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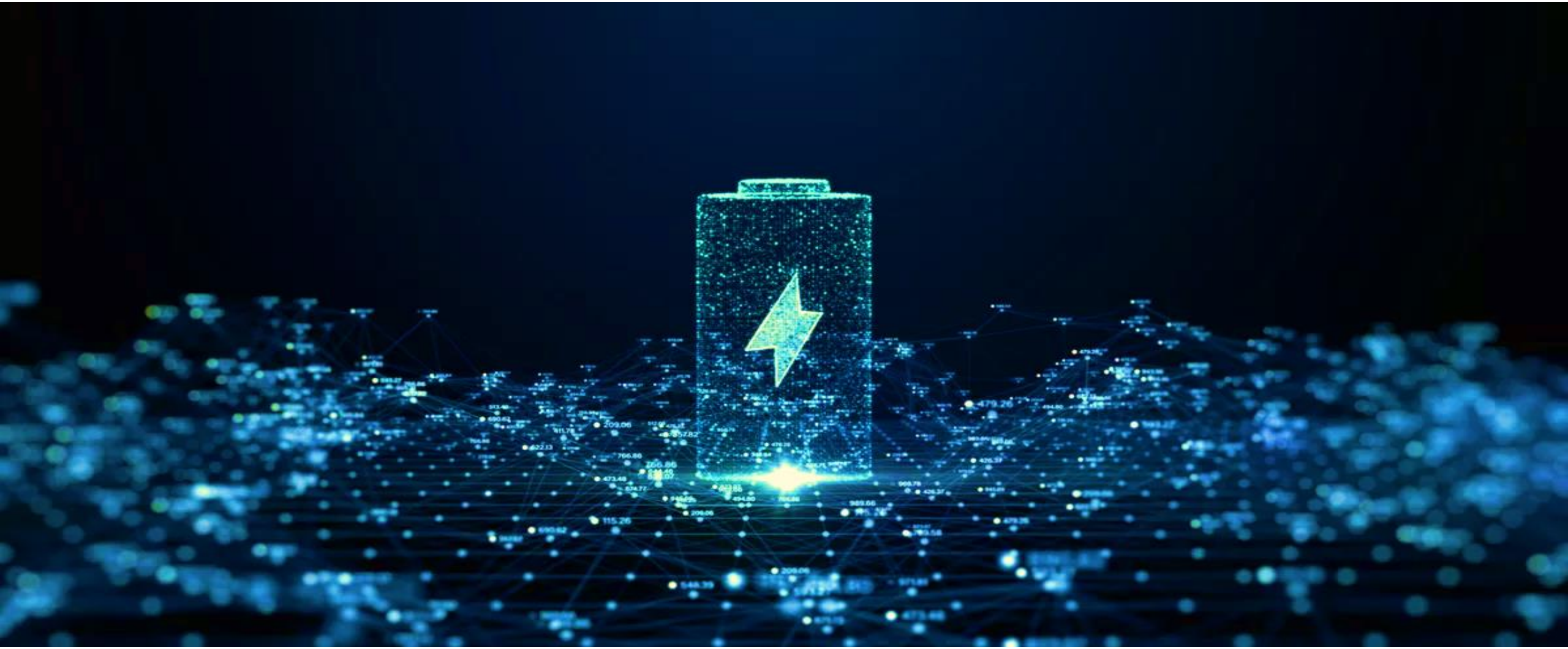


Battery ecosystem – What's next

Impact of technology on current and future state of the industry – A perspective

February 2024

Executive Summary

Market Study

- US EV market is **outpacing** EU and China in terms of growth. Traditional OEMs gaining market traction
- Regulations continue to provide a strong tailwind for batteries growth
- ICE phase out timelines coming closer further accelerating demand growth for **gasoline fuel alternatives**

Evolving Battery Landscape

- Liquid state Li-ion have some **potential challengers**, the likes of Sodium Ion in the short term and solid-state batteries in the mid term
- Rewarding **breakthroughs** have been made in laboratories but **real-world** applications stays questionable
- **Recycling** remains a priority. Initiatives are growing in this sector, but progress appears to be slow

