

Singapore Battery Consortium

2022 Q3 Newsletter



SINGAPORE BATTERY CONSORTIUM

Understanding curation of recent industry developments and technology news

Recent industry developments and technology news are specifically curated based on the relevance to the progression of the industry. Each news event is categorized based on importance and area of focus (see below for description for both).

15 January 2020
SK Innovation announces 10 GWh expansion of factory in U.S.
 Very **3** Important | Energy **4** Storage

SK Innovation will build its second U.S. factory in Georgia, from which it intends to ship another 9.8 GWh to VW in Tennessee. Its total production goal of 100 GWh by 2025 outpaces its publicly known manufacturing projects, so expansions near already-planned facilities will likely be a forthcoming trend. In the Southeast U.S., automotive manufacturers are nearby: VW is in Tennessee, Daimler has factories in South Carolina and Alabama, where Hyundai also is, and Volvo, BMW, and Kia are located in Georgia. Clients should expect SK Innovation to ramp up production near customers and keep chipping away at its 2025 goal.

- 1 Link:** Hyperlink to original news article. Note some news articles may be behind paywall.
- 2 Analysis:** Writeup of the news event as it relates to industry development and recommendations for action.
- 3 Importance:** Take on the potential importance of the event from "Truly Disruptive" to "Ignore"
- 4 Area of Focus:** Category of the news event based on the to the topic.

Importance	Description
Truly Disruptive	A game-changing, landmark development
Very Important	Significant news that will have strong implications
Average Importance	Worth noting, but not likely to be too important or disruptive
Low Importance	An over-hyped development, which is not worth monitoring closely
Ignore	Misleading or irrelevant development, worth being cautious about

Area of Focus	Description
Built environment energy use	Hardware and software technologies for commercial and residential energy consumption
Business models and regulations	Novel business models for energy production, consumption, and distribution, as well as policies with transformational impact on new energy technology development
Energy for mobility	Energy sources for powering road, rail, aviation, and marine – includes movement of goods and people
Energy storage	Various forms electrochemical energy storage, such as Li-ion and solid-state batteries
Stationary storage	Utility-scale and long-duration energy storage for grid services, renewables integration and backup, and microgrid support

RECENT INDUSTRY DEVELOPMENTS AND TECHNOLOGY NEWS

Second-life battery applications gaining traction as automotive OEMs face pressures on end-of-life processing

1 July 2022



Ambri lands 300-MW order with zero existing pilot deployments

Low Importance

Stationary storage

Earth&Wire ordered a total of 300 MW/1,200 MWh of Ambri's liquid metal batteries. Ambri will begin delivering batteries by 2024, and finish installation by 2026. Earlier in June, Ambri opened an expanded manufacturing facility despite having no publicly deployed systems. The company targeted its first prototype operation by April 2022 but has yet to announce if that goal was met. Clients should be critical of Ambri's strategy. Expanding manufacturing and promising technology delivery before field tests are extremely risky actions for a stationary storage company; despite raising USD 144 million last year, Ambri's battery is unlikely to be ready for the scale the company expects.

11 July 2022



Energy Superhub Oxford launches Europe's most powerful EV charging hub and hybrid battery system

Very Important

Energy for mobility

Partly funded by the U.K. government's industrial strategy challenge fund, the 3-year-old demonstration program launched a 10-MW charging hub to offer ultra-rapid charging for 42 EVs, with ability to scale to 400 EVs. It also includes a hybrid battery system developed by Pivot Power that combines a 5-MWh vanadium flow battery from Invinity Energy Systems with a 50-MWh lithium-ion battery from Wärtsilä. The charging hub that is entirely powered by renewable energy showcases an impressive collaboration and is the first to be directly connected to the U.K.'s national grid. A handful of follow-up announcements demonstrates the strong blueprint of the program.



Mercedes-Benz



12 July 2022

Mercedes-Benz becomes next OEM to jump into battery second life without a clear strategy

Average Importance

Energy storage

Moment Energy will integrate Mercedes-Benz's end-of-life (EOL) electric vehicle batteries into its 60-kWh energy storage unit. The announcement didn't clarify which party would assume responsibility for collection and testing, but it will probably be Mercedes. As more OEMs start exploring battery EOL options, second-life applications have seen a resurgence in interest, and smaller energy storage systems are a natural first market. Although there is some opportunity for technology advancement — like building a battery management system that accounts for used-battery performance or creating faster, more accurate battery testing processes — the major hurdle in second-life applications is commitment from OEMs and cell manufacturers to invest in a business that holds little incentive for the EOL battery supplier.

RECENT INDUSTRY DEVELOPMENTS AND TECHNOLOGY NEWS

Novel materials continue to be a key innovation focus despite the commercial success of incumbent Li-ion



27 July 2022

[Rivian vehicles hit the road in Amazon delivery fleets](#)

Rivian's custom vehicles have hit the road in multiple American cities including Chicago, Dallas, Nashville, San Diego, and Seattle. This is part of a deal the two companies signed in 2019, for Rivian to deliver 100,000 vehicles to Amazon by 2030. While the companies have not disclosed the number of vehicles in this first delivery, the initial agreement was for the delivery of 10,000 vehicles in 2021. Circumstances such as the COVID pandemic appear to have pushed timelines back slightly. Clients can expect more Rivian deliveries to Amazon in the upcoming months and years.

Average Importance

Energy for mobility



29 July 2022

[Northvolt and Stora Enso to produce hard carbon sourced from lignin](#)

Battery manufacturer Northvolt and wood-derived products supplier Stora Enso announced a partnership that would incorporate lignin-derived hard carbon into batteries. Northvolt was founded as a company dedicated to building sustainable batteries in Europe, and carbon-based anode products are one of the hardest battery materials to source sustainably. On the other hand, hard carbon is typically not used in Li-ion batteries because it has more capacity loss and operates at lower voltages than seen with graphite. If Northvolt plans on incorporating hard carbon anodes into its Li-ion batteries, it will likely be for low-performance applications.

Average Importance

Energy storage



CUBERG

1 August 2022

[Cuberg achieves another major milestone by almost doubling the cycle life of a lithium metal cell](#)

Since the acquisition of Cuberg by Northvolt more than a year ago, Cuberg has developed a scalable battery technology that promises high energy density and applications beyond electric vehicles. Recently, the company assessed its next-generation lithium metal cell technology — a 5-Ah pouch cell at 25 °C ambient temperature — which confirms that its cycle life nearly doubled from 370 to 672 with 80% capacity retention at C/2 charge and 1C discharge rates. Also, the cells reach an energy capacity of about 330 Wh/kg at 1C discharge. Cuberg's announcement brings its lithium metal battery technology closer to commercial viability compared to other companies. As the company ramps cell capacity to 20 Ah, clients should look for production viability, product delivery, and customer validation to gauge further progress.

Average Importance

Energy storage

RECENT INDUSTRY DEVELOPMENTS AND TECHNOLOGY NEWS

QuantumScape continues to grab headlines for technology improvements, but struggles to scale up manufacturing



3 August 2022

[EnergyHub expands its portfolio, including V2G solutions for utilities](#)

Average Importance

Energy for mobility

According to the company, the new piece of the software added to the core platform, branded as EnergyHub EV, enables vehicle-to-grid (V2G) capabilities and supports all electric vehicle (EV) and charging station brands. The software aggregates and monitors EVs as well as forecasts EV charging load, enabling services such as load shifting (optimizing battery charging schedules) and peak demand management (providing V2G services based on alerts provided by the distribution network). Currently, EnergyHub works with over 60 utilities from the U.S., ChargePoint, and other partners managing more than 2.9 GW of flexible assets.



