[Korea]

October 7, 2020

# TIGER KRX Secondary Battery K-New Deal ETF
(364980 KS)

## Investing in the heart of EVs

*Mirae Asset Daewoo Co., Ltd.*
**Yeon-ju Park** yeonju.park@miraeasset.com
**Chuljoong Kim** chuljoong.kim@miraeasset.com

**Invest in Korean battery and battery materials companies**

**An ETF that offers diversified exposure to the battery/battery materials supply chain**
- We forecast electric vehicle (EV) penetration to increase from 3-4% in 2020 to 15-20% in 2025.
- If the fall in battery prices accelerates, medium-term EV penetration could exceed estimates.
- Another driver of battery market growth is the energy storage systems (ESS) market, which is set to grow rapidly due to an increasing share of renewables in the power generation mix and falling battery prices.
- Given the characteristics of battery technologies, the global battery and battery materials markets are likely to remain concentrated around top-tier players.
- The TIGER KRX Secondary Battery K-New Deal ETF offers investors diversified exposure to the battery/battery materials supply chain.

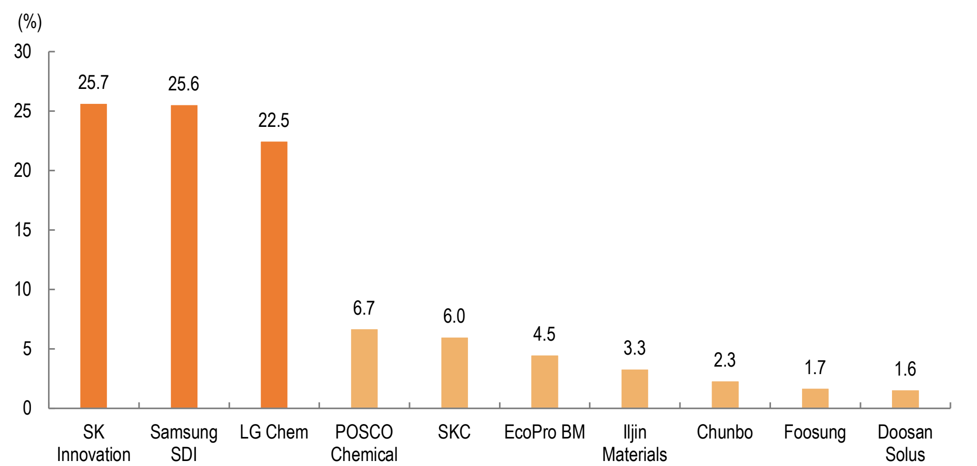
**Global EV market to expand more than fivefold by 2025**

**Tesla, COVID-19, and falling battery prices to drive full-fledged growth of the EV market**
- Tesla's EV models have begun to take meaningful share from premium conventional vehicles.
- Tesla's competitiveness will likely increase further with the upcoming production of the Model Y in China (2021) and the scheduled operation of new facilities in Germany and the US (2H21).
- Conventional automakers are releasing compelling EV models of their own.
- The EV transition has accelerated since the COVID-19 outbreak, driven by increased subsidies.
- We expect the global EV market to expand more than fivefold by 2025 (compared to 2020).
- At its Battery Day event on Sep. 22, Tesla revealed a plan to reduce battery costs per kWh by 56% over the next three years. Even if battery prices decline only 20–30%, Tesla's sales volume is likely to exceed current market expectations.

**Korean companies to maintain competitive advantage**

**Globally competitive Korean battery and battery materials companies**
- The global EV battery market is highly concentrated; the top four suppliers (two of which are Korean) control 70-80% of the market.
- Due to the characteristics of battery technologies, it is difficult for latecomers to carve out their own space in the market.
- Competitive battery materials companies are well-positioned to achieve strong growth over the medium and long term through collaboration with leading battery manufacturers.
- The market for electrolytic copper foil (elecfoil), a key battery material, is also concentrated around major companies. In the cathode materials market, Korean companies have more competitive formulas than their global rivals.
- Risks include possible changes in government policies and delays to battery development.

**TIGER KRX Secondary Battery K-New Deal ETF constituents**




Source: Mirae Asset Daewoo Research

# CONTENTS

# I. Investment summary

## Invest in batteries/battery materials, the heart of EVs

The global EV market is poised for full-fledged growth. Tesla—an EV market pioneer since the 2012 launch of the Model S—has begun to take meaningful share from premium conventional vehicles, supported by: 1) successful volume production of the Model 3; and 2) enhanced cost competitiveness with the start of production in China.

Tesla's competitiveness will likely increase further, supported by: 1) the Model Y's China production scheduled for 2021 (the compact SUV will surely prove popular in the Chinese market); and 2) additional capacity coming online in 2H21 (Gigafactory in Berlin and Terafactory in Texas). At its Battery Day event on Sep. 22, Tesla revealed a plan to reduce battery costs per kWh by 56% over the next three years. Even if battery prices decline only 20–30%, Tesla's sales volume is likely to exceed current market expectations.

Conventional automakers are stepping up their efforts to meet the competitive threat from Tesla. European automakers, in particular, are moving swiftly to adapt to the EV era, viewing the transition as inevitable in light of stricter environmental standards and increased EV subsidies since the COVID-19 outbreak. We expect automakers to continue to release compelling EV models to compete against Tesla.

We forecast EV penetration to increase from 3-4% in 2020 to 15-20% in 2025. If the fall in battery prices accelerates due to advances in technology by Tesla and battery manufacturers, EV penetration in 2025 and beyond could exceed estimates.

Meanwhile, the global ESS market—another key driver of lithium-ion battery market growth—is likely to expand more than sevenfold by 2025 (90GWh) compared to 2020 (12GWh). As the US market illustrates, an increasing share of renewables in the power generation mix should spur higher ESS demand to ensure grid/power supply stability. In addition, we foresee ESS battery prices declining further around 2023 (aided by technology innovation), which should cause ESS demand growth to accelerate.

The TIGER KRX Secondary Battery K-New Deal ETF tracks key battery and battery materials companies at the heart of the growing EV market. The ETF's constituents include companies related to battery cells, elecfoil, cathode materials, and electrolytes.

The global EV battery market is highly concentrated, with the top four suppliers having a combined market share of 70-80%. Entry barriers are high; many latecomers have sought to penetrate the market over the past five years, but top-tier suppliers—with proven track records and know-how in volume production—have only increased their dominance. Relative to their global rivals, Korean battery cell producers have an upper hand in terms of production capacity, formulas, and customer bases. They also have greater exposure to the European market, where EV sales have been growing rapidly on the back of government subsidies amid the pandemic.

The elecfoil market also presents barriers to entry (heavy fixed-cost burden) and is likewise concentrated around major companies. In the cathode materials market, Korean companies have more competitive formulas than their global rivals. For electrolyte additives, which also have high technological entry barriers, demand should grow as battery technologies develop.

Risk factors for the battery/battery materials sector include potential changes in government policies, delays to battery technology development, and intensifying competition. Overall, we believe leading players stand to benefit from the expansion of the EV market.

# II. EV market outlook

## 1. The beginning of market competition

Led by Tesla, the global EV market is poised for full-fledged growth. Tesla—an EV market pioneer since the 2012 launch of the Model S—has begun to take meaningful share from premium conventional vehicles, supported by: 1) successful volume production of the Model 3; and 2) enhanced cost competitiveness with the start of production in China.

Tesla's competitiveness will likely increase further, supported by: 1) the Model Y's China production scheduled for 2021 (the compact SUV will surely prove popular in the Chinese market); and 2) additional capacity coming online in 2H21 (Gigafactory in Berlin and Terafactory in Texas). At its Battery Day event on Sep. 22, Tesla revealed a plan to reduce battery costs per kWh by 56% over the next three years. Even if battery prices decline only 20–30%, Tesla's sales volume is likely to exceed current market expectations.

Conventional automakers are stepping up their efforts to meet the competitive threat from Tesla. European automakers, in particular, are moving swiftly to adapt to the EV era, viewing the transition as inevitable in light of stricter environmental standards and increased EV subsidies since the COVID-19 outbreak. We expect automakers to continue to release compelling EV models to compete against Tesla.

We forecast EV penetration to increase from 3-4% in 2020 to 15-20% in 2025. If the fall in battery prices accelerates due to advances in technology by Tesla and battery manufacturers, EV penetration in 2025 and beyond could exceed estimates.

