

● POLITY

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INTERNATIONAL RELATIONS

INS SUMITRA FOILS HIJACK ATTEMPT ON IRANIAN-FLAGGED VESSEL IN GULF OF ADEN

CONTEXT: INS Sumitra, an Indian Naval ship deployed in the Gulf of Aden ensured quick resolution of hijack situation, ensuring safe release of an Iranian-flagged fishing vessel and its crew.



INS Sumitra, on anti-piracy operations along the East coast of Somalia and the Gulf of Aden, responded to a distress message regarding hijacking of an Iranian flagged Fishing Vessel (FV) Iman. The pirates boarded FV taking crew as hostages. INS Sumitra intercepted the vessel, acted in accordance with the established Standard Operating Procedures to coerce the pirates for safe release of crew along with the boat and ensured successful release of all 17 crew members along with the boat.

The fishing vessel was subsequently sanitised and released for onward transit. Piracy, which has vanished since the peak around 2010, has come back now in the region against the backdrop of the Houthi attacks on commercial shipping.

Enhanced surveillance

The Navy has substantially enhanced maritime surveillance efforts in central and north Arabian Sea and augmented force levels in response to past pirate related incidents. The Indian Navy has currently deployed 12 warships on anti-piracy and maritime security operations in the Arabian Sea and Gulf of Aden.

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INTERNATIONAL RELATIONS

MALDIVES' MAIN OPPOSITION PARTY MULLS IMPEACHMENT AGAINST PRESIDENT MUIZZU

CONTEXT: Tensions are high in the Maldives as President Muizzu's policies strain relations with India, the country's longtime ally, while the opposition prepares for an impeachment motion and upcoming elections.

STORY SO FAR: Following his election on a pro-China, anti-India platform, Maldivian President Muizzu set a deadline for Indian troop withdrawal and intensified ties with China. This triggered outrage from the opposition MDP and the Indian public, leading to calls for boycotts and concerns about regional security. The MDP, with potential support from another faction, plans to impeach Muizzu, raising political tension further.

MAJOR ISSUES GRIPPING THE MALDIVES:

1. Muizzu's Anti-India Tilt:

Campaign Promise: President Muizzu campaigned on strengthening ties with China and distancing from India, the Maldives' traditional ally.

Hostile Actions: He set a deadline for Indian troops to withdraw, reviewed India-Maldives agreements, and fast-tracked relations with China, including military port visits.

Opposition and Backlash: This triggered outrage from the Maldivian Democratic Party (MDP), the Indian public, and social media, raising concerns about regional security and China's growing influence.

2. Impeachment Looming:

MDP's motion: Citing security risks and alleged power misuse, the MDP, with 42 seats and potential support from others, plans to impeach Muizzu.

Political tension: This further escalates political turmoil in the Maldives.

3. Upcoming Elections and Uncertain Future:

- Parliamentary elections on March 17 will be a crucial test for Muizzu and his policies.
- Public backlash due to his anti-India stance could swing the vote towards the MDP, reshaping the Maldives' political landscape.
- The elections' outcome and the impeachment motion's fate will significantly impact the Maldives' future and its relationships with India and China.

WHY THE MALDIVES MATTERS:

- Located strategically in the Indian Ocean, the Maldives acts as a gateway to South Asia and the Middle East.
- Its proximity to key shipping lanes and potential access to ports make it crucial for both India and China.
- Maintaining a strong presence in the Maldives grants strategic

depth and influence in the region.

- India, traditionally the Maldives' closest ally, is concerned about growing Chinese influence and potential threats to its strategic interests.
- China, vying for regional dominance, sees the Maldives as a foothold for expanding its maritime presence and economic reach.

Potential Outcomes:

MDP victory: Could lead to India-Maldives rapprochement and limit Chinese influence.

Muizzu's consolidation: Could solidify his pro-China stance and pose challenges for India's regional interests.

ADDITIONAL INFORMATION:

The Maldives is an upper-middle-income economy with tourism as its primary industry.

China has provided significant loans and investments to the Maldives in recent years.

The Indian Ocean region is increasingly becoming a focal point of competition between India and China, with implications for maritime security and trade routes.