Hydrogen Economy and its Potentials

- Green Hydrogen as a fuel source is growing. A Hydrogen and battery complementary synergetic system appears promising
- For passenger vehicles hydrogen is **lagging**. Batteries **take lead** both in terms of efficiency and established infrastructure
- Hydrogen **takes the lead** in replacing energy sources like coal in manufacturing, natural gas for heating and as a fuel source for Long distance travel (Aviation, Marine and more)

Market Study

Current Battery Ecosystem – Key Findings and Observations

Major End Markets (EV & ESS)

- US EV market growth **surpassing** that of China and Europe, with an increasing number of collaborations on the horizon. Korean battery cell manufacturers, including LGES, SKI, and SDI, maintain a **robust** market presence, bolstered by previously announced joint ventures
- The ESS industry growth is **outpacing** EVs. Chinese firms CATL and EVE lead with LFP offerings. Korea's catch-up, led by entities like LGES and L&F, will take time

Regulation

Inflation Reduction Act

Critical Raw Mineral Act

Emission regulation

- The U.S. IRA has introduced nuanced supply chain localization guidelines. Companies such as LGES, Pana, and SKI are on track to meet AMPC[1] by '23, with SDI following by '25
- While there's a gentle shift towards **diversifying** mineral sources **beyond China**, it's a strategic long-term vision for OEMs. The FEoC[2] will play a pivotal role in shaping Chinese participation in the U.S. EV market
- Potential **market shifts** from EU CRMA, the Net Zero Industry Act, and the updated U.S. EPA[3] regulations seem to be **subtle**

Incumbents & Competition

EV only Players

Conventional OEMs

Multi-sourcing/ Near term Consolidation

- Over a 3–5-year cycle, the EV segment of traditional OEMs is projected to outpace TSLA/BYD growth, yet the long-term EV penetration rate for traditional OEMs remains uncertain
- In the short-term, HMC, BMW, Mercedes in the US, and BMW, KIA, VW in Germany led BEV market growth in 1H23
- OEMs are trending towards **multi-sourcing** to mitigate sourcing risks, inviting new industry players. While battery cell supply-demand varies, top players are **consolidating their market share**

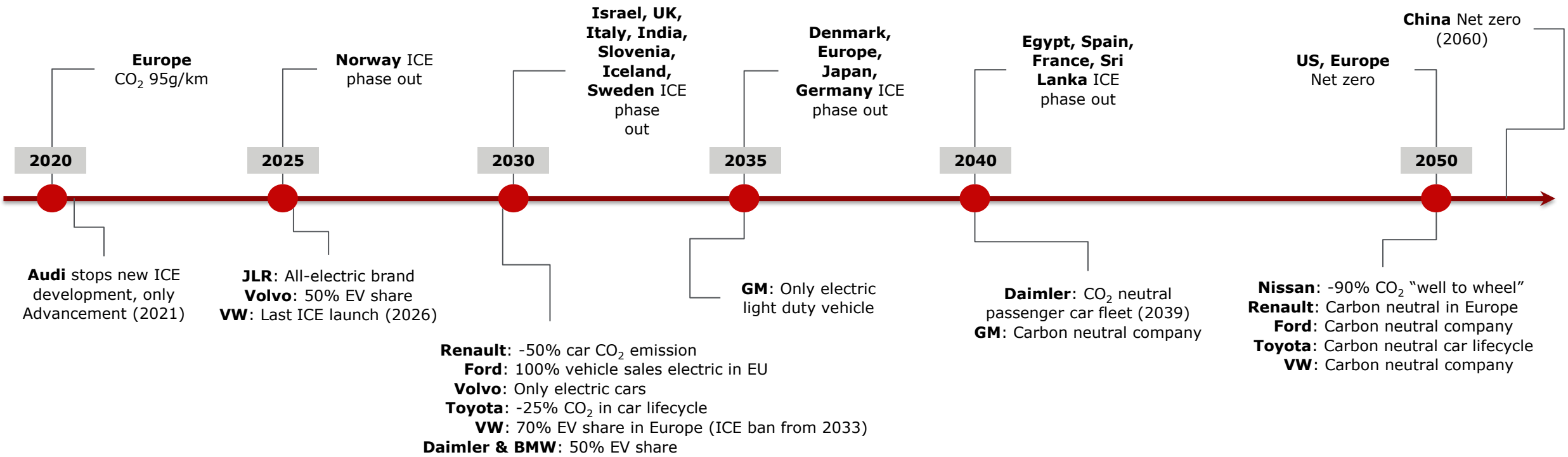
Notes: 1.Advanced Manufacturing Production Credits 2. Foreign entities of concern 3. Environmental Protection Agency