**Table 1. Global automotive and EV market forecasts**

| | | 2018 | 2019 | 2020F | 2021F | 2022F | 2023F | 2024F | 2025F |
|---|---|---|---|---|---|---|---|---|---|
| Automotive market | US | 17,305 | 17,576 | 15,985 | 16,784 | 17,288 | 17,634 | 17,634 | 17,634 |
| ('000 units) | Europe | 16,217 | 16,359 | 14,991 | 15,591 | 16,059 | 16,380 | 16,400 | 16,500 |
| | China | 28,081 | 25,769 | 25,000 | 26,000 | 26,500 | 27,000 | 27,500 | 28,000 |
| | Other | 36,282 | 35,082 | 35,082 | 35,783 | 36,499 | 37,229 | 37,973 | 38,733 |
| | Total | 97,885 | 94,785 | 91,058 | 94,159 | 96,346 | 98,243 | 99,507 | 100,867 |
| EV penetration | US | 2.0% | 1.9% | 3.4% | 5.0% | 8.5% | 10.7% | 13.0% | 15.6% |
| | Europe | 2.4% | 3.6% | 10.0% | 16.0% | 20.0% | 22.0% | 25.0% | 27.0% |
| | China | 3.9% | 4.1% | 5.2% | 6.7% | 8.1% | 10.7% | 13.8% | 17.3% |
| | Other | 0.6% | 0.4% | 1.0% | 2.0% | 5.0% | 8.0% | 10.0% | 12.0% |
| | Total | 2.1% | 2.2% | 4.1% | 6.2% | 9.0% | 11.6% | 14.1% | 16.6% |
| EV sales volume | US | 350 | 332 | 545 | 840 | 1,465 | 1,886 | 2,287 | 2,754 |
| (BEV+PHEV, '000 units) | Europe | 386 | 587 | 1,499 | 2,495 | 3,212 | 3,604 | 4,100 | 4,455 |
| | China | 1,107 | 1,061 | 1,312 | 1,741 | 2,156 | 2,885 | 3,798 | 4,843 |
| | Other | 206 | 135 | 351 | 716 | 1,825 | 2,978 | 3,797 | 4,648 |
| | Total | 2,049 | 2,115 | 3,707 | 5,791 | 8,657 | 11,353 | 13,983 | 16,699 |

Source: Mirae Asset Daewoo Research estimates

## 2. Tesla: Driving the EV market forward

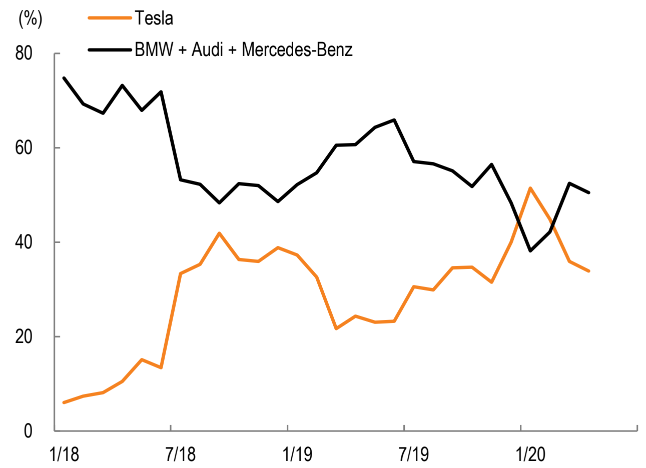
In 2010, General Motors (GM) released the Volt, the world's first mass-market plug-in hybrid EV (PHEV). As battery prices were high at the time, the model was limited by a small battery pack and a lack of differentiation vs. conventional vehicles; unsurprisingly, it was met with a cool reception. Notably, amid weak demand for the Volt, LG Chem had to deal with low utilization at the new EV battery plant it had built in the US. All in all, the future of the EV market appeared bleak.

However, Tesla's launch of the Model S in 2012 turned the fortunes of the EV market around. The EV maker adopted cylindrical battery cells, which cost only one-third as much as prismatic or pouch cells, and installed more cells in its battery packs to increase driving range. In addition, the Model S offered a differentiated driving experience (e.g., quicker acceleration), which allowed for a higher price tag compared to other EV models.

The popularity of the Model S confirmed the potential of the EV market, prompting conventional automakers and battery manufacturers to accelerate their R&D efforts. In many cases, these players adopted concepts pioneered by Tesla, such as the use of battery management system (BMS) technologies to overcome the short cycle life of cylindrical battery cells. Against this backdrop, battery prices began to decline sharply.

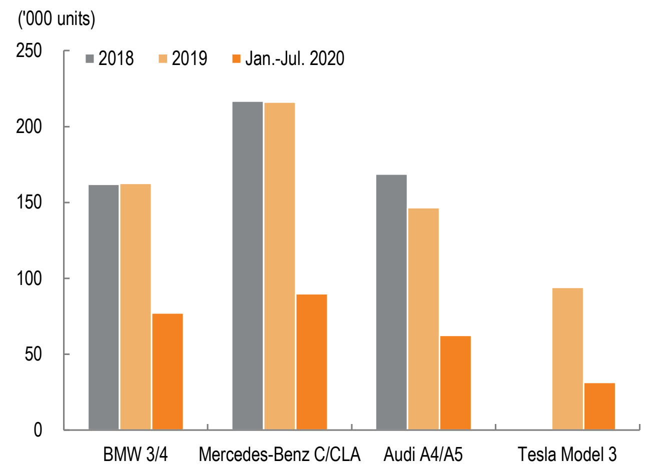
Initially, Tesla did not have a meaningful impact on the overall market, as it was focused on the luxury segment (W100mn price range). However, the EV maker advanced into the premium mass-market segment by launching the Model 3 (US$50,000). The Model 3 took market share from conventional automakers following its release in the US in 2017 and achieved stronger-than-expected sales growth in Europe after being launched in the region in 2019.

**Figure 1. US M/S of Tesla and three major European premium automakers**




Source: MarkLines, Mirae Asset Daewoo Research

**Figure 2. Sales comparison: Tesla Model 3 and comparable conventional vehicles**




Source: MarkLines, Mirae Asset Daewoo Research

Thus far in 2020, Tesla has displayed remarkable growth in China, thanks to the start-up of the Shanghai Gigafactory. Compared to the EV maker's US plant, the Shanghai plant boasts stronger cost competitiveness (e.g., lower capex and labor costs), enabling lower product prices. Moreover, as locally produced EVs are eligible for the Chinese government's tax benefits and subsidies, actual consumer prices have declined further.

For example, the Model 3 Standard Plus produced in China now costs CNY250,000 after subsidies, down CNY100,000 from a year ago. Factoring in the purchase tax exemption for EVs, the Model 3 sells at a lower price than the Audi A4, a key conventional competitor. In light of Tesla's strong price competitiveness, as well as its strong brand awareness and high fuel efficiency, the popularity of its models in China comes as no surprise.

While global vehicle sales volumes have sharply contracted in 2020, hurt by the pandemic, Tesla has been generating record sales, supported by the start-up of the new plant in China.

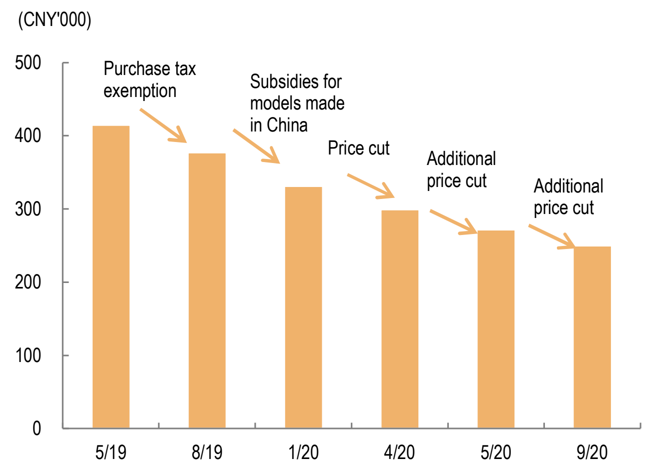
We expect Tesla's sales momentum to pick up in 2H20 and 2021, given that the Model 3 Long Range is set to be manufactured in China beginning in 2H20. In addition, Tesla is set to procure cell-to-pack (CTP) LFP batteries from China's CATL. Compared to NCM batteries, which Tesla currently sources from LG Chem, CTP LFP batteries are heavier but cheaper; as such, Model 3 prices could decline further.

Meanwhile, the launch of the Model Y is scheduled for 2021. As SUVs are popular in China, the model is likely to record higher sales volumes than the Model 3 over the medium and long term. While the Model Y still has a relatively high price tag, the start-up of Chinese production in 2021 should pave the way for lower prices and solid sales—as was the case with the Model 3.