CONCLUSION: The Maldivian archipelago's political turmoil and its shifting allegiances have significant implications for the larger geopolitical landscape of the Indian Ocean. The outcome of the upcoming elections and the fate of Muizzu will determine whether the Maldives will continue its historical ties with India or chart a new course with China, with major consequences for both regional powers.

INTERNATIONAL RELATIONS

ASEAN CAUTIOUSLY HOPES FOR PROGRESS ON MYANMAR, SOUTH CHINA SEA CONFLICTS

CONTEXT: The Association of Southeast Asian Nations (ASEAN) Foreign Ministers met in Laos to discuss the ongoing crisis in Myanmar and disputes in the South China Sea.

BACKGROUND: ASEAN Foreign Ministers met in Laos amidst crises. Myanmar junta sent a high-level representative for the first time since the coup, sparking cautious optimism for progress on the stalled five-point peace plan. Meanwhile, China's assertive posture in the South China Sea cast a shadow, with tensions rising between China and countries like the Philippines and Vietnam. Laos, the new ASEAN chair, seeks to navigate these challenges, facing skepticism due to its size and close ties to China.

MAJOR ISSUES OF THE ASEAN MEETING

1. Myanmar's Participation in ASEAN Meeting:

- Myanmar's military junta sent a high-level representative to attend the ASEAN Foreign Ministers meeting in Laos, signalling a positive shift.
- It is the first time Myanmar participated in a high-level ASEAN meeting since seizing control in February 2021.

2. Laotian Foreign Minister's Optimism:

- Laos, as the current rotating ASEAN leader, expressed guarded optimism about addressing issues in Myanmar and the South

China Sea.

- Laotian Foreign Minister Saleumxay Kommasith sees potential for engagement, acknowledging the complexity of Myanmar's situation.

3. Humanitarian Assistance to Myanmar:

- Thailand is planning to provide more humanitarian aid to Myanmar, where over 2.6 million people have been displaced due to civil war.
- ASEAN is prioritizing humanitarian assistance as an immediate step, supporting a Thai initiative for a humanitarian corridor.

4. ASEAN's Five-Point Consensus for Myanmar:

- ASEAN's plan for Myanmar includes an immediate cessation of violence, dialogue among concerned parties, ASEAN mediation, humanitarian aid provision, and a visit by a special envoy.
- Myanmar's military leadership has so far ignored this plan, and the humanitarian crisis continues.

5. Laos' Special Envoy to Myanmar:

- Laos has sent a special envoy to Myanmar to engage with the ruling military council and work towards implementing ASEAN's five-point consensus plan.

6. South China Sea Disputes:

- The meeting addressed China's assertive actions in the South China Sea, a concern for ASEAN nations.
- ASEAN emphasized the importance of the 2002 and 2012 declarations on conduct in the South China Sea for a peaceful resolution.

7. Philippines-Vietnam Meeting on South China Sea Tensions:

- Philippine President Ferdinand Marcos Jr. met with Vietnamese officials to discuss ongoing tensions in the South China Sea.
- The Philippines seeks support from ASEAN amid increasing hostilities with China, concerned about a potential broader conflict involving the U.S.

8. China's Influence and ASEAN's Unity:

- Laos, a landlocked and economically challenged ASEAN nation, is seen as having close ties to China.
- Speculation arises about Laos seeking China's help in dealing with the Myanmar crisis, but ASEAN's unity and China's non-interference stance remain uncertain.

9. Concerns about China's Role and ASEAN's Unity:

- ASEAN members, including Vietnam, the Philippines, Malaysia, and Brunei, have maritime disputes with China in the South China Sea.
- There is concern about Beijing's encroachment, with an estimated \$5 trillion in international trade passing through the South China Sea annually.

10. Efforts for Peace and Stability:

- ASEAN, despite scepticism due to Laos' economic limitations, aims to play a role in resolving regional crises, emphasizing diplomatic solutions and humanitarian aid.