4 August 2022

[Cummins ventures into energy storage with investment in VoltStorage](#)



Average Importance

Energy storage

Cummins invested USD 24 million in VoltStorage. This investment aligns with its plan to scale up solutions focused on grid integration and energy storage. In collaboration with VoltStorage, the company plans to scale vanadium redox flow battery (VRFB) systems for commercial and agricultural applications and focus on the research and commercialization of iron salt batteries. This strategic investment by Cummins in VoltStorage will benefit the company in the near term with its VRFB technology, and VoltStorage will have better support to explore alternative flow battery technologies.



5 August 2022

[QuantumScape makes progress with 24-layer cell and production automation](#)

Average Importance

Energy storage

In its quarterly letter to shareholders, QuantumScape announced it has successfully created a 24-layer prototype cell with promising cycling stability up to 100 cycles, and it is developing a new catholyte formulation that is operational at $-30\text{ }^{\circ}\text{C}$. Additionally, the company noted that it has made strides to create more uniformity in its electrolyte film production and automate cell stacking. However, one easily overlooked detail is that QuantumScape is also developing its own form factor. Considering the hurdles associated with manufacturing a solid oxide electrolyte and assembling it into a cell, it should be no surprise that QuantumScape is looking to optimize its technology with a new form factor as well.

RECENT INDUSTRY DEVELOPMENTS AND TECHNOLOGY NEWS

Off-road vehicles remains an untapped opportunity for electrification in the transportation sector



5 August 2022

[Nexeon raises USD 200 million](#)

Average Importance

Energy for mobility

In January, SKC had announced its investment and a licensing agreement for Nexeon's silicon material; this final round adds chemical company Ingevity to the list of strategic investors. Nexeon will use the funding to scale up manufacturing for its silicon anode materials, which the company claims are already in use by battery manufacturers, to a capacity on the scale of tens of thousands of metric tons. Although Nexeon is gaining commercial traction, giving it a head start in the composite silicon anode space, its materials only allow for approximately 10% silicon loading, which only provides incremental performance improvements compared to graphite anodes.



5 August 2022

[Enzinc raises USD 4.5 million seed round for zinc-air batteries](#)

Ignore

Energy storage

Following a USD 1.5 million grant from the California Energy Commission, Enzinc closed a seed round led by venture capital firm 3x5 Partners. Enzinc's technology utilizes a sponge-like zinc anode material, which the company claims deters dendrite formation, and the air cathode is made from nanostructured porous carbon. Last year, the company achieved 1,000 cycles, though it did not disclose testing conditions, and current funding will be used to scale its prototype. Clients should ignore Enzinc for now; though there is some interest in zinc-based batteries, Enzinc's technology has far to go before it can demonstrate value in energy storage.



8 August 2022

[Electric terminal truck company Orange EV raises USD 35 million](#)

Average Importance

Energy for mobility

Orange EV's institutional funding round was led by S2G ventures and CCI. Orange EV plans to use the capital to scale its manufacturing to meet growing demand. The company produces terminal tractors, which operate in areas like ports, manufacturing plants, and distribution centers, meaning that they do not have high range requirements. The North American Council for Freight Efficiency points to these vehicles as prime candidates for electrification. Clients can therefore expect such vehicles to quickly increase in number.

RECENT INDUSTRY DEVELOPMENTS AND TECHNOLOGY NEWS

Raw materials security continues to drive activity in novel lithium extraction technologies



12 August 2022

GM prepays Livent USD 198 million for six years of lithium



Average Importance

Energy storage

Automakers have moved to secure supplies of raw materials to avoid shortages or procure materials from spot markets where prices are highest. Many have signed offtake agreements for key minerals such as nickel, lithium, and cobalt, while Volkswagen, BMW, and GM have all invested in projects aimed at more novel lithium extraction techniques. This announcement that GM would prepay for such a large amount of lithium is highly unusual, but speaks to the scarcity of lithium supplies and the measures automakers will go to secure raw materials. Clients should expect announcements like this to become more frequent, especially lithium, given the shortage is likely to last years, not months.



12 August 2022

DLE startup EnergyX raises USD 450 million in hopes of a future IPO

Very Important

Energy storage

In the race to commercialize direct lithium extraction (DLE) technology, Texas-based startup EnergyX has landed a USD 450 million commitment from Global Emerging Markets, a USD 3.4 billion private equity group. EnergyX plans to use the funds to scale its technology and future lithium extraction projects in South America, and eventually go public sometime in 2024.



YAMATO
TRANSPORT

16 August 2022

Japanese study eyes adding cartridge batteries to commercial EVs to shorten charging times

Average Importance

Energy for mobility

Yamato Transport and Commercial Japan Partnership Technologies Corporation (CJPT), announced an upcoming study on cartridge batteries for commercial electric vehicles (EVs). Yamato and CJPT aim to standardize and commercialize replaceable and rechargeable cartridge batteries compatible with all commercial vehicles' fixed batteries. The venture's goal is to reduce recharging times by connecting them with fixed batteries, limiting battery size to actual driving range needs. In battery swapping, the biggest bottleneck is the lack of standardized batteries across all automakers. Last-mile solutions like the proposed cartridge batteries help ease range anxiety. Clients should monitor this development to understand the challenges of implementing battery swapping in commercial vehicles.

RECENT INDUSTRY DEVELOPMENTS AND TECHNOLOGY NEWS

Asia-based battery manufacturers continue to expand geographical footprint with international facilities



23 August 2022

[Motional and Lyft launch all-electric robotaxi service in Las Vegas](#)

An undisclosed number of IONIQ 5-based robotaxis will be available for riders to summon on the Lyft app in daylight hours on select routes in Las Vegas. Initially, the vehicles will have two safety operators in the front seats with Motional aiming for fully driverless rides in 2023. Similar to Motional's deployment with Via in the city, riders will not be charged; the main goal of this launch is to gather rider feedback. Nevada's less stringent autonomous vehicle regulations will likely allow Motional to relatively quickly increase the number of vehicles on Las Vegas' streets.

Average Importance

Energy for mobility



Mercedes-Benz



24 August 2022

[Mercedes-Benz sets itself as first customer of CATL in Hungary](#)

Mercedes-Benz announced it will be the first customer of CATL's upcoming production facility at Debrecen, Hungary. CATL's plant will have a production capacity of 100 GWh of cells at an investment of USD 7.5 billion and a claimed carbon-neutral production. Europe's focus on developing a domestic battery industry was initially focused on not over-relying on an Asian supply chain. Nevertheless, foreign companies like CATL, LG Chem, and Samsung SDI expanded their European footprint. Clients should recognize that foreign companies are welcome to develop a local supply chain rather than importing goods —aimed to produce local benefits as well as resolve supply chain issues.

Average Importance

Energy for mobility



6 September 2022

[Nio's battery swapping stations utilized as virtual power plants by State Grid](#)

China has recently faced high electric loads due to hot weather. State Grid, which supplies power to more than 1.1 billion people in China, mitigated peak load by reducing the power of charging stations during peak hours, which increased electric vehicle (EV) charging times by 5–6 minutes, temporarily closing down fast chargers, and encouraging EV owners to charge during off-peak hours. During these circumstances, State Grid utilized Nio's swapping stations as virtual power plants by discharging batteries for 5–10 minutes, reducing the grid's peak load. The average power reduction per swapping station was 100 kW, but there was no disruption to customer services.