Tesla's Berlin Gigafactory is set for completion in July 2021. We expect the Berlin Gigafactory, which should be more cost-competitive than the US production base, to help the EV maker tighten its grip on the European market. In addition, Tesla's second US plant, the Cybertruck Terafactory in Austin, Texas, is set to launch pilot production in 2H21. The Cybertruck has a starting price of US$40,000 and a driving range of more than 400km, offering compelling value compared to conventional vehicles with comparable driving performance.

We estimate Tesla's EV sales volume to expand rapidly from 500,000 units in 2020 to 2-3mn units in 2025, on the back of rapid capacity additions and lineup expansion.

**Figure 3. Price trend of Tesla Model 3 Standard Plus in China**




Source: Industry data, Mirae Asset Daewoo Research

**Figure 4. Tesla Cybertruck**


Source: Tesla, Mirae Asset Daewoo Research

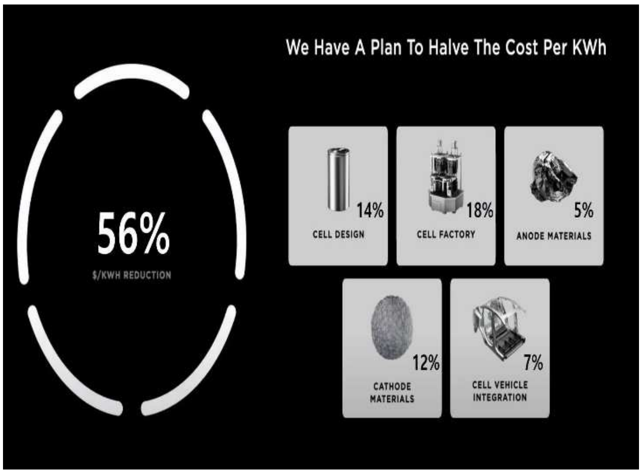
At its Sep. 22 Battery Day event, Tesla announced that it would endeavor to simultaneously reduce its battery cell costs and expand its battery production capacity over the medium term via a five-part road map (encompassing new cell design, high-speed assembly, and dry electrode technology). Specifically, Tesla plans to: 1) reduce battery costs per kWh by 56% over the next three years; 2) produce 100GWh of its own battery cells in 2022; and 3) scale up production to 3TWh by 2030.

Tesla has been aggressively pushing for battery cost reductions. Batteries account for 30-40% of total EV costs, and a decline in battery costs is essential for EVs to match conventional vehicles in terms of economic viability. Notably, Tesla has stated that a 56% battery cost reduction would enable production of an EV model priced at US$25,000.

It is uncertain whether Tesla's plans will come to fruition, given the EV maker's lack of experience in battery production and the difficulties associated with manufacturing cutting-edge batteries at scale. In our view, collaborating with existing battery makers would help Tesla produce cells with bigger form factors and achieve rapid assembly capabilities.

Even if battery prices decline only 20–30%, Tesla's sales volume is likely to exceed current market expectations. It remains to be seen if the EV maker's efforts to drive down battery costs will go according to plan. Still, it is meaningful that Tesla is spearheading battery price cuts on the back of its industry-leading BMS technology, strength in process automation, and track record in EV volume production. All in all, we expect Tesla's initiatives to accelerate the fall in overall battery prices and the expansion of the EV market.

**Figure 5. Tesla's plan to reduce the cost of battery packs**




Source: Tesla, Mirae Asset Daewoo Research

**Figure 6. Tesla's new cylindrical battery cell design**


Source: Tesla, Mirae Asset Daewoo Research

## 3. Europe steps up EV policy support: Dieselgate and pandemic

Following the “Dieselgate” emissions scandal in 2015, European automakers, including Volkswagen, announced a full-scale transition to EVs, unveiling massive capex plans.

Starting in 2020, automakers must display a 20% reduction in $CO_2$ emissions to avoid fines in Europe. As environmental regulations are likely to tighten further, automakers will have to sell a certain number of EVs in the region going forward.

As the COVID-19 pandemic escalated, some market participants argued that $CO_2$ emissions-related penalties should be deferred to help struggling automakers. However, during the economic recovery following the peak of the pandemic, policymakers focused on ramping up support for EVs, guided by the belief that an eco-friendly approach would be essential to navigating the debt-riddled post-COVID-19 world. Importantly, European governments appear committed to strengthening their efforts to help automakers enhance their EV competitiveness amid accelerating electrification.

**Figure 7. Estimated penalty payments for excess $CO_2$ emissions by European automaker**

JATO

Penalty payments for excess emissions
Assumption: no changes until 2021

| | Δ Actual vs Target g/km | Penalty (€/unit) | Units Regs 2018 (000) | Total Penalty (€ billion) |
|---|---|---|---|---|
| VW Group | 26.6 | 2,525 | 3,638 | 9.19 |
| PSA | 23.1 | 2,194 | 2,457 | 5.39 |
| Renault Group | 23.2 | 2,207 | 1,615 | 3.57 |
| BMW Group | 27.5 | 2,609 | 1,018 | 2.66 |
| Hyundai-Kia | 30.0 | 2,852 | 1,011 | 2.88 |
| Ford | 27.1 | 2,576 | 992 | 2.56 |
| FCA | 35.5 | 3,373 | 961 | 3.24 |
| Daimler | 33.6 | 3,192 | 941 | 3.01 |
| Toyota | 7.8 | 745 | 733 | 0.55 |
| Nissan Group | 19.0 | 1,807 | 630 | 1.14 |
| Volvo | 25.5 | 2,425 | 317 | 0.77 |

Source: JATO, Mirae Asset Daewoo Research

**Figure 8. Germany raises EV subsidies without additional diesel support**

*Jun 4, 2020 - 02:12 pm*

**Germany doubles EV subsidies, no more diesel support**

AC | BAFA | BATTERIES | BEV | CHARGING STATIONS | DC | ELECTRIC BUSES | ELECTRIC TRANSPORTERS | ELECTRIC TRUCKS | FCEV

Concerning the environmental bonus, the euro amount of the subsidy for BEV and FCEV would be calculated as follows:

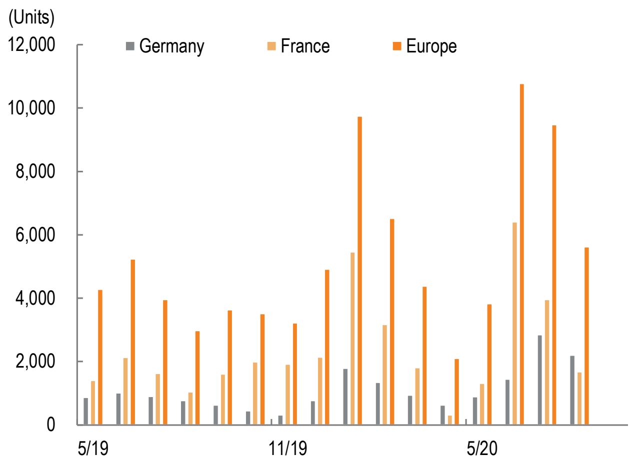
| Basic net list price | Federal share (doubled) | Manufacturer share (net) | Total (net) |
|---|---|---|---|
| 40,000 | 6,000 | 3,000 | 9,000 |
| 40,000 to 65,000 | 5,000 | 2,500 | 7,500 |

For PHEV, the environmental bonus comes together as follows:

| Basic net list price | Federal share (doubled) | Manufacturer share (net) | Total (net) |
|---|---|---|---|
| 40,000 | 4,500 | 2,250 | 6,750 |
| 40,000 to 65,000 | 3,750 | 1,875 | 5,625 |

Source: Electrive, Mirae Asset Daewoo Research

**Figure 9. Sales volume of the Renault Zoe has surged following subsidy hikes**




Source: SNE Research, Mirae Asset Daewoo Research

Tesla has been taking meaningful share from premium conventional vehicles not only in the US but also in Europe and China. However, conventional automakers are stepping up their efforts to confront the competitive threat by steadily releasing EV models.

At present, conventional automakers' EV models are generally less marketable than Tesla models. For example, Audi's e-tron falls short of Tesla's EVs in terms of price (roughly W20mn more expensive than the Model 3) and range.