CONCLUSION: The ASEAN Foreign Ministers meeting in Laos offered cautious hope for progress on the Myanmar crisis and South China Sea tensions. Myanmar's junta participation marked a rare diplomatic step, while Laos, despite its limitations, expressed optimism and initiated a special envoy. Humanitarian aid remains a priority, with Thailand stepping up assistance for Myanmar's displaced millions. However, challenges loom large. ASEAN's

five-point consensus plan for Myanmar faces military resistance, and China's assertive posture in the South China Sea remains a source of concern. The Philippines' anxieties highlight the potential for wider conflict, while Laos' close ties to China raise questions about its influence and ASEAN's unity. Despite these uncertainties, the meeting reaffirmed ASEAN's commitment to regional peace and stability, emphasizing diplomatic solutions and humanitarian efforts. The road ahead will be long and arduous, but ASEAN's renewed engagement offers a glimmer of hope for a more peaceful and stable Southeast Asia.

SCIENCE AND TECHNOLOGY

JAPANESE MOON PROBE BACK TO WORK AFTER SUNLIGHT REACHES ITS SOLAR PANELS

CONTEXT: The Japan Aerospace Exploration Agency (JAXA) successfully established communication with the probe on Sunday night, and the craft has resumed its mission, taking pictures of the moon's surface and transmitting them to the earth.



Smart Lander for Investigating Moon (SLIM), Japan's first lunar mission hit its target in a precision touchdown on January 20, but landed the wrong way up, leaving its solar panels unable to see the sun.

Engine failure

After a last-minute engine failure, Smart Lander for Investigating Moon (SLIM) made a rougher-than-planned landing. JAXA used battery power to gather as much data as possible about the touchdown and the probe's surroundings.

With power, SLIM has continued work to analyse the composition of olivine rocks on the lunar surface with its multi-band spectral camera, seeking clues about the moon's origin and evolution, the agency said. Earlier observations suggest that the moon may have formed when the earth hit another planet.

A black-and-white photo posted by JAXA on social media showed the rocky lunar surface, including a rock named as "Toy Poodle" after seeing it in initial images. The probe is analysing six rocks, all of which have been given the names of dog breeds.

Slim chances

The SLIM landed about 55 metre away from its target, in between two craters near the Shioli crater, a region covered in volcanic rock. Previous moon missions have typically aimed for flat areas at least 10 km wide.

SLIM carried two autonomous probes, which were released just before touchdown, recording the landing, surroundings and other lunar data. The landing made Japan the world's fifth country to reach the moon surface, after the U.S., the Soviet Union, China and India.

ECONOMICS AND DEVELOPMENT

FINMIN SAYS ECONOMY LIKELY TO GROW CLOSER TO 7% IN 2024-25

CONTEXT: Ahead of the Interim Union Budget, the Finance Ministry pegged India's real GDP growth at closer to 7% in 2024-25 with 'considerable scope' to outpace 7% by 2030, adding that the economy will hit \$5 trillion in the next three years, making it the third largest in the world.

Bullish report

FinMin contends the state of the Indian economy today is far better than when Narendra Modi assumed power in 2014

- CEA says 7% growth when the world struggles to grow 2% is better than 8-9% growth when the world grows at 4%

- Structural reforms since 2014 have strengthened macroeconomic fundamentals, the Finance Ministry argues

- FinMin outlines reforms such as the GST and IBC but only makes passing mention of demonetisation in 2016



Two phases

The review split India's growth story into two phases—1950 to 2014 and '2014-2024: Decade of transformative growth'—and noted that despite some positive developments, the state of the Indian economy was far from encouraging when Prime Minister Narendra Modi 'assumed power in his first term in office'.

The economy had clocked lower than 5 % growth of GDP at factor cost at constant prices for two consecutive years, 2012-13 and 2013-14, food inflation was high, and structural constraints such as difficulties in quick decisions on projects, ill-targeted subsidies cramping fiscal space for public investment, and a large informal sector, were denting growth.

Since then, the Indian economy has undergone many structural reforms introduction of the Goods and Services Tax and the Insolvency and Bankruptcy Code, along with the push to build infrastructure that have strengthened its macroeconomic fundamentals. These reforms have led to India emerging as the fastest-growing economy among G20

economies. The economy is generating jobs and an impressive post-pandemic recovery has seen urban unemployment rate decline to 6.6 %.