Source: Regulatory Bodies, IEA, Company Websites, Alphasense

Battery Demand driver : Emission Regulation

Battery technology has been critical in phasing out of ICE and achieving net-zero economy

ICE engine phase out roadmap

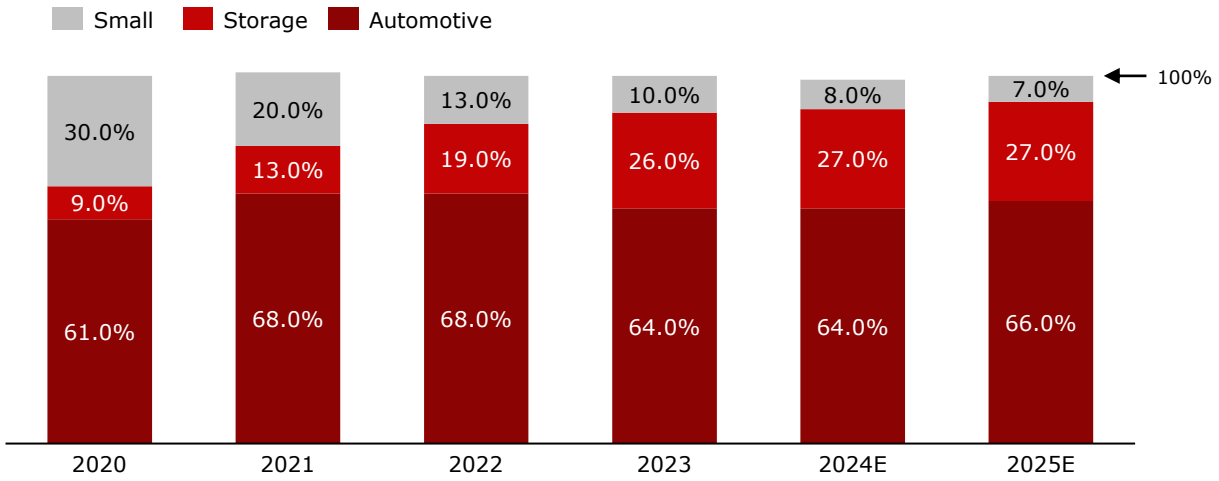


Source: The International Council on Clean Transportation

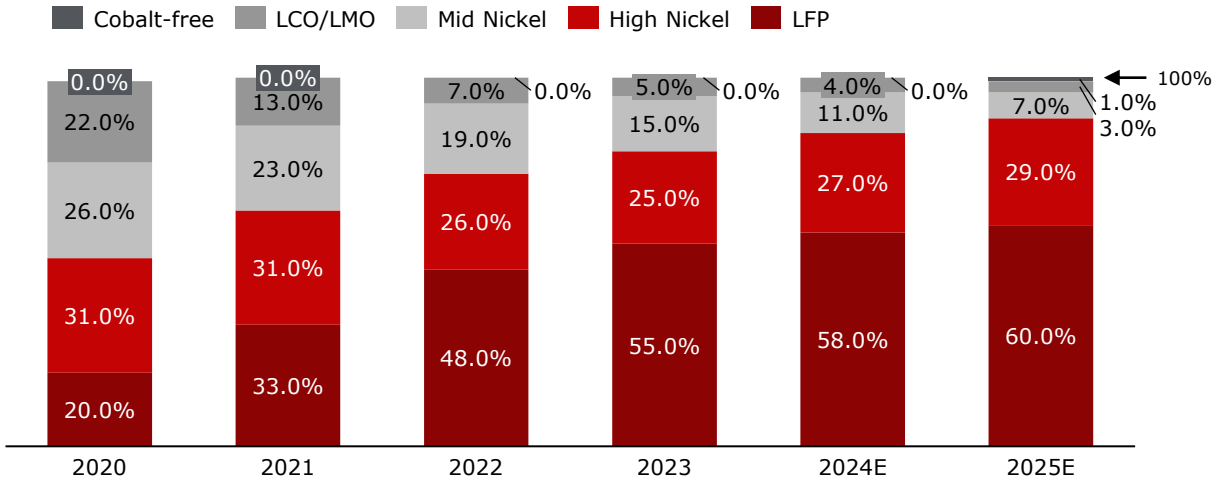
Global Battery Demand: Sectors, Chemistries & Supply Chain