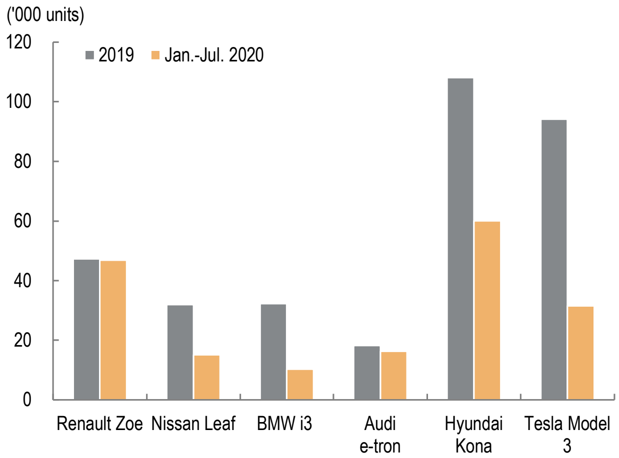
We see several reasons for this competitiveness gap. First, the use of conventional vehicle platforms to produce EVs (vs. dedicated EV platforms) is detrimental to battery efficiency and battery space optimization. Second, conventional automakers are inferior to Tesla in BMS technology and economies of scale. Typically, the development of an EV model costs at least several hundred billion won. However, while Tesla is expected to sell 500,000 Model 3s in 2020, conventional automakers generally record only tens of thousands of sales per EV model, meaning that they incur higher development costs per unit.

**Table 2. Tesla vs. non-Tesla EV models**

| | Price (EUR'000) | Segment | Range (km) | Battery capacity (kWh) | Range/battery capacity (km/kWh) | Weight (kg) | Battery performance (kg*km/kWh) | 0-100km/h (s) | Power (kW) |
|---|---|---|---|---|---|---|---|---|---|
| Tesla Model 3 Long Range Dual Motor | 60 | Compact sedan | 560 | 75 | 7.5 | 1847 | 13,791 | 4.6 | 258.0 |
| Tesla Model 3 Standard Range | 44 | Compact sedan | 354 | 50 | 7.1 | 1611 | 11,406 | 5.8 | 150.0 |
| Audi e-tron Quattro | 77 | Mid-sized SUV | 400 | 95 | 4.2 | 2490 | 10,484 | 5.7 | 300.0 |
| Mercedes-Benz EQC | 80 | Compact SUV | 416 | 80 | 5.2 | 2495 | 12,974 | 5.1 | 300.0 |
| Jaguar I-Pace | 81 | Mid-sized SUV | 480 | 90 | 5.3 | 2133 | 11,376 | 4.8 | 294.0 |
| HMC Kona EV | 41 | Small-sized SUV | 449 | 64 | 7.0 | 1743 | 12,228 | 7.6 | 150.0 |
| Volkswagen ID.3 Mid-Range (Pro) | 35 | Hatchback | 420 | 58 | 7.2 | 1719 | 12,448 | 7.0 | 150.0 |
| Volvo Polestar 2 | 60 | Mid-sized sedan | 500 | 78 | 6.4 | 1900 | 12,179 | 4.9 | 300.0 |
| BMW iX3 | 70 | Compact SUV | 400 | 70 | 5.7 | 2100 | 12,000 | 5.0 | 200.0 |
| Tesla Model Y Long Range | 58 | Compact SUV | 540 | 75 | 7.2 | 1850 | 13,320 | 5.8 | 211.0 |
| Tesla Model Y Standard Range | 47 | Compact SUV | 390 | 50 | 7.8 | 1700 | 13,260 | 6.3 | 150.0 |

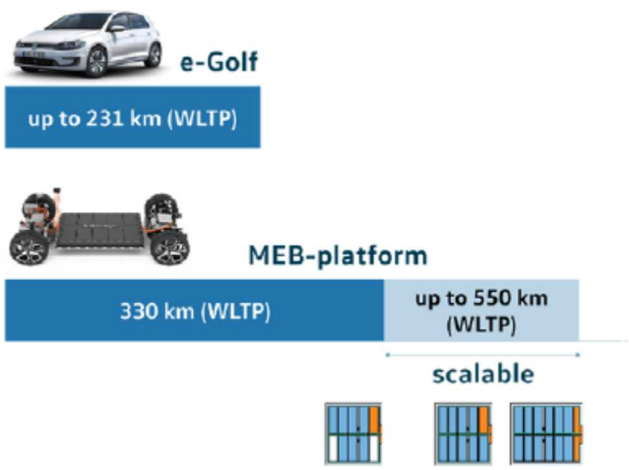
Source: Press reports, Mirae Asset Daewoo Research

**Figure 10. Europe: EV sales volume by model**




Source: MarkLines, Mirae Asset Daewoo Research

**Figure 11. Volkswagen plans to enhance its EV competitiveness via a dedicated EV platform (MEB)**




Source: Volkswagen, Mirae Asset Daewoo Research

Against this backdrop, traditional automakers are ramping up their EV strategies.

Volkswagen was the first conventional automaker to openly declare its commitment to electrification. The automaker has already developed a dedicated EV platform (MEB), and the first model built on the platform—the ID.3—began to hit the streets in Sep. 2020. The ID.3, which Volkswagen is pushing as its new flagship model, offers strong price appeal.

Notably, the dramatic increase in the German government's EV subsidies has further improved the economics of the ID.3. In Germany, buyers of EVs priced over EUR40,000 are eligible for a grant of EUR9,000; factoring this in, the price of the ID.3 is even lower than that of the Volkswagen Golf (a comparable conventional car).

In 2021, Volkswagen plans to release the ID.4, the first all-electric SUV built on its MEB platform, which is estimated to be priced nearly EUR10,000 lower than the Tesla Model Y.

In addition, other traditional automakers, including BMW, Daimler, and HMC, are looking to launch a large number of compelling EV models in 2020-22. The releases of new EV models with improved commercial appeal, coupled with the marked increase in Europe's EV subsidies, should trigger full-fledged EV market growth going forward.

**Figure 12. Cost comparison: Volkswagen ID.3 vs. other major EV models.**

The VW ID.3 in cost comparison

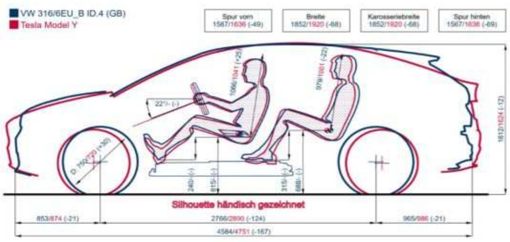
| Model | VW ID.3 1st Pro Performance (58 kWh), 150 kW | VW Golf 1.5 eTSI Style DSG, 110 kW | VW Golf 2.0 TDI Style DSG, 110 kW | Tesla Model 3 Standard Range Plus, 236 kW | Nissan Leaf (62 kWh) e+ Acenta, 160 kw | Hyundai IONIQ Elektro Style, 100 kW |
|---|---|---|---|---|---|---|
| Base price (€) | 38.987* | 31.905 | 34.425 | 43.880* | 37.237* | 39.284* |
| Depreciation[1] | 295 | 353/296* | 390/329** | 337 | 320 | 337 |
| Fixed costs[1] | 78 | 99 | 123 | 148 | 105 | 101 |
| Operation costs[1] | 91 | 119 | 94 | 85 | 104 | 83 |
| Servie and Tire costs[1] | 56 | 61 | 66 | 86 | 63*** | 56 |
| *Total costs[1]* | *520* | *632/574*** | *673/611*** | *656* | *592* | *576* |
| *Total costs[1] (Cent/km)* | *41,6* | *50,5/46*** | *53,8/48,9*** | *52,5* | *47,4* | *46,1* |

Source: Volkswagen, Mirae Asset Daewoo Research

**Figure 13. Comparison: Volkswagen ID.4 vs. Tesla Model Y**

**After ID.3 comes ID.4: again a true Volkswagen – the best overall package!**

AKTIENGESELLSCHAFT




- 17cm shorter – 6cm more interior length, 1,9m smaller turning circle
- High quality interior, VW.OS and digitalization (mass-relevant use cases)
- Established dealer & service base
- ~10.000 EUR price advantage
- Model Y with better acceleration (not volume market relevant) and charging speed
- More software-centered

| | ID.4 | Model Y | |
|---|---|---|---|
| Length | 4,58 | 4.775 mm (Herstellerangabe**) | -0,17 |
| Wheelbase | 2.766 mm | 2.875 mm (Herstellerangabe**) | -124 |
| Interior | | | +0,06 |
| Turning Circle | 10,2m | 12,1m | +1,9m |
| Battery Size | 82 b, 78 n | 78,3 (Herstellerangabe*) | Similar |
| Range (WLTP) | 522 | ~ 505 (Herstellerangabe**) | Similar |
| Charging (DC) | 125 | 250 | -125 |
| Acceleration | 8,5 | 5,1 (max. range)** 3,7 (perf.)** | -3 |
| Price | 44.500 (RWD) 49.000 (AWD) | 53-55.000 58.620 (AWD) | -10.000 -9.000 -15.000 large fleet |