Average Importance

Stationary storage



RECENT INDUSTRY DEVELOPMENTS AND TECHNOLOGY NEWS

Growing energy security concerns continue to position electric vehicles as energy assets via V2G applications



13 September 2022

Lightyear raises EUR 81 million to meet EUR 30,000 targets for its commercial solar EV

Average Importance

Energy for mobility

In a recent press release, the Dutch solar electric vehicle (EV) designer Lightyear announced EUR 81 million in investments from government agencies in North Brabant and Limburg and private firms Invest-NL, which invested EUR 25 million, SHV, and DELA. These funds will be used to produce 250 models of Lightyear's first iteration, the "Lightyear 0," and the development of its at-scale production model, the "Lightyear 2." Lightyear 2 is expected to hit the market in 2025 and cost EUR 30,000; the startup already has 10,000 preorders for Lightyear 2.

Highland



14 September 2022

Unlocking flexible assets to support the power grid by providing V2G services during high-demand periods

Average Importance

Stationary storage

The project is being developed in Beverly, Massachusetts, by Highland Electric Fleets (HEF) in partnership with Proterra, Thomas Built Buses, Rhombus, and Synop. It implements two school buses with a battery system. So far, the buses have participated in 32 vehicle-to-grid (V2G) events from National Grid, adding up to 7 MWh of energy during periods of high demand caused by the high summer temperatures (during July and August of 2022). HEF plans to deploy more projects in the states of Vermont, Maryland, Colorado, California, and Virginia.



26 September 2022

Lithion Recycling closes Series A, snagging GM Ventures as a major investor

Average Importance

Energy storage

GM, which has a joint venture with LG Energy Solution called Ultium Cell, will further support its battery business with an investment in Canadian startup Lithion Recycling. The battery recycling company already has a demonstration battery processing facility, which opened in January 2020. Automakers with an existing battery manufacturing business are investing in battery recycling to use the technology for recovering manufacturing scrap and then build capacity for end-of-life pack recycling. However, the most notable piece of this investment news is that Lithion and GM will collaborate on building more recyclable battery packs. Though it won't be a major issue for another 10 years or more, automated pack disassembly and waste processing will be necessary as volumes of waste batteries skyrocket.

ENERGY STORAGE MARKET FORECAST

The energy storage market is set for massive growth

Mobility applications will drive demand

The critical role of energy storage in the energy transition will drive dramatic growth in its demand. Usage in electric vehicles (EVs) will drive the most growth — 92% of demand in 2040 — due to large pack sizes and a large addressable market. Stationary applications will capture dramatically less energy storage demand, but significantly higher system-level costs will capture nearly one-third of revenue in 2040.

Availability and cost of raw materials will dictate the pace of growth

Dramatic cost reductions in energy storage previously came from growing economies of scale. Today, those cost reductions are maximized, and the costs of batteries are closely tied to the price of raw materials. Further, automakers are scrambling to secure cell supplies to avoid potential shortages. With few alternatives to Li-ion batteries commercially available today, a lack of growth in the Li-ion supply chain could limit growth.





Residential



Commercial and industrial



Utility

ENERGY STORAGE MARKET FORECAST

Methodology

Stationary storage is divided into three sectors: residential, behind-the-meter commercial and industrial, and front-of-the-meter utility. Energy consumption varies across the three categories, and the market sizes are similarly distinct given the same energy demand.

- **Residential:** Residential energy storage systems are almost always tied to rooftop solar installations. We assume a 5-kW system size across geographies.
- **Commercial and industrial:** Commercial and industrial energy storage is primarily used for backup and demand charge reduction. Our model assumes a 100-kW battery and a 4-hour duration.
- **Utility:** Utility scale takes up the largest market share of stationary storage with the most possible applications. Systems range from single MW to over 100 MW and typically have a discharge duration between 2–4 hours.

ENERGY STORAGE MARKET FORECAST

Methodology

To model stationary storage technology adoption, the forecast model utilizes a logistic function to simulate an S-curve. The function uses the following input parameters:

- **Past Deployments:** The existing energy storage infrastructure provides the starting point for the forecast, and it also provides insight for potential disruptions. In 2019, the energy storage market stagnated, in part due to large deployment numbers in 2018, and a lack of supportive regulations to integrate new assets.
- **Historic Energy Mix and Projected Penetration of Renewables:** Energy storage growth is intrinsically paired with the penetration of renewables. Grids will continue growing nondispatchable capacity for renewables while retiring traditional fossil fuel generators. The rate of change of the grid determines the timing for a specific energy storage market.
- **EV Fleet Size:** Fleet size by 2040 will determine additional energy needs not immediately predicted by historic power production patterns or stated capacity goals of renewables. Electrification of the transport sector and the additional load it creates are considered in our forecasts.
- **Replacement Rates:** The model assumes a 10-year retirement rate of energy storage assets, primarily based on Li-ion capabilities. Regions with slower growth will see replacement rates start to dominate the projected demand.

ENERGY STORAGE MARKET FORECAST

Methodology

Electrification of the transport sector has driven the vast majority of demand for energy storage. In this forecast we've considered demand from road-based transportation including the following vehicle types:

- **Light-duty vehicles:** Light-duty vehicles are primarily privately owned passenger vehicles but include smaller commercial vehicles, Class 2 and under.
- **Medium-duty vehicles:** Medium-duty vehicles (MDVs) are primary commercial vehicles between Classes 3–6.
- **Heavy-duty vehicles:** Heavy-duty vehicles (HDVs) include Class 7 and Class 8 trucks, which are used for commercial purposes. This category includes vehicles used in both shorter regional and long-haul routes.
- **Buses:** This category includes intracity buses used to move people within cities as well as intercity buses that travel longer distances between cities.

Light-duty vehicle



Medium-duty vehicle



Heavy-duty vehicle



Heavy-duty vehicle



ENERGY STORAGE MARKET FORECAST

Methodology

We also use logistic functions, or S-curves, for mobility applications as they are commonly used to predict the timing and magnitude of technology adoption. The following factors are used to calculate S-curve parameters:

- **Historical Vehicle Sales:** Many regions are already seeing meaningful EV penetration above 10% as market penetration increased significantly during the COVID-19 pandemic. Our S-curves consider the calculated S-curve parameters from historical adoption.
- **Powertrain Costs:** Vehicle costs are a significant factor in customers purchasing vehicles. We consider both upfront costs for each powertrain in our forecasts as well as total cost of ownership (TCO). In light-duty vehicles, upfront costs are more important, while in commercial applications (MDVs and HDVs), TCO is weighted more heavily.
- **Regulations and Subsidies:** Regions with the strongest financial subsidies and regulations surrounding the adoption of EVs have seen the largest adoption to date, making this an important metric to consider in forecasts. The main types of regulations we consider are financial subsidies for EVs, bans of vehicles with internal combustion engines (ICE), and fuel efficiency standards.
- **Consumer Sentiments:** While most consumer surveys should be taken with a grain of salt, considering respondents may not be familiar with EV technology, there is no denying that consumer interest in EVs is accelerating and impacting demand.