ECONOMICS AND DEVELOPMENT

‘10% RAISE IN ALLOCATION FOR DUTY REMISSION PLAN MAY HELP COVER MORE SECTORS’

CONTEXT: The budgetary allocation for the popular export benefit scheme, Remission of Duty and Taxes on Exported Products (RoDTEP), is likely to get a 10 % increase in 2024-25, over the ₹ 15,069 Cr. allocated last fiscal, which may allow the Commerce Department to extend the scheme for iron and steel, pharmaceuticals and chemical sectors for the entire financial year.

Unlike most other sectors that get covered under RoDTEP on a permanent basis, the scheme incorporates iron and steel items, pharmaceuticals and chemicals on a piecemeal basis depending on the availability of funds. The Commerce Department is expecting a 10% increase in allocation for the RoDTEP scheme in 2024-25. As exports are not likely to increase steeply because of the strained geopolitical conditions, it can be anticipated the RoDTEP amount will be enough to meet the demand of the additional three sectors as well. So, one could hope the scheme will be extended to iron and steel, pharma and chemicals for the entire fiscal year.

At present, benefits under the scheme are available till June 30, 2024 for the three identified sectors. It will lapse after the date if not extended. The RoDTEP scheme, announced in January 2021 as a replacement for the WTO-incompatible MEIS scheme, remits embedded duties/taxes on inputs to exporters. These include VAT on fuel used in transportation, mandi tax and duty on electricity used during manufacturing, and input taxes not rebated under other schemes.

Outlay constraints

During inception, the scheme covered 8,731 items from most export sectors with the exception of organic and inorganic chemicals, pharmaceuticals and iron and steel. The only reason these sectors were excluded was outlay constraint as they qualify for substantial benefits due to relatively high exports.” said the source.

The Commerce Department later extended the scheme to the remaining three sectors as well, but for a limited period, retaining the flexibility to take an appropriate decision on further extension later. It was not the Department of Expenditure which directed the scheme should be extended for the three identified sectors for a certain time. The Commerce Department itself did so to ensure that Budget-imposed restrictions were not breached.

Exports shrink

India’s exports during April-December 2023 shrunk 5.7 % to \$ 317.12 billion compared with the same period last year on adverse geopolitical conditions, including the Red Sea crisis that disrupted India’s exports to the EU, U.S. east coast and parts of West Asia and Africa.

ECONOMICS AND DEVELOPMENT

HK COURT ORDERS EVERGRANDE TO LIQUIDATE AS \$300-BN DEBT PLAN FAILS

CONTEXT: A Hong Kong court ordered China Evergrande, the world’s most heavily-indebted real estate developer, to undergo liquidation in the wake of a failed effort to restructure debt of \$ 300 billion owed to banks and bondholders that fuelled fears about China’s rising debt burden.

China Evergrande Group is one of the biggest of a series of Chinese developers that have collapsed since 2020 under official pressure to rein in surging debt the ruling Communist Party views as a threat to China’s slowing economic growth. But a crackdown on excess borrowing has tipped the property industry into crisis, making it a drag on the economy, as scores of other developers ran into trouble, their predicaments rippling through financial systems in and outside China.

Containing risks

Global financial markets were rattled earlier by fears an Evergrande liquidation could cause global shockwaves. Evergrande’s Hong Kong-traded shares plunged almost 21 % early Monday before they were suspended from trading. But Hong Kong’s benchmark Hang Seng index was up 0.8 % and other property developers saw gains in their share prices.

China’s largest real estate developer, Country Garden, gained 2.9 % and Sunac China Holdings jumped 4 %. Some other property companies logged moderate declines. The Shanghai Composite index dropped 0.6 % while Shenzhen’s A-share index fell more than 2 %.

Attempt at ‘refining’

Evergrande gained a reprieve from the Hong Kong court in December after it said it was attempting to “refine” a new debt restructuring plan of more than \$ 300 billion in liabilities.

Asset disposal

Evergrande first defaulted on financial obligations in 2021, just over a year after Beijing clamped down on lending to property developers in an effort to cool a property bubble. If affected, we will still make every effort to ensure the smooth advancement of risk resolution and asset disposal, and still make every effort to advance all work fairly and in accordance with the law.