Source: Electrek, Mirae Asset Daewoo Research

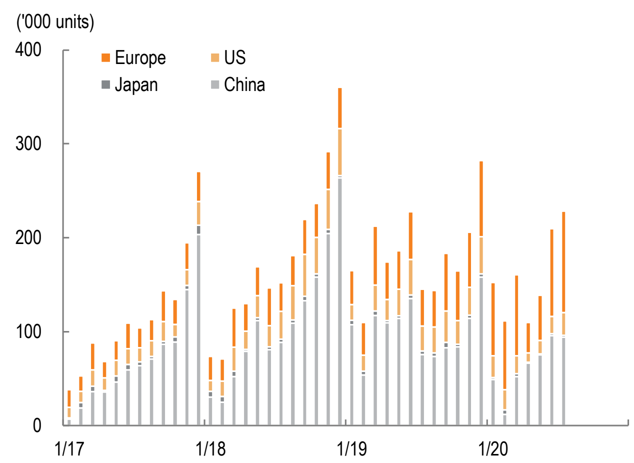
## 4. The rise of EVs in China

Starting in 2015, the Chinese government aggressively expanded EV subsidies to promote sales, driving rapid market growth. The government's strategic focus on EVs was aimed at securing leadership in the growing EV market.

Since 2018, however, subsidy cuts have led to a sharp market slowdown; the government decided to phase out subsidies to encourage automakers to cut costs and become more competitive. Going forward, we expect China to increasingly transition from a subsidy/regulation-driven to a private demand-driven EV market.

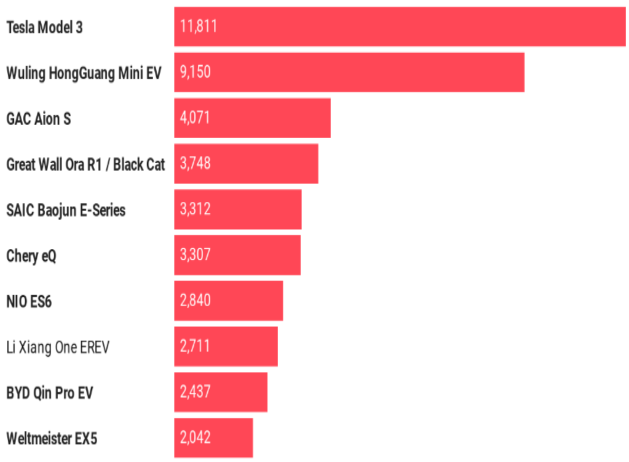
Notably, as Tesla's EV models have begun to take meaningful share from premium conventional vehicles with the start-up of production in China, conventional automakers are expected to step up their efforts to defend market share, aggressively ramping up capacity and releasing compelling EV models of their own. In addition, declining battery prices have been removing the price advantage of conventional vehicles over EVs.

**Figure 14. EV sales volume by region**



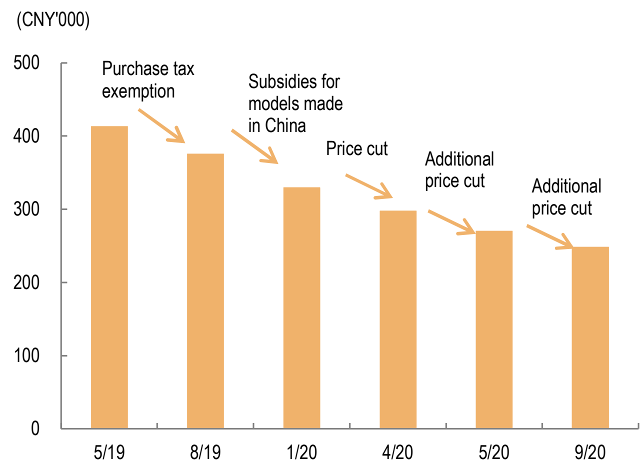

Source: SNE Research, Mirae Asset Daewoo Research

**Figure 15. Top 10 EV models (by sales) in China (Aug. 2020)**



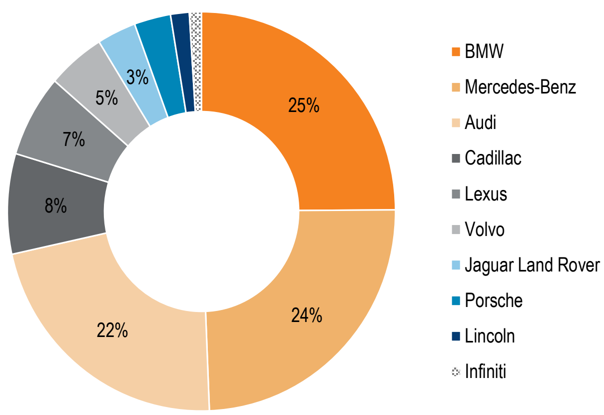

Source: InsideEVs, Mirae Asset Daewoo Research

**Figure 16. Tesla Model 3 price trends in China**




Source: Industry data, Mirae Asset Daewoo Research

**Figure 17. Premium auto M/S in China (2019)**




Source: Gasgoo, Mirae Asset Daewoo Research

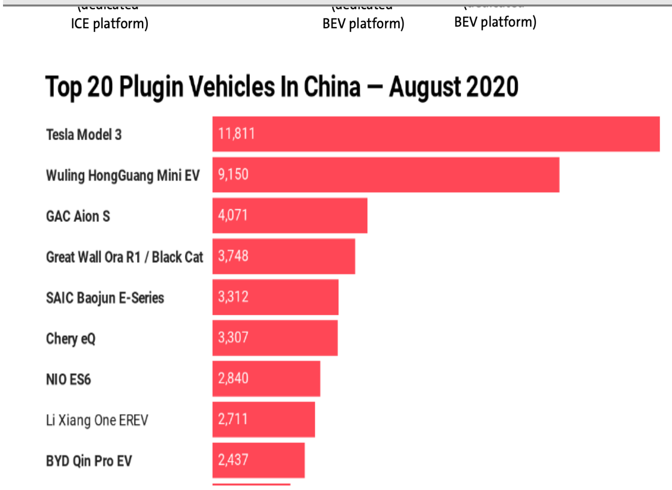
## 5. Improving EV economics

Amid intensifying market competition, we expect automakers to achieve economic viability in EVs even without subsidies in 2022-23, sooner than initially anticipated (2025), aided by: 1) improving battery technology; and 2) economies of scale.

We estimate that Tesla will be able to cut battery costs by more than 20%, as the company has decided to adopt CATL's LFP battery for the Model 3. Meanwhile, LG Chem plans to raise its battery density by more than 20% by using NCMA and long-cell technologies in 2022-23, and Samsung SDI will apply NCA to its large-sized prismatic batteries to achieve a similar level of density improvement. As such, we expect battery costs to drop from US$130/kWh to around US$100/kWh in 2022-23.

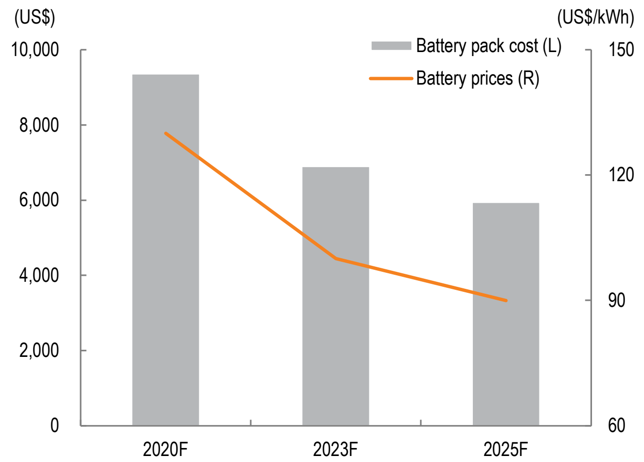
Moreover, other costs are also likely to decrease sharply. Volkswagen estimates that its adoption of a dedicated EV platform will improve its productivity by around 30%, meaning a 30% reduction in fixed costs, including labor costs. We also expect to see economies of scale take shape. If global EV sales expand from 400,000-500,00 units in 2020 to 3mn units in 2025, Volkswagen's R&D expenses per unit will shrink sharply (based on the assumption that the company will spend more than W2tr on dedicated EV platform development).