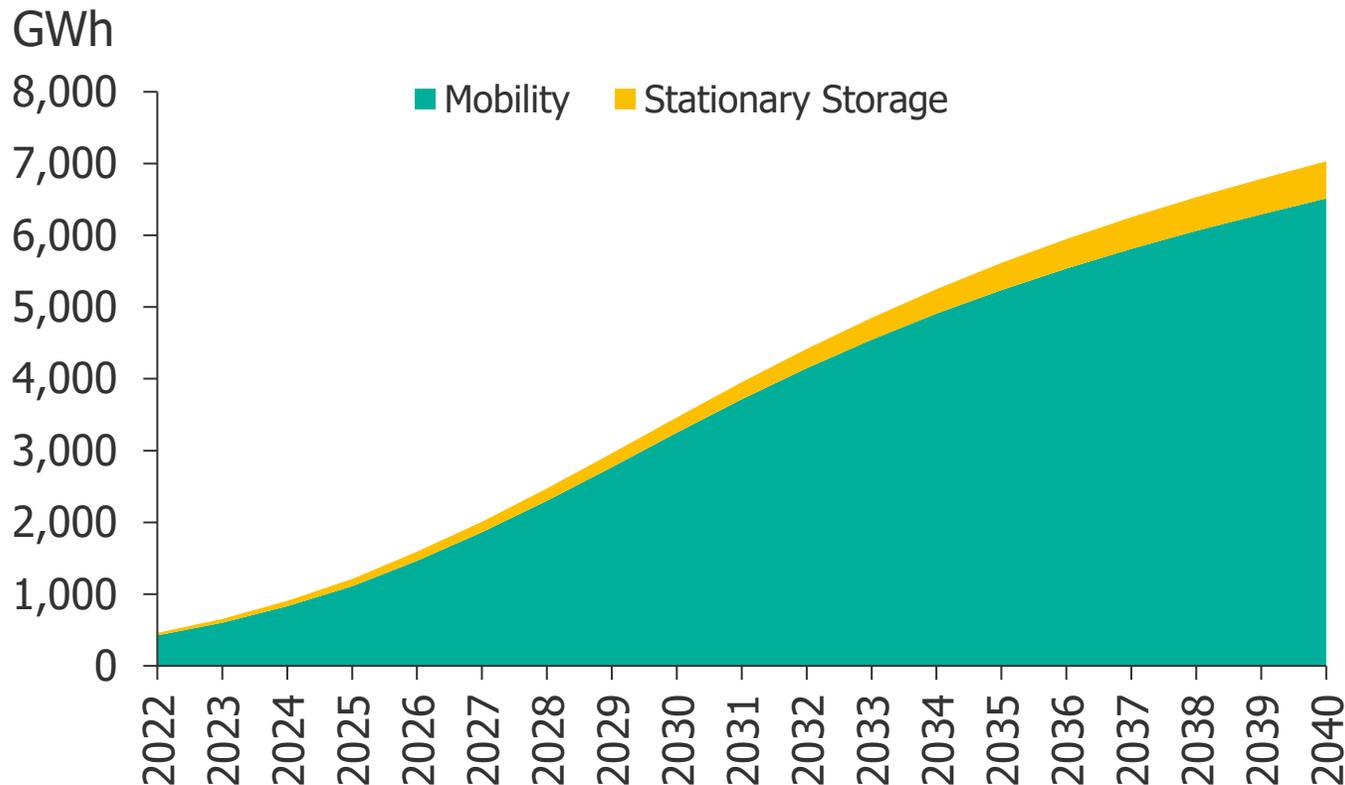
ENERGY STORAGE MARKET FORECAST

Mobility will remain the biggest market for energy storage, making up 92% of energy storage demand by 2040

The electrification of transport will remain a key driver of energy storage growth, while stationary storage deployments will be closely tied to regional energy needs. Increased revenue in stationary storage is tied to system costs, particularly for smaller behind-the-meter applications.

Technology and investment trends in energy storage will be dictated by automakers and battery manufacturers. Ongoing supply crunches have caused producers to reconsider low-cost battery materials and have created more urgency around high energy density batteries to use less material. Li-ion batteries will be the dominant energy storage technology, though stationary storage will have a more diverse distribution of technologies by 2040.

Global Energy Storage Demand



ENERGY STORAGE MARKET FORECAST

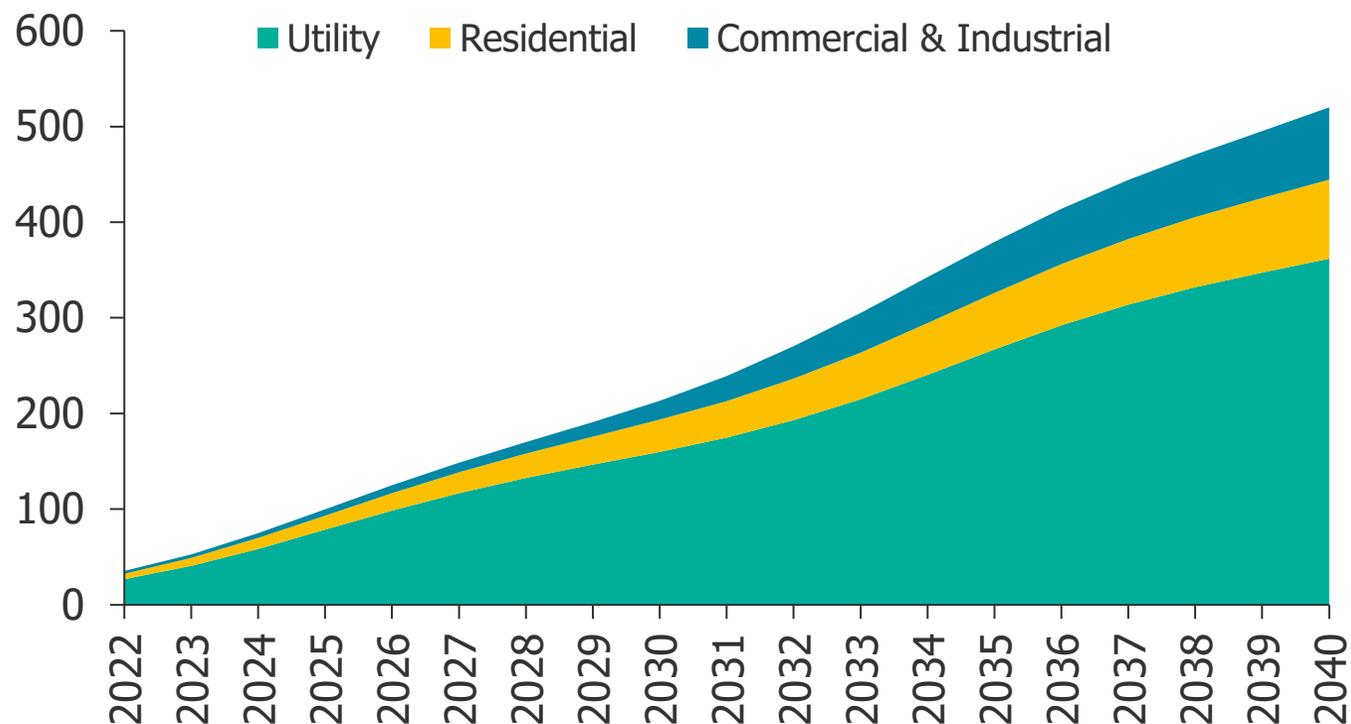
Utility-scale energy storage will account for 70% of total demand by 2040

Behind-the-meter storage growth is largely driven by falling Li-ion cost; however, it is no longer only deployed for backup and reliability, but can serve as a valuable distributed asset. Residential energy storage will be more attractive in regions like Australia where feed-in tariffs are expiring, and residential systems are more economically competitive.