Real estate drove China’s economic boom, but developers borrowed heavily as they turned cities into apartments and office towers. That pushed total corporate, government and household debt to the equivalent of more than 300% of annual economic output, unusually high for a middle-income country.



“Education is the ability to listen to almost anything without losing your temper or your self-confidence.” - Robert Frost

GEOGRAPHY

WHAT IS HUMBOLDT'S ENIGMA AND WHAT DOES IT MEAN FOR INDIA?

CONTEXT: Alexander von Humboldt (1769-1859) – a polymath who recorded observations on various natural phenomena across the fields known today as geography, geology, meteorology, and biology suggested there was a relationship between temperature, altitude, and humidity on one hand and the occurrence patterns of species – or their biodiversity – on the other.

Humboldt's enigma

The world's tropical areas receive more energy from the Sun because of the earth's angle of inclination. The greater primary productivity facilitates greater diversity: more ecological niches become available, creating more complex ecosystems and greater biological diversity.

The proponents of Humboldt's enigma have held that the earth's tropical areas by themselves don't contain all the biodiverse regions. Mountains have been an important exception. The mountains, outside the tropics are highly biodiverse.

The biodiversity in our tropical areas, south of the Tropic of Cancer passing through Madhya Pradesh and Chhattisgarh. These areas are supposed to be the most diverse in the country. The Western Ghats plus Sri Lanka biodiversity hotspot lies in this zone. The eastern Himalaya are much more diverse. Some scientists have even suggested this part of the mountain range is the second-most diverse area of perching birds in the world. For river birds, the eastern Himalaya may be the most diverse.

What drives biodiversity?

The history of the earth, its geography, and the climate are the main drivers of mountain diversity. And different biodiversity at different locations is the result of changes in how these factors have intermingled over time and space.

First: geological processes, like uplifts, result in new habitats where new species arise, so the habitats are 'cradles'. Second: species on some climatologically stable mountains persist there for a long time, so these spots are 'museums' that accumulate many such species over time.

Coastal tropical sky islands (mountains surrounded by lowlands), like the Shola Sky Islands in the Western Ghats, are a good example. Here, old lineages have persisted on the mountain tops as climates and habitats fluctuated around them in the lower elevations. This is the reason some of the oldest bird species in the Western Ghats, such as the Sholicola and the Montecincla, are housed on the Shola Sky Islands.

The northern Andes range – including Chimborazo – is considered the most biodiverse place in the world. If we start from the foothills of the Andes and climb, we're going to encounter different temperatures and rainfall levels that support everything from tropical evergreen biomes in the lower elevation to the alpine and tundra biomes near the top. Such a large variation over short distances supports the

immense biodiversity found in mountain regions – and worldwide.

Scientists have found that the more heterogeneous the geological composition of mountains is, the more biodiverse they are. Around the world, all mountains with high biodiversity have high geological heterogeneity as well, especially in the tropics. Even in tropical regions, where we expect higher biodiversity, some mountains with a lower variety of rocks are relatively less biodiverse. So high geological heterogeneity often produces unique habitat patches on mountains within similar climate regimes, and promotes diversification.

Climate dissimilarity is still one crucial factor, something Humboldt also indicated based on his observations of the Chimborazo and understood to be a paradigm. Researchers have also found some groups of birds to have evolved elsewhere and dispersed to the Himalaya, resulting in higher diversity there.

What do we still not know?

Multiple factors drive diversification and the Humboldt's enigma in different parts of the world. Then again, scientists have also advanced more than a hundred different hypotheses on how diversity varies in different parts of the world, and they contend with the enigma in different ways.

The National Mission on Himalayan Studies, the National Mission for Sustaining the Himalayan Ecosystem, and the National Mission on Biodiversity and Human Wellbeing need to be strengthened, bolstered by the will to support basic research on diversity.

POLITY AND GOVERNANCE

PROS AND CONS OF SIMULTANEOUS ELECTIONS

CONTEXT: India's debate on simultaneous elections for Lok Sabha and State assemblies weighs the potential benefits of cost, governance, and cohesion against concerns about federalism, democratic feedback, and constitutional amendments.