A brief look at the battery demand across sectors, the popular chemistries and the supply chain

Global Battery Demand Mix



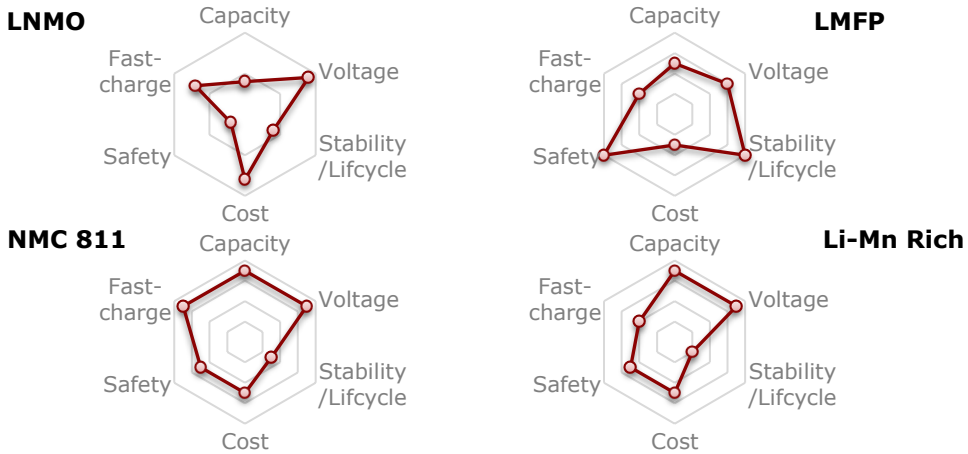
Global Battery Demand Chemistry Mix



Global EV Battery Supply Chain

Mining	Processing	Battery Material
Copper (Peru, Chile)	**Copper** (China, Chile)	**Battery Component** (China, Japan, Korea)
Lithium (Australia, Chile)	**Lithium** (China, Chile)	**Battery Cell /Pack** (China, EU, US, Korea)
Nickel (Indonesia, Philippines)	**Nickel** (Indonesia, China)	
Cobalt (DRC)	**Cobalt** (China)	
Rare Earths (China)	**Rare Earths)** (China)	

Popular Battery Chemistry Comparison



Source: Idtechx, JP Morgan, IEA

Innovations in Battery Technology

Battery Technologies 2023

Fueling the future of energy storage and EV revolution

Leading innovations

Sodium ion batteries

✓ Enhanced safety, potential for EVs

✓ Offers a cost advantage without needing critical minerals

Solid state batteries

✓ Emerging as strong alternatives

✓ Solid-state Lithium-Sulfur batteries have been highlighted for enhancing energy density and safety

Flexible batteries

✓ Lightweight

✓ Integrated into wearables and textiles

Other innovations

- **NanoBolt Lithium Tungsten Batteries:** Using nanotubes for faster recharging
- **Zinc-Based Batteries:** Resemble lithium-ion, ideal for solar storage
- **Cobalt-Free Batteries:** Use high nickel and lithium iron phosphate for sustainability
- **TankTwo's String Cell™:** Quick swapping & recharging for Evs

Emergence of battery recycling: *As the demand for batteries increases, so does the importance of repurposing and recycling them. Initiatives are growing in this sector, led by companies such as CATL in China and Redwood Materials in America*