**Figure 18. Volkswagen's cost analysis: EV vs. conventional**



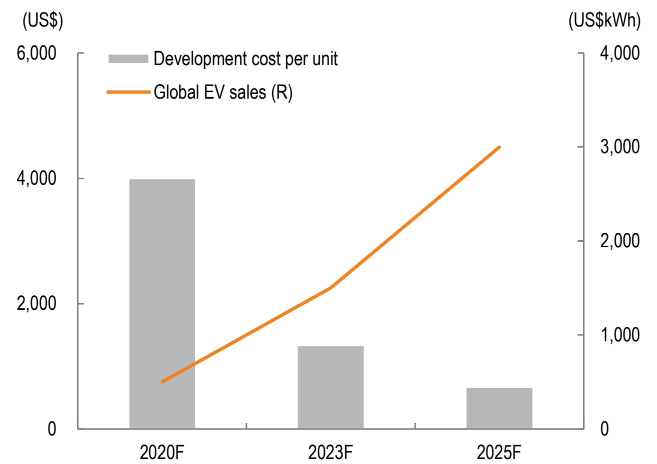

Source: Volkswagen, Mirae Asset Daewoo Research

**Figure 19. Battery price and EV-use battery pack costs (60kWh)**



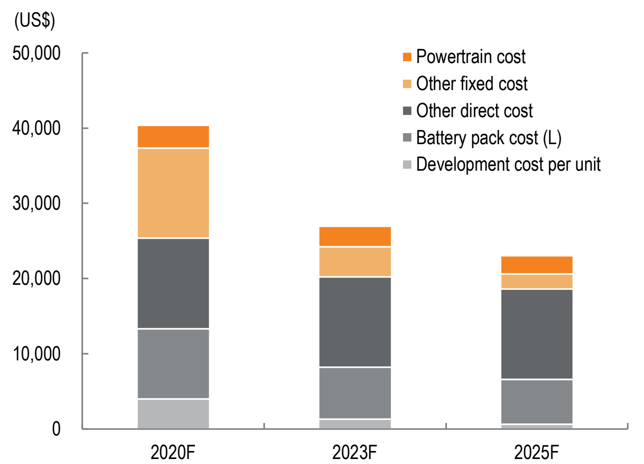

Source: Industry data, Mirae Asset Daewoo Research

**Figure 20. R&D expenses per unit**




Source: Industry data, Mirae Asset Daewoo Research

**Figure 21. EV manufacturing cost estimate for Volkswagen**




Source: Industry data, Mirae Asset Daewoo Research

# III. ESS, another driver of battery market growth

## 1. Global ESS battery demand to grow sevenfold through 2025

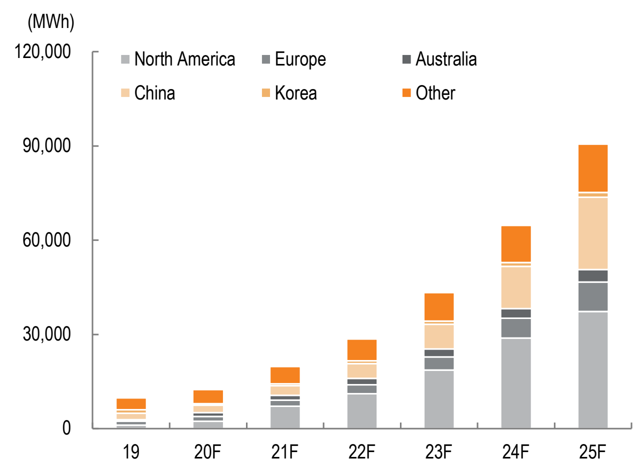
We expect the global ESS market—another key driver of lithium-ion battery market growth—to expand more than sevenfold to 90GWh in 2025 (from 12GWh in 2020). As the US market illustrates, an increasing share of renewables in the power generation mix should spur higher ESS demand to ensure grid/power supply stability. In addition, we foresee ESS battery prices declining further around 2023 (aided by technology innovation), which should cause ESS demand growth to accelerate.

In the near term, ESS market growth should stand out in the US and Australia. The US ESS market is likely to expand sharply from 2.4GWh in 2020 to 7.1GWh in 2021, supported by the completion of massive-scale projects (e.g., California). Meanwhile, ESS facilities are becoming more economically viable in Australia given its low population density, growing mix of renewables, unstable power supply (stemming from the closure of coal-fired power plants), and aging grids; Australia's ESS market is likely to double YoY to 1.2GWh in 2020.

In Europe, regulatory hurdles and high population density have weighed on ESS market growth; installations contracted markedly from 1.4GWh in 2018 to 1.1GWh in 2019. However, we think ESS demand in the region will inevitably pick up amid strengthening emissions regulations. The European Commission and governments in major European countries have recently begun to expand policy support for ESS projects.

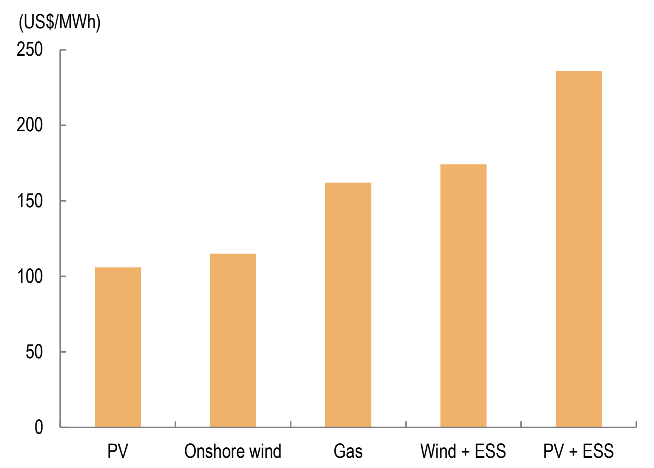
In China, ESS demand had remained soft until recently due to inadequate government support. However, medium-term growth potential looks strong, in light of the arrival of grid parity for renewables and the expected decline in battery prices. Wood Mackenzie expects China to become Asia's largest ESS market by end-2024, with ESS installations reaching 12.5GW/32.1GWh (vs. 489MW/843MWh in 2017).

**Figure 22. ESS market outlook by region**




Source: Mirae Asset Daewoo Research estimates

**Figure 23. Estimated power generation cost by source in Australia (1H20)**




Source: BNEF, Mirae Asset Daewoo Research

## 2. ESS adoption in the US

In the US, Southern California Edison (SCE) and Pacific Gas & Electric (PG&E) are planning to collectively install 1.2GW/4.8GWh of battery energy storage by Aug. 2021. These capacity plans are far higher than the US's total ESS deployment in 2019 (523MW/1.1GWh; Wood Mackenzie estimates).

In Nov. 2019, the California Public Utilities Commission called on power providers to secure 3.3GW in new clean energy resources by 2023 (50% by Aug. 2021), in anticipation of a major shortfall in grid capacity due to the planned closures of gas-fired power plants and the growing mix of renewables.

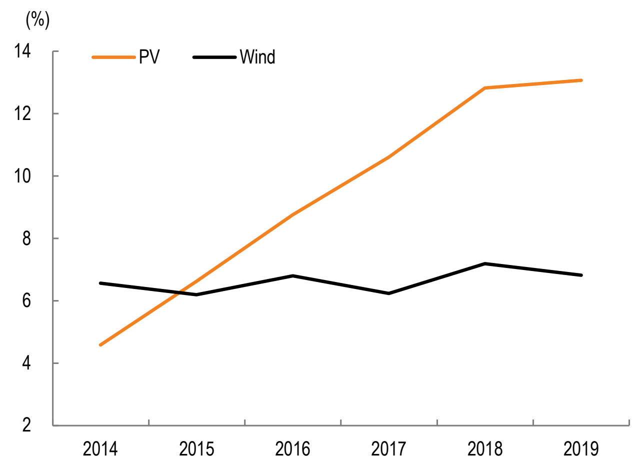
In response, several power suppliers, including SCE, have undertaken massive-scale ESS projects. ESS facilities boast numerous advantages; for example, they are more eco-friendly than gas-fired power plants and cheaper than peaking power plants. They also have relatively short installation periods.

ESS facilities also help address the "duck curve" problem—the timing mismatch between peak demand and generation—that poses challenges (e.g., grid pressure and reduced electricity quality) for renewable energy sources. In the state of California, solar/wind power accounts for 20% of total energy production.

Utility-scale energy storage projects are gaining significant momentum in the Western part of the US (beyond California).