Utility-scale installation sizes keep increasing, with Vistra's Moss Landing system reaching 1,600 MWh. Energy storage will be vital as grids deal with congestion and intermittency while working to retire fossil fuel generators. Though Li-ion remains the most popular battery choice, the landscape in 2030 will fit technology to applications served.

Global Stationary Storage Demand

Annual installed capacity (GWh)



ENERGY STORAGE MARKET FORECAST

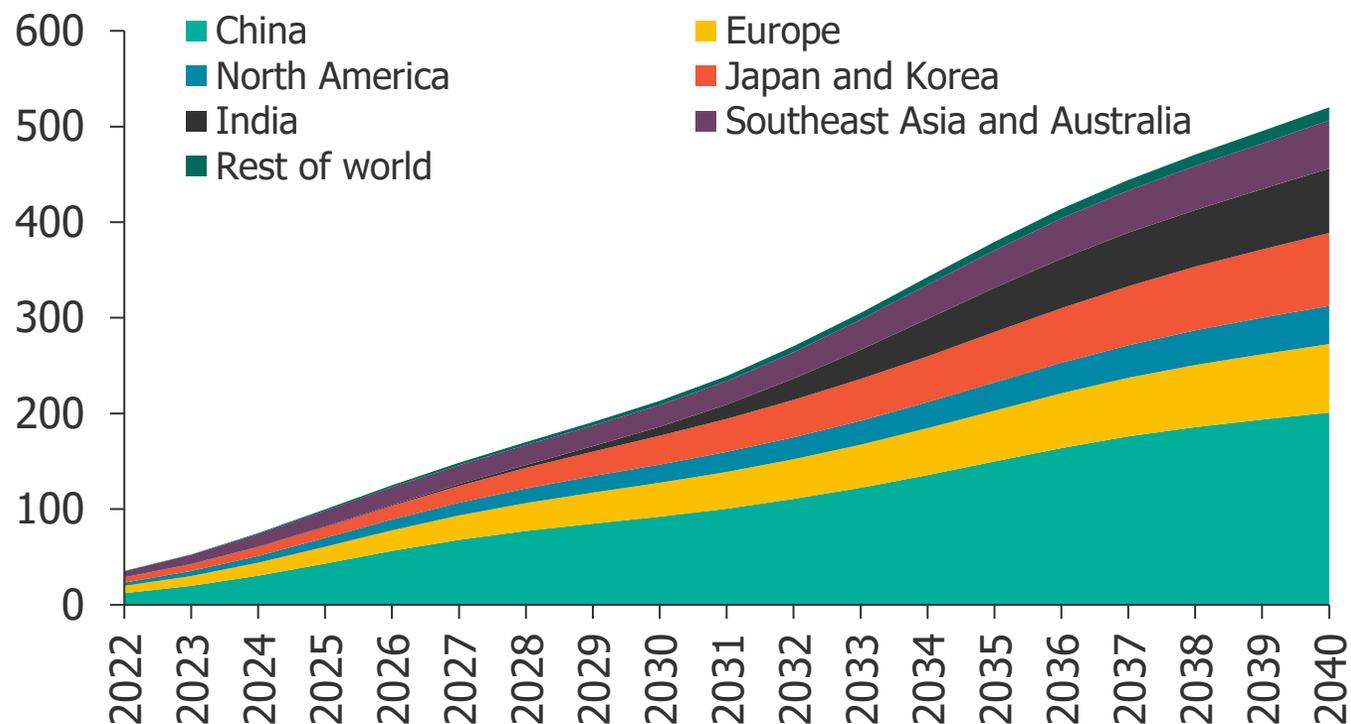
The global stationary storage market amount to 520 GWh in annual deployments in 2040

Energy storage demand is intrinsically tied to the grid energy mix or user need behind the meter. Grids integrating low levels of intermittent renewables will depend on short-duration energy storage for grid services applications to stabilize energy supply. Meanwhile, regions with higher renewables penetration will integrate large systems for longer durations of four hours or above and pursue more diverse revenue streams.

Policy will play a critical role in how energy storage is deployed. Countries with high renewables penetration have already begun removing regulatory barriers that restrict battery use. Regions that define energy storage as a dispatchable power asset and build market mechanisms to make it profitable will attract more investment.

Global Stationary Storage Demand

Annual installed capacity (GWh)



ENERGY STORAGE MARKET FORECAST

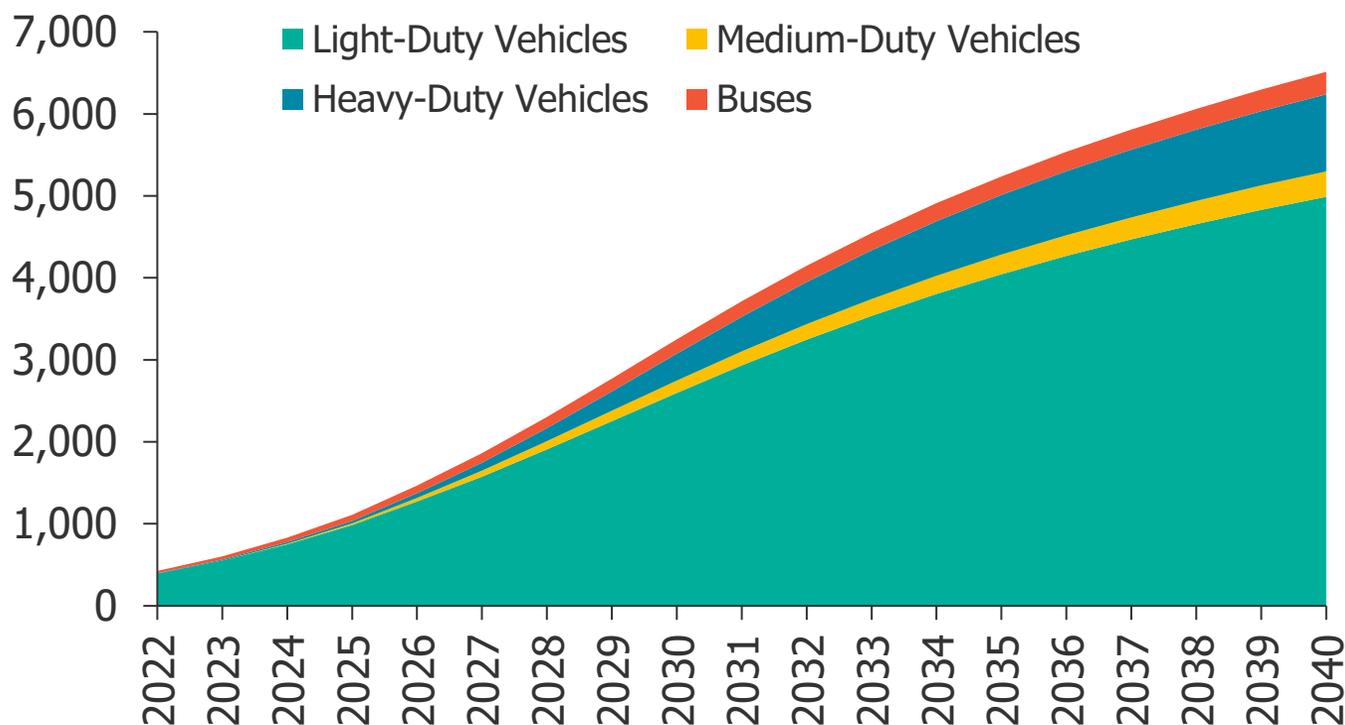
Demand for energy storage for mobility set to grow from an expected 423 GWh in 2022 to 6,513 GWh in 2040

Mobility applications will remain the biggest market for advanced energy storage in the future. The large market for light-duty vehicles (LDVs) is the biggest source of demand, as a combination of consumer interest in EVs and a regulatory push to eliminate emissions intersect in the 2020s.