THE GIST

- During the first four general election cycles in 1952, 1957, 1962, and 1967, the elections to the Lok Sabha and State legislative assemblies were held simultaneously.
- It is estimated that the cost of holding general elections to the Lok Sabha is around ₹4,000 crore for the Central government. Each State assembly election would also cost a considerable amount of money according to the size of the State.
- Conducting elections simultaneously to the Lok Sabha and all State assemblies would result in national issues overshadowing regional and State-specific issues. National political parties would have a significant advantage over regional parties on account of this mechanism.

STORY SO FAR:

The High-Level Committee established in September 2023 under the chairmanship of former President Ramnath

Kovind is undertaking a comprehensive examination of the potential for synchronized elections encompassing the Lok Sabha, State Legislative Assemblies, and local bodies across India. The Committee has formally invited submissions from political parties, the Law Commission, and other relevant stakeholders on this proposed electoral reform measure.

BACKGROUND:

- Simultaneous elections were held for Lok Sabha and State Assemblies in India's first 4 elections (1952-1967).
- Since then, frequent dissolutions led to unsynchronized elections, with only 4 states aligning with Lok Sabha in 2019.
- The idea of simultaneous elections was revived by the Election Commission (1982) and Law Commission (1999).

WHY THERE SHOULD BE SIMULTANEOUS ELECTIONS?

- **Cost saving:** Combining elections reduces government and party expenses significantly. Lok Sabha elections cost Rs 4000 Crore to Central Govt.
- **Improved governance:** Less frequent campaigning allows politicians to focus on policy and administration.
- **Enhanced efficiency:** Administrative resources and security forces wouldn't be diverted every year.
- **Reduced polarization:** Frequent elections with high stakes can exacerbate social divisions.

CHALLENGES INVOLVED

- **Loss of focus on regional issues:** National concerns could overshadow state-specific problems, potentially harming smaller parties and federalism.
- **Reduced electoral feedback:** Fewer elections might weaken the feedback loop between voters and governments, hindering responsive policymaking.
- **Constitutional hurdles:** Implementing fixed five-year terms requires amending Articles 83, 85, 172, and 174, along with possible changes to Article 356 on the President's rule.
- **Loss of flexibility:** Fixed terms limit the ability to dissolve parliament/assemblies in case of instability or government collapse, potentially leading to political deadlock.
- **Advantage for national parties:** Larger national parties may benefit from economies of scale and national media coverage, further marginalizing regional groups.

WHAT ARE THE VARIOUS RECOMMENDATIONS?

Partial bundling: Combine Lok Sabha elections with half of State Assembly elections, holding the remaining half 2.5 years later. This requires adjustments to term lengths and legal amendments.

Mandatory confidence vote: Link no-confidence motions to simultaneous confidence votes for alternate governments, encouraging stable coalitions.

Limited premature dissolutions: Shortened terms for prematurely dissolved houses discourage frequent elections and incentivize finding solutions.

Consolidated by-elections: Group by-elections and hold them annually to reduce disruption and cost.

International examples: Consider models like South Africa (fixed 5-year terms), Sweden/Germany (fixed terms with specific confidence motion processes).

AN IDEAL SOLUTION:

MAJOR POINTS ON SIMULTANEOUS ELECTIONS IN INDIA:

Lack of Consensus:

Political parties disagree on conducting simultaneous elections for Lok Sabha and all State assemblies.

Proposed Solution:

- Hold Lok Sabha elections in one cycle, followed by State elections two and a half years later.
- Implement additional measures like:
 - Mandatory confidence votes with no-confidence motions.
 - The limited term length for houses dissolved early.
 - Annual, consolidated by-elections.

Benefits:

- Reduces cost and campaign disruptions.
- Improves governance with focused work periods.
- Lessens election-related polarization.

Challenges:

- Requires constitutional amendments.
- Concerns about neglecting regional issues and feedback.
- Potential loss of flexibility in dissolving houses.

Way Forward:

- Build consensus among political parties.
- Implement necessary legal changes.
- If achieved, could continue benefiting India for years to come.