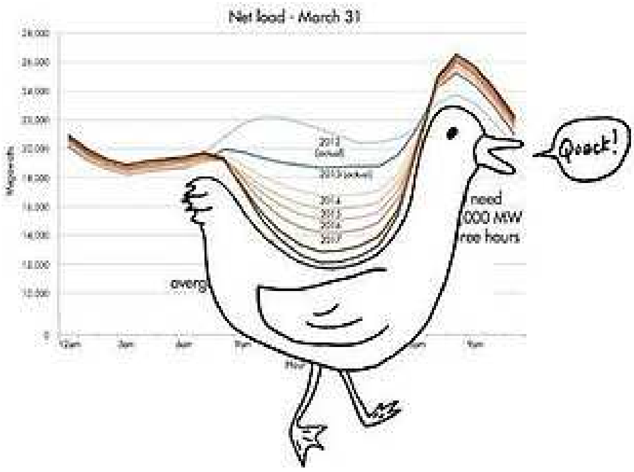
According to a recent study by the Lawrence Berkeley National Laboratory (published in Jul. 2020), 28% (102GW) of solar PV capacity within interconnection queues were solar-plus-storage hybrids at end-2019. In 2019, stand-alone storage projects also increased by a whopping 50GW.

**Figure 24. Energy mix of solar and wind power in California**




Source: California Energy Commission, Mirae Asset Daewoo Research

**Figure 25. "Duck curve" problem exacerbates grid instability**




Source: CAISO, press materials, Mirae Asset Daewoo Research

ESS demand is surging due to rising renewable energy generation and declining battery prices; indeed, the utilization of storage systems is increasingly being viewed as an efficient way to address the aforementioned "duck curve" problem and ensure grid stability and power quality. Against this backdrop, policy support for ESS is growing, with large-scale installations becoming mandatory in several states that meet a significant portion of their energy needs via renewables. Moreover, with battery prices falling significantly, ESS facilities can now serve as a substitute for peaking power plants and, in some cases, compete with baseload power plants. Simply put, ESS solutions, which were once primarily used for frequency regulation, are now gaining in importance in the electricity market.

In the US, the cost of utility-scale solar power generation is estimated to have fallen from US$250/MWh (excluding investment tax credit) in 2010 to US$53.8/MWh in 2018—lower than the costs associated with coal, nuclear, gas, and even wind generation. The costs are even lower in Western states that enjoy abundant sunlight. In 1H20, solar power accounted for 16% of California's energy mix, and its contribution is on the rise in Nevada, Hawaii, and Arizona.

Unfortunately, the rising share of renewables has led to increased grid pressure and occasional power supply disruptions. In response, California (1.3GW by 2020) and other states (12GW in ESS capacity to be installed in seven states by 2030) have mandated the installation of energy storage solutions.

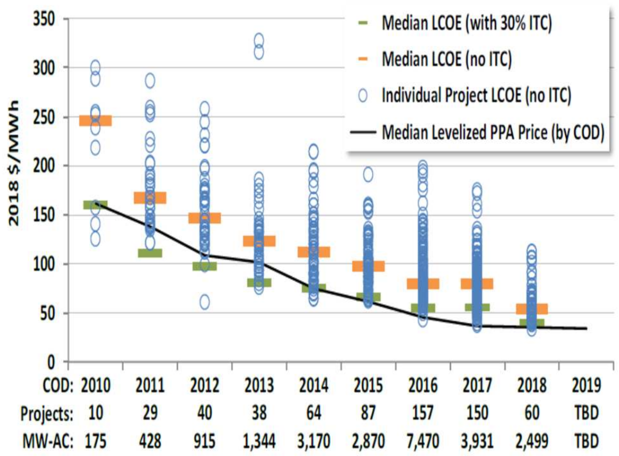
Looking ahead, we expect ESS demand growth to accelerate, as: 1) solar PV projects are increasing in scale amid falling power generation costs; and 2) several key states are seeking to source more energy from renewable sources under the renewable portfolio standard (RPS). As of end-2019, there was 350GW of solar PV power capacity in interconnection queues.

**Table 3. ESS installation mandates by state**

| State | Notes |
|---|---|
| California | Installation of 1.3GW by 2020; in service by 2024 |
| Massachusetts | Bill H.4857 (Aug. 2018): 1GWh by 2025 |
| New York | Oct. 2018 mandate: 3GW by 2030 |
| New Jersey | May 2018 mandate: 2GW by 2030 |
| Virginia | Feb. 2020 mandate: 3GW by 2035 |

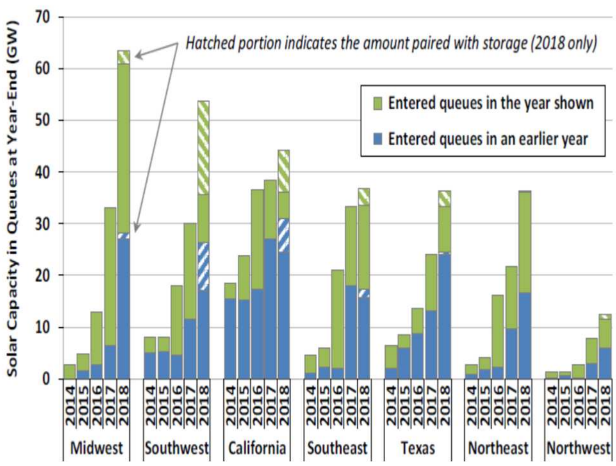
Source: Press materials, Mirae Asset Daewoo Research

**Figure 26. Power purchase agreement (PPA) price trends for US utility-scale solar PV projects**




Source: Lawrence Berkeley National Laboratory, Mirae Asset Daewoo Research

**Figure 27. US solar PV projects in interconnection queues**




Source: Exeter Associates, Mirae Asset Daewoo Research

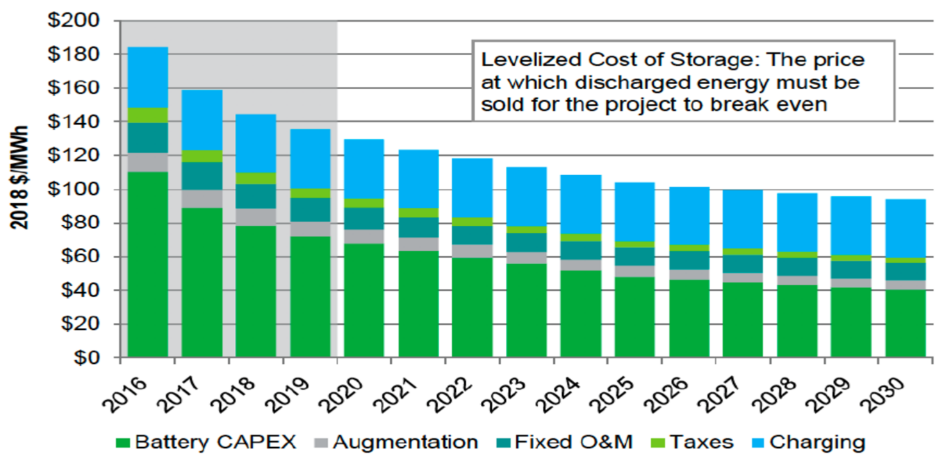
The economics of ESS have improved significantly amid a sustained fall in battery prices.

IHS Markit estimates that the average power generation cost of ESS in the US has fallen from US$160/MWh in 2017 to US$130/MWh in 2020 (based on four-hour duration batteries), following a drop in ESS installation costs from US$630/kWh in 2017 to US$470/kWh in 2020 (BNEF and GTM Research estimates). Battery costs—which account for 50% of total costs—have plunged by around 43%, and non-battery costs have also fallen.

Although fossil fuel power plants still enjoy a cost edge, ESS facilities are already competitive enough to replace gas peaking power plants. Lazard estimates the power generation costs of US gas peaking power plants at US$150-200/MWh.

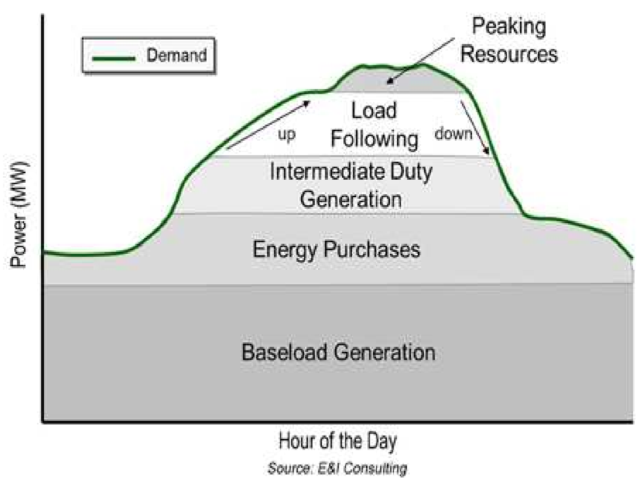
In fact, ESS have started to replace peaking power plants in the US. Notably, Elsevier estimates that 28GW of peaking power capacity can be substituted with ESS, and GTM Research and Wood Mackenzie project that over 20GW of additional peaking power capacity will be needed over the next decade.