Current state

- 65% surge in Li-ion battery demand
- Battery cost at ~$150/kWh
- Focus on: Energy, Charging, Cost, Grid Storage

Challenges

✗ Scaling Up: While some innovative batteries show promise, they currently face challenges related to scalability

✗ Material Shortages: The growth in battery technologies has led to an increased demand for critical materials like lithium, cobalt, and nickel

✗ Cost Concerns: The price per kWh affects EV competitiveness. Battery prices are influenced by fluctuations in critical mineral prices

Source: ScienceDaily, IEA, World Economic Forum, Technology Reviews

Solid state batteries : Challenges and Prospects

The battery technology is proven but scalability seems to be a major issue

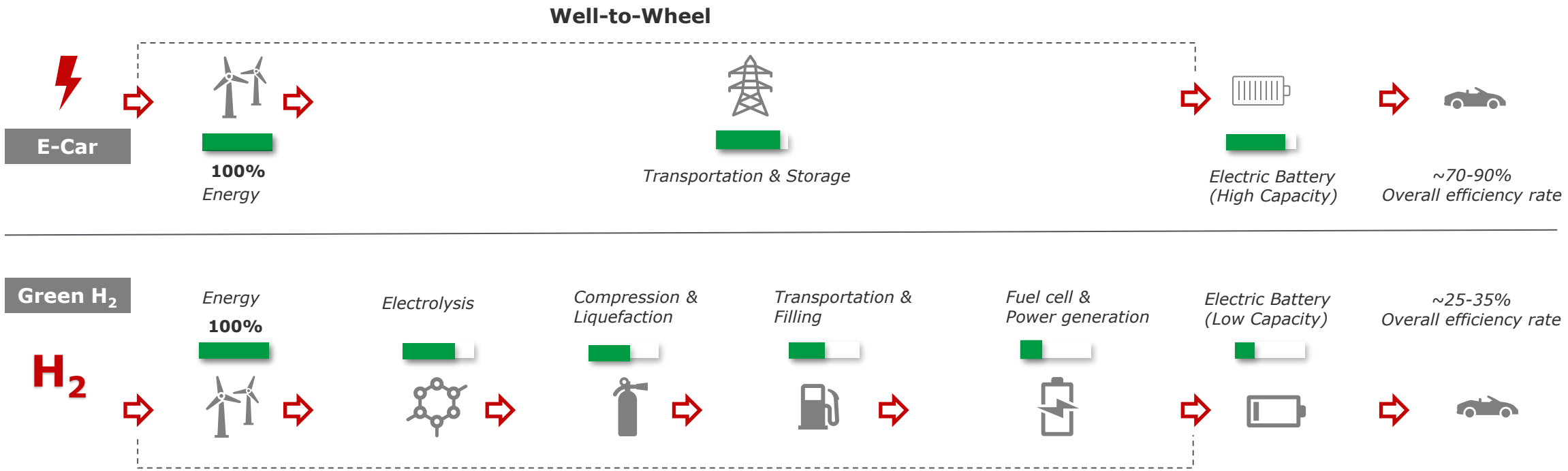
Challenges		Outlook
Scalable and cost-effective manufacturing processes are still lacking, posing an **economic challenge.** Current manufacturing is non-transferable to SSB	**Lack of Manufacturing**	Investments are being made to **refine** the **manufacturing process** before scaling. Hybrid SSBs are probable in the short run
SSBs require 5-10x of Li compared to the current Li-ion batteries. Additionally, some chemistries include extremely rare and precious metals such as Platinum	**Material Challenges**	**Alternative chemistries** are being researched on by various players with interesting results. **Recycling initiative** remains a priority
Electric Vehicle SSB are sensitive to moisture and require high mechanical pressure to operate making their design complex and the manufacturing costs **>40,000$**	**High Cost**	**Cost will decline** as prototypes are approved and commercialized, and with timely tech improvements will become cost-competitive
Although solid-state batteries promise higher energy densities, achieving this in a stable manner is a hurdle	**Poor Stability**	R&D is showing promising results. Toyota is expecting a 2027 mass market ready tech

Source: ScienceDaily, IEA, ACS publications, Researchgate

Hydrogen Economy | A Boon or Curse for Batteries?