Commercial vehicles, including MDVs, HDVs, and buses, are smaller in number but represent a greater share of emissions. Adoption in these segments is more frequently driven by the TCO; as gas prices remain volatile, many fleet owners are expected to adopt EVs, regardless of the regulatory environment.

Global Mobility Demand

Annual energy storage demand (GWh)



ENERGY STORAGE MARKET FORECAST

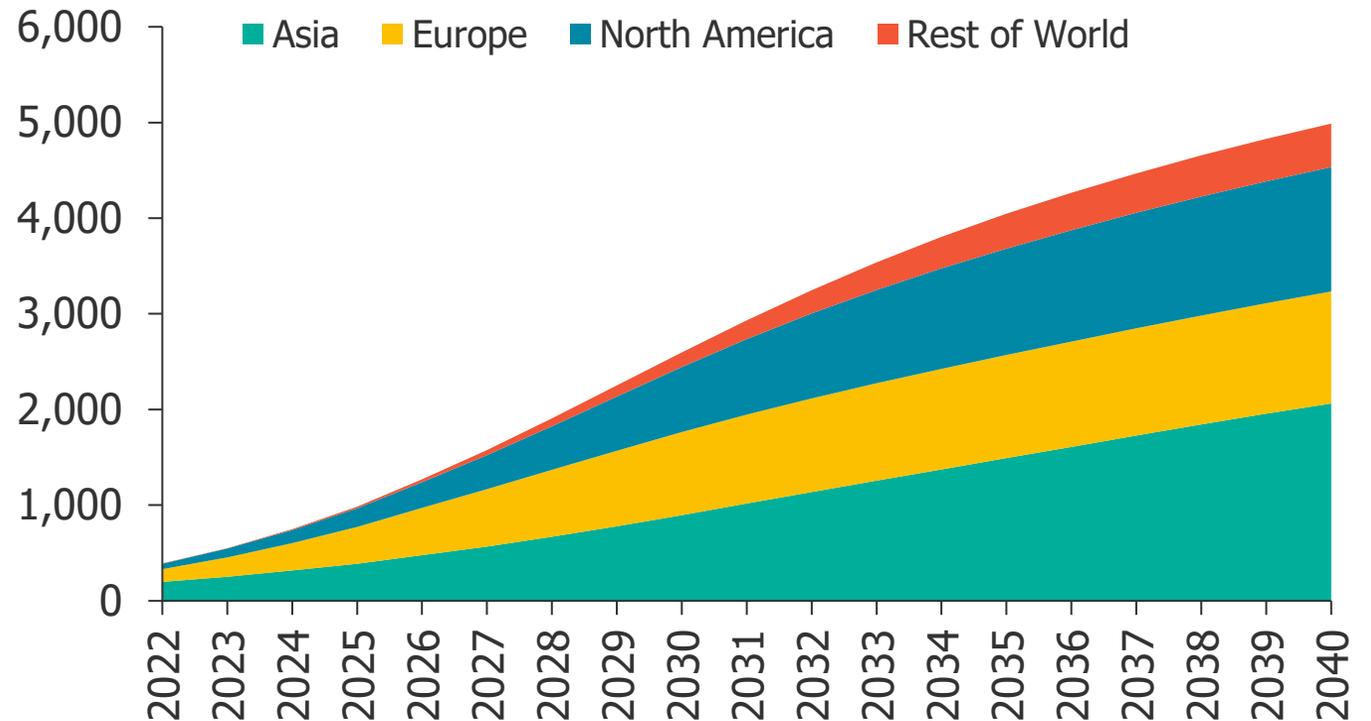
Light-duty vehicles: The supply of batteries is the biggest concern for automakers

Today, the global average for battery pack sizes is 50.8 kWh, but this number may change in the future. Automakers want to provide longer-range BEVs for customers, but also want to minimize costs and supply chain risks for the large battery pack. In the most likely scenario, battery sizes will continue to increase slightly to entice more customers to consider EVs. However, automakers facing strict emissions regulations and a shortage of Li-ion batteries may opt for smaller battery pack sizes.

Regionally significant variations exist as battery packs in North America are larger than those in other regions, in part due to longer travel distances and more daily miles traveled; this is unlikely to change.

Global Light-Duty Vehicle Demand

Annual energy storage demand (GWh)



ENERGY STORAGE MARKET FORECAST

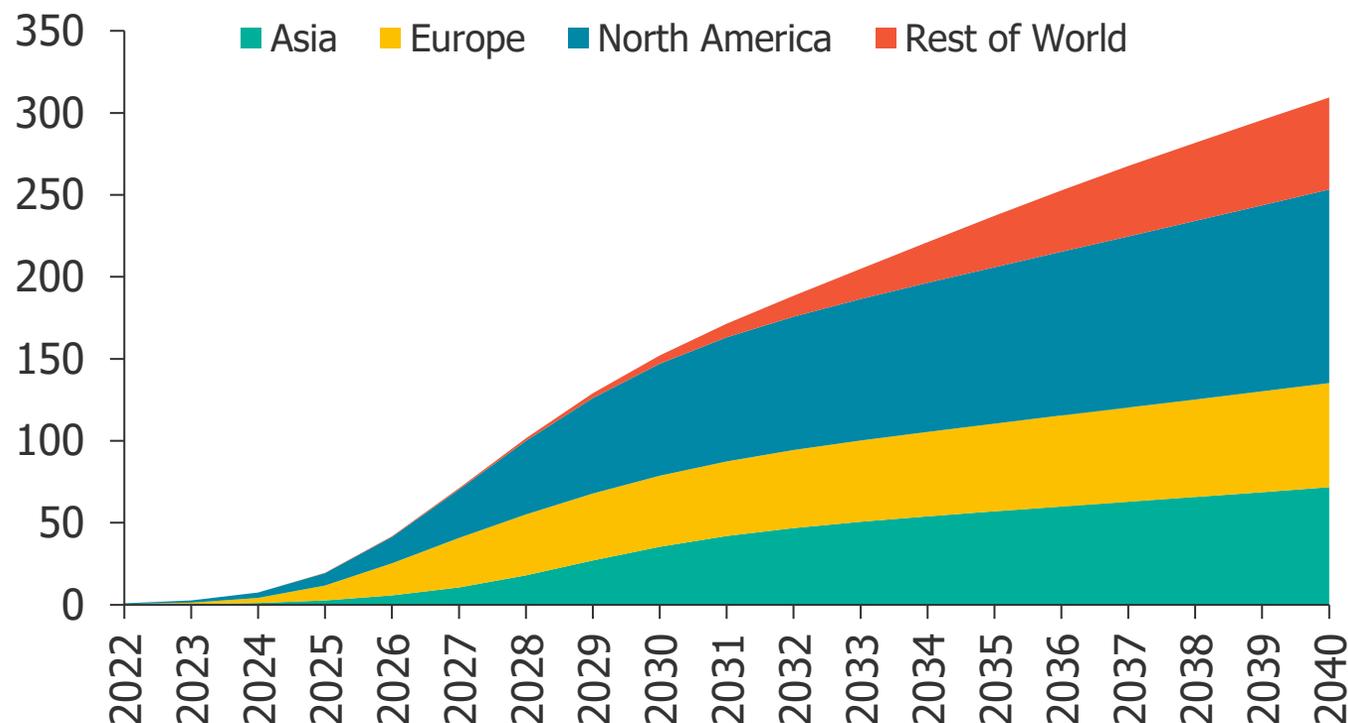
Medium-duty vehicles: Electrification will happen in shorter-range vehicles first, leading to increases in pack size

Pack sizes in MDVs vary significantly; most vehicles have battery packs between 100 kWh and 150 kWh, but the Freightliner eM2 can be equipped with a 325-kWh battery to serve longer-range applications.