CONCLUSION: While the allure of cost-savings and cohesive governance draws India towards simultaneous elections, concerns for regional focus, democratic feedback, and constitutional hurdles remain. A middle ground, like holding Lok Sabha and State elections in separate cycles, coupled with measures like mandatory confidence votes and consolidated by-elections, might offer a workable solution. Building consensus and overcoming legal challenges is crucial for this reform to benefit India's future elections.

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SCIENCE AND TECHNOLOGY

IMPROVING BATTERY TECHNOLOGIES FOR SPEEDY EV ADOPTION

CONTEXT: The sales of Electric Vehicles (EV) in India recorded a 50 % growth compared to 2022. While actual volumes remain small (6 % of vehicles registered in 2023), the industry is poised for phenomenal growth with the Indian EV market expected to reach \$ 100 billion by 2030. The battery system accounting for 40 % of the vehicle cost. The projected growth of the EV market is dependent on advances in battery technology translating to better economics and enhanced user experience (longer range, faster charging and improved safety).

The lithium battery

Almost all EVs are powered by lithium-ion batteries. It consists of two electrodes (an anode and a cathode) separated by a liquid electrolyte. Lithium atoms in the anode give up electrons which travel to the cathode through an external wire — this stream of electrons provide the current which powers the motor of the vehicle. Simultaneously, lithium ions (now positively charged from loss of an electron) travel through the electrolyte to reach the cathode. During charging, the process is reversed with lithium ions being forced to travel back through the electrolyte to the anode.

Lithium, the lightest solid element has a high propensity to give up its electron. The small size enables the lithium ion to efficiently travel between electrodes through the electrolyte. This translates to lighter and smaller batteries with an ability to store large amounts of energy. Its energy density while high compared to earlier battery technologies, pales in comparison to petrol. Batteries are still slow to charge (compared to the few minutes it takes to fill petrol at a pump). There is a need to make batteries more affordable and increase their life-span. There are environmental concerns primarily related to the mining of lithium and other elements (such as cobalt, nickel).

On improving the battery

The efforts toward improving the EV battery can be broadly classified into three approaches. The first approach retains the basic structure of the lithium-ion battery while making tweaks to the electrodes. An ideal electrode should be light weight; store a lot of lithium; provide sufficient pathways for lithium to easily enter and exit the electrode (higher voltages and faster charging); and be made of materials that are cheap, non-toxic and easily available. But invariably there are trade-offs involved. For example, Tesla uses cathodes based on Nickel-Manganese-Cobalt (NMC) and Lithium Iron Phosphate (LFP) in their batteries. While NMC batteries have high energy density and thus provide longer range, LFP batteries have longer life, better stability, are less toxic and have faster charging times.

Another approach to improving battery performance involves deploying sensing and control infrastructure around the battery to increase safety, extend battery life and speed-up charging. For instance, a temperature sensor can be installed to detect dangerous conditions and shut down the

battery, preventing a fire. Monitoring parameters such as internal temperature, voltage and current and appropriately modulating the charging current and voltage can result in faster charging while maintaining battery life. Charging a battery involves moving lithium ions from the cathode to the anode. A Battery Management System (BMS) consists of sensors to measure parameters such as temperature, voltage and current; electronic circuitry to control the battery; and a compute engine to process the sensor data and issue appropriate control commands. Advances in battery management and charging algorithms are generally easier to deploy since they do not involve any fundamental changes to the battery chemistry.

Paradigm shifts

The liquid electrolyte used in EV batteries is highly flammable. The Solid-State Lithium Battery (SSB) replaces this with a heat resistant lightweight solid electrolyte. Further, the anode of an EV battery consists of a carbon based porous/layered scaffolding (typically graphite) — which houses lithium atoms (a crude analogy is water stored in a sponge). The carbon scaffolding provides the required stability during charging and discharging, as lithium is reactive. However, the solid electrolyte in an SSB provides sufficient structural stability and good separation between the anode and the cathode, that the carbon scaffolding is no longer needed at the anode. This can significantly reduce the weight of battery and also improve charging speed. Consumers can expect EVs that travel further with a single charge, are faster to charge and are safer across a wider range of temperatures, sometime before the end of this decade.



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