BEV vs FCEV Technologies

Hydrogen car consumes 2-3x more electricity for the same distance than a battery car



Well to Wheel Efficiency

- According to studies, all-electric cars can achieve an outstanding overall Well-to-Wheel efficiency of **70-90%**, depending on a particular example
- Hydrogen fuel cell vehicles require 2-3 times more energy for the same distance due to a Well-to-Wheel efficiency of **25-35%**
  - **45%** energy loss occurs during hydrogen production via electrolysis and compression & liquefaction
  - An additional **55%** of the remaining energy is lost in the in-vehicle conversion from hydrogen to electricity
  - Resulting efficiency for hydrogen-powered cars ranges between **25-35%** depending on the model
  - The efficiency rate is **poorer** than the currently existing gasoline ICE vehicles

Source: Volkswagen

BEV vs FCEV Technologies

Hydrogen car technology is expensive and lacks refueling infrastructure whereas battery powered cars are mass market ready and cost effective

FCEV Advantages and Disadvantages

Advantages

- Emission-free
  - Output consists of water vapor
- Hydrogen availability is infinite
  - Via electrolysis
- Long range vehicles
  - Up to 600 km
- Fast refueling
  - 3-5 minutes

VS

Disadvantages

- Lower efficiency
  - Due to high energy losses
- Highly flammable
  - Low point of volatility
- Poor Infrastructure
  - ~90 filling stations globally
- High Costs
  - Expensive to purchase and maintain

Food for thought

- Battery-powered cars excel in environmental sustainability and are market-ready with a growing model range
- **Cost-effectiveness** is a strong suit for electric vehicles, already matching combustion engine prices
- Hydrogen vehicles face persistent **cost barriers** due to complex technology and high fuel expenses
- Current **operating costs** for hydrogen cars are significantly higher, around $9-12 per 100km, versus $2-6 for battery cars
- Concerns over long-distance travel are **diminishing**, as next-gen electric cars will offer 400-600km ranges and faster charging.

Conclusion

The verdict is unequivocal: for passenger vehicles, the evidence overwhelmingly **supports battery technology** over hydrogen solutions. From an efficiency standpoint, leveraging fuel cells would essentially require **doubling** the consumption of renewable energy compared to battery-powered cars, simply **not sustainable** for any economy focused on long-term viability

Source: IEA, World Economic Forum, Hydrogen council, Department of Energy

What’s Next?

Evolution of Batteries – Potential Scenario

Technologies co-exist with different tech serving different needs

2023-2027

Current state

❑ **LFP Battery dominates**

LFP dominating the landscape in the short term. Strong flow of investment in its chemistry improvement and further R&D

❑ **NMC batteries & other chemistries fill gaps**

NMC batteries market share is reducing but stays a strong competitor. Na-ion chemistry shows promise

❑ **Hydrogen & SSB Prototypes**

Strong investments flow in Hydrogen and solid-state battery technology R&D

2027-2030

Lithium domination

❑ **Li-ion Battery Monopoly continues**

Li-ion battery cost <$80/kwh as gigafactories come online, technology improves, and metal prices normalize

❑ **Na-ion batteries, a strong alternative**

Na-ion batteries flourish. Gigafactories can be retrofitted to produce Na-ion quickly

❑ **Hydrogen & SSB breakthroughs**

Hydrogen as fuel replace coal partly in manufacturing. Hydrogen fuel cell EVs and SSB commercialization(first wave)

Beyond 2030

Commercial viability for hydrogen and SSB

❑ **Liquid state battery position strong**

Multiple battery chemistries in the market divided based on region and use-case

❑ **Hydrogen becomes cost competitive**

Hydrogen supply chain strengthens, and fuel cell technology improves making H_2 a strong complementary technology

❑ **SSBs become mass market ready**

SSBs become prominent but stay premium

Post-2027, we anticipate a battery landscape shift with sodium-ion alongside lithium-ion dominance. Beyond 2030, hydrogen and SSB batteries will gain momentum due to cost-effective mass production

Source: Secondary Resources, Transjovan Analysis

About Transjovan Capital

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