bat-tery Pack of HEV" World Electric Vehicle Journal 1, no. 1: 94-99. https://doi.org/10.3390/wevj1010094.

[14] Gaurav Prashar, Hitesh Vasudeva, A comprehensive review on sustainable cold spray additive manufacturing: State of the art, challenges and future challenges, Journal of Cleaner Production, 10.1016/j.jclepro.2021.127606, 310, (127606), (2021).

[15] Y. Lyu, A.R.M. Siddique, S.H. Majid, M. Biglarbegian, S.A. Gadsden, S. Mahmud, Electric vehicle battery thermal manage-ment system with thermoelectric cooling, Energy Reports, Vol-ume 5, 2019, Pages 822-827, ISSN 2352-4847, https://doi.org/10.1016/j.egyr.2019.06.016.

[16] G. J. May and P. Lenain, "Batteries for solar photovoltaic appli-cations in telecommunications service," Proceedings of Power and Energy Systems in Converging Markets, 1997, pp. 207-210, doi: 10.1109/INTLEC.1997.645889.