The battery makes up a significant portion of the cost of the vehicle; therefore, vehicles with smaller daily vehicle miles traveled will likely electrify first with smaller (and cheaper) battery packs. Use-cases requiring longer-range will electrify later, as cost reductions are needed for a stronger TCO. Ultimately, this means average battery pack sizes will increase significantly over time in the MDV space.

Global Medium-Duty Vehicle Demand

Annual energy storage demand (GWh)



ENERGY STORAGE MARKET FORECAST

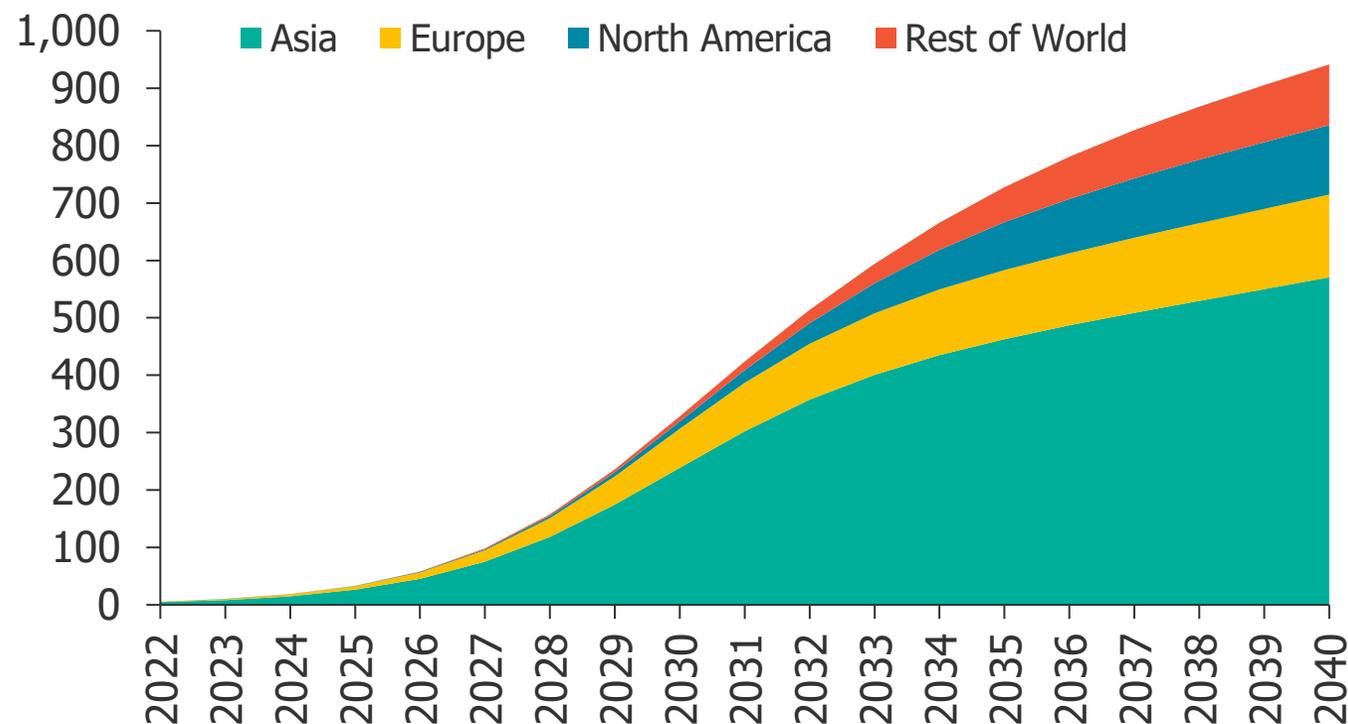
Heavy-duty vehicles: Large pack sizes averaging between 250 kWh and 450 kWh drive energy storage demand

Among all vehicle types, HDVs will have the largest battery packs, but smaller sales mean its impact on the broader energy storage space is somewhat limited. Like with MDVs, we expect smaller regional haul routes to first electrify using smaller battery packs. Over time, longer-range trucks with bigger battery packs will be introduced.

Specifically in the heavy-duty transportation space, driving regulations are going to impact the choice of powertrain and battery size. Whereas in the U.S., drivers can drive eight hours before a mandated 30-minute break, in Europe, drivers must take a 45-minute break after driving 4.5 hours. European regulations with more frequent breaks translate into more opportunities to charge, making battery electrification more of a reality.

Global Heavy-Duty Vehicle Demand

Annual energy storage demand (GWh)



ENERGY STORAGE MARKET FORECAST

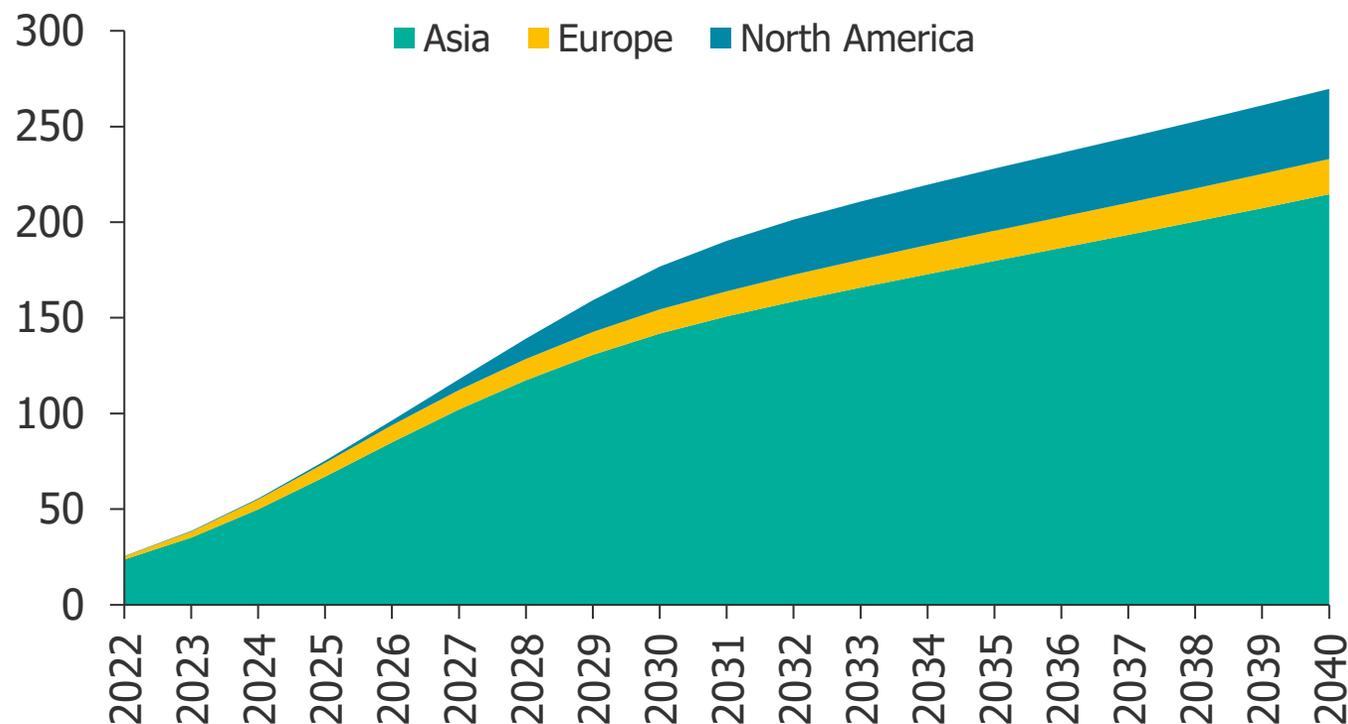
Buses: Low volumes make their impact on battery demand minimal despite large pack sizes

Most of these batteries will be needed in Asia, where roughly 80% of the world's buses are sold. Pack sizes will increase for the same reason as for other commercial vehicles; future cost reductions in battery prices will make longer-range vehicles with larger packs more cost competitive.

One challenge somewhat unique to buses is the electrical load from heating and cooling. Buses need to condition their space for riders, with doors frequently opening and closing, leading to some early adopters finding buses did not provide enough range. In climates that require heating and cooling, pack sizes will need to increase to accommodate this additional load and may convince operators to adopt fuel cells for longer routes.

Global Buses Demand

Annual energy storage demand (GWh)



ENERGY STORAGE MARKET FORECAST

Challenges in grid integration will emerge with larger number of electric vehicles in the market

Integrating small numbers of EVs into the electrical grid will not threaten grid stability. Much like integrating solar photovoltaics, challenges in integrating vehicle charging to the grid emerge as high rates of penetration are achieved. As EV sales increase rapidly, the grid in some regions will begin to feel strain from these vehicles — strain that will only increase in the future.

Without managing EV charging, infrastructure will limit growth. Two new pieces of EV infrastructure are important in managing this new electrical load:

- **Vehicle-to-grid (V2G) charging** enables vehicles to not only accept power from the grid to charge their batteries, but also to discharge batteries to provide grid services and compensate owners for its use. Historically vehicles were not designed for V2G, but today, Hyundai, Ford, and Nissan have released vehicles capable of and designed for V2G charging. Market reforms, like Federal Energy Regulatory Commission Order 2222 in the U.S., will further unlock the value of EVs as a grid asset.
- **Battery swapping** schemes allow vehicles to quickly gain range without pulling large amounts of power from the grid. Stored batteries in a charging station can slowly charge or even participate in grid services with excess capacity, eliminating the spike in demand that fast charging brings. Costs for battery swapping scheme are roughly equivalent to those of fast charging, and the biggest barrier is a lack of automakers committed to producing swapping-enabled vehicles.

ENERGY STORAGE MARKET FORECAST

Stationary storage growth is tied to a slower moving electricity market and uncertain business models

Growth of stationary storage markets will largely depend on the grids they serve. Behind-the-meter deployments are less dependent on the overall energy mix, but incentives for users to install their own systems will come from regions with evolving grids along with market reforms that unlock new revenue streams. Utility-scale energy storage will remain the largest market sector, but widespread integration will require commercial acceptance of non-Li-ion battery technologies and shifts in both regulations and business models.

Apart from regional grid structures, there are other factors contributing to demand in stationary storage:

- **Timelines for deployment must be shorter.** Historically, the time between a project announcement and field operation could be two years or more. As project developers and system integrators gain experience, that time has decreased; however, strains on Li-ion battery supply for stationary storage has once again kept timelines long. Alternative technologies like flow batteries will somewhat solve the security of supply challenge, but commercial immaturity will cause a similar delay.
- **Projects will become more bankable as clearer business models emerge.** Across all stationary storage technologies, bankability — how readily investors will finance a project — will improve when markets provide clearer paths for revenue. In some instances, that means defining energy storage as its own category in energy markets and lowering barriers for systems to charge and discharge. For technologies with a shorter deployment history, more defined business models will allow for greater confidence in revenue opportunities.

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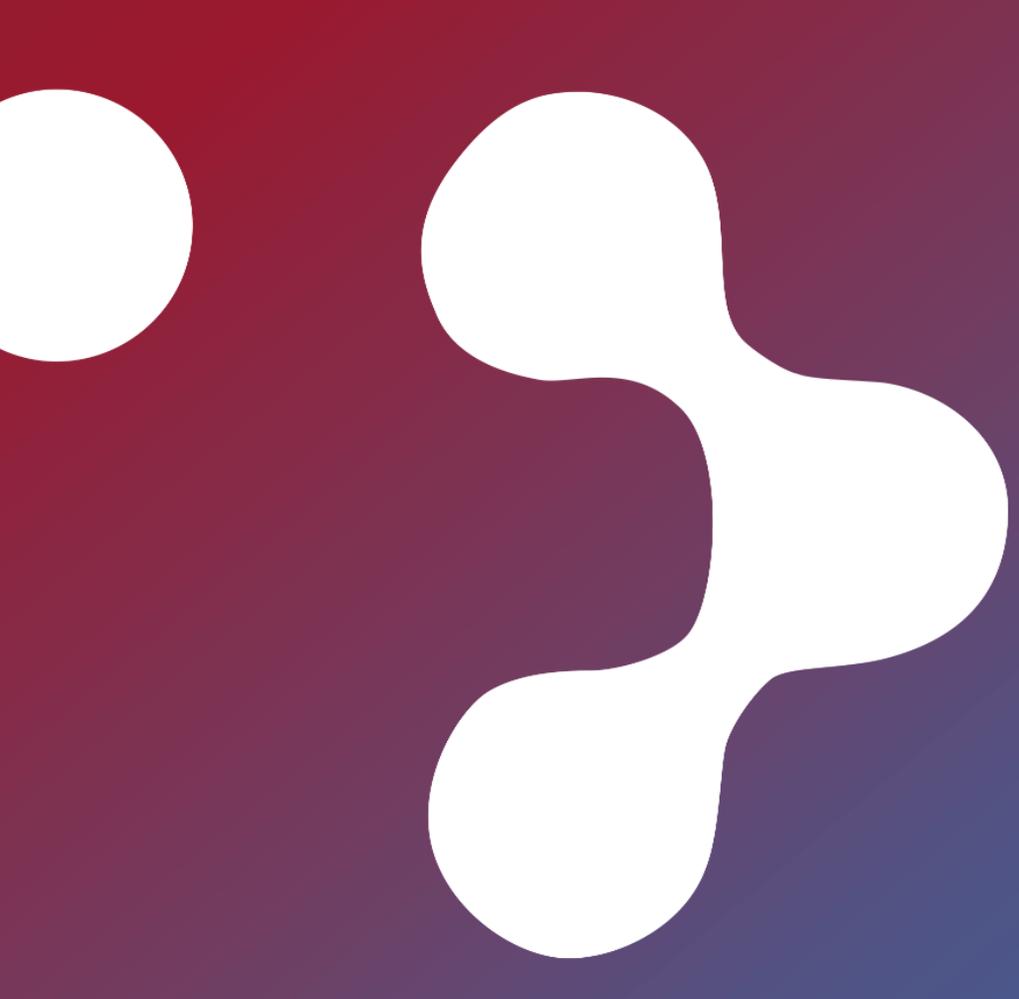
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