**Figure 28. US utility-scale ESS power generation cost estimates (four-hour duration batteries)**



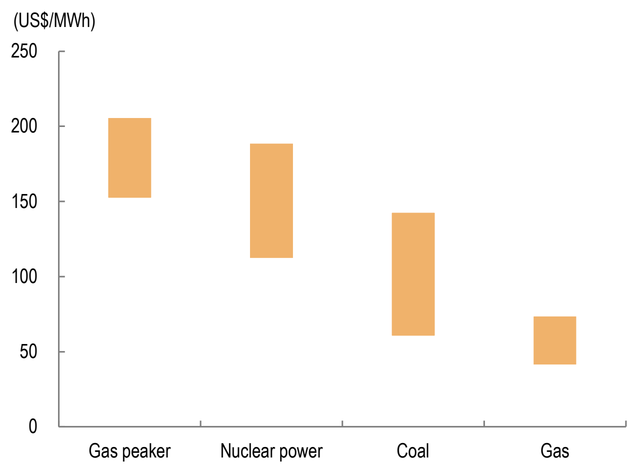

Source: IHS Markit, "Battery Energy Storage Overview," Mirae Asset Daewoo Research

**Figure 29. Power supply/demand**




Source: E&I Consulting, Mirae Asset Daewoo Research

**Figure 3022. Fossil fuel power generation cost estimates (Nov. 2018)**




Source: Lazard, Mirae Asset Daewoo Research

Consensus estimates for the US ESS market are being revised upward, despite COVID-19. Wood Mackenzie projects US ESS demand to increase sharply from 523MW in 2019 to 1.5GW in 2020, 3.6GW in 2021, and 7GW in 2025.

We believe actual demand growth could beat expectations. First, assuming that US solar power demand reaches 25GW in 2025 and that 30% of solar PV projects that year are solar-plus-storage hybrids (based on four-hour duration batteries), we estimate the relevant ESS demand alone will reach around 7.5GW. We believe this assumption is reasonable, given that 28% of solar PV projects within interconnection queues were solar-plus-storage hybrids at end-2019.

In addition, ESS facilities stand a strong chance of replacing peaking power plants. In the US alone, ESS could potentially replace 28GW of peaking power capacity. We also expect the residential/commercial ESS markets to grow steadily.

Based on battery energy capacity (MWh), we forecast ESS demand growth to outpace supply growth going forward. Of note, battery duration has been increasing in line with ESS solutions' growing importance to overall power supply. While the battery duration averaged less than one hour when ESS applications were confined to frequency regulation, the latest utility-scale ESS projects typically have a battery duration of around four hours.

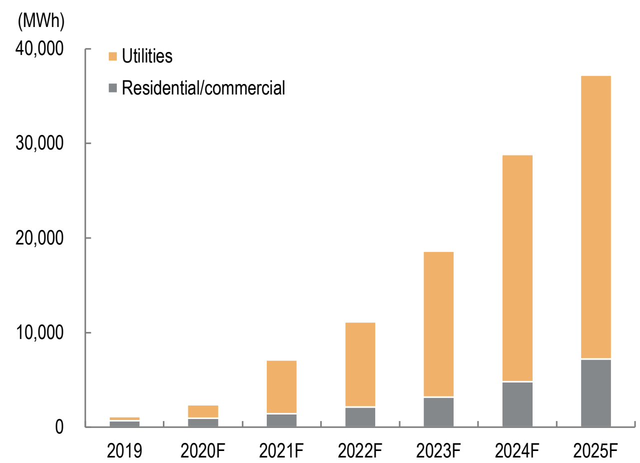
Meanwhile, the massive power shortage that hit California in August is likely to accelerate ESS market growth. The state experienced its first rotating power outages in 19 years, due to a spike in power demand amid a historic heat wave and supply disruptions caused by the increased energy mix of renewables. Considering California's commitment to 100% clean energy by 2045, we expect large-scale ESS projects to gain momentum.

**Table 4. US solar power demand and solar-plus-storage market estimates** (MW, %, hours, MWh)

| | 2020F | 2021F | 2022F | 2023F | 2024F | 2025F |
|---|---|---|---|---|---|---|
| Solar power demand (MW) | 18,000 | 19,000 | 20,000 | 22,000 | 24,000 | 25,000 |
| Proportion of solar-plus-storage (%) | 5 | 10 | 15 | 20 | 25 | 30 |
| Battery duration (hours) | 2.0 | 3.0 | 3.0 | 3.5 | 4.0 | 4.0 |
| Battery demand (MWh) | 1,800 | 5,700 | 9,000 | 15,400 | 24,000 | 30,000 |

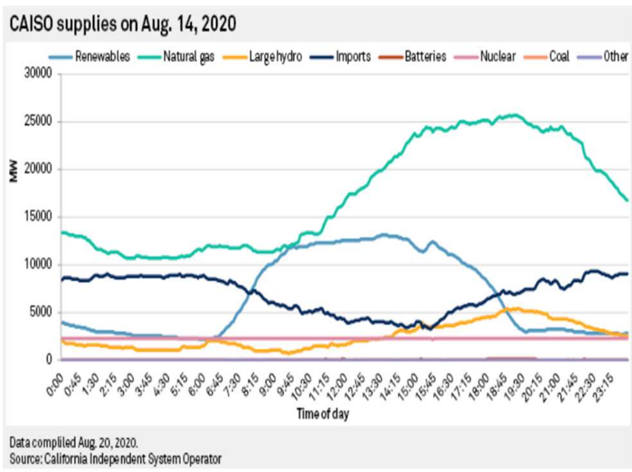
Source: Mirae Asset Daewoo Research estimates

**Figure 23. US ESS market estimates**




Source: Mirae Asset Daewoo Research estimates

**Figure 32. Power generation trend by source in California (Aug. 2020)**




Source: CAISO, Mirae Asset Daewoo Research

## 3. Global ESS market to grow sevenfold through 2025

We expect the global ESS market to expand more than sevenfold to 90GWh in 2025 (from 12GWh in 2020). As the US market illustrates, an increasing share of renewables in the power generation mix should spur higher ESS demand to ensure grid/power supply stability. In addition, we foresee ESS battery prices declining further around 2023 (aided by technology innovation), which should cause ESS demand growth to accelerate.

In the near term, ESS market growth should stand out in the US and Australia. The US ESS market is likely to expand sharply from 2.4GWh in 2020 to 7.1GWh in 2021, supported by the completion of massive-scale projects (e.g., California). Meanwhile, ESS facilities are becoming more economically viable in Australia given its low population density, growing mix of renewables, unstable power supply (stemming from the closure of coal-fired power plants), and aging grids; Australia's ESS market is likely to double YoY to 1.2GWh in 2020.

In Europe, regulatory hurdles and high population density have weighed on ESS market growth; installations contracted markedly from 1.4GWh in 2018 to 1.1GWh in 2019. However, we think ESS demand in the region will inevitably pick up amid strengthening emissions regulations. The European Commission and governments in major European countries have recently begun to expand policy support for ESS projects.

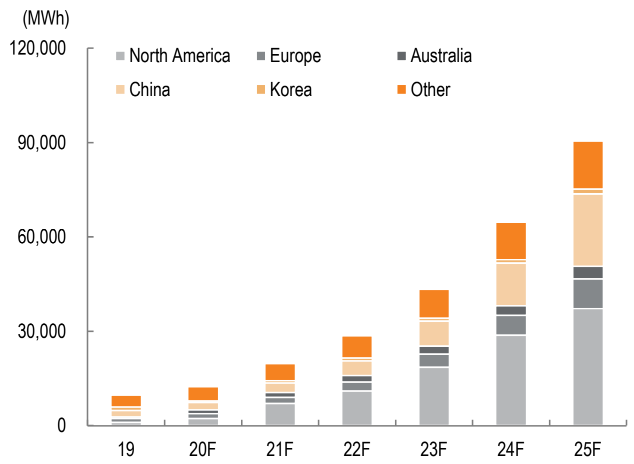
In China, ESS demand had remained soft until recently due to inadequate government support. However, medium-term growth potential looks strong, in light of the arrival of grid parity for renewables and the expected decline in battery prices. Wood Mackenzie expects China to become Asia's largest ESS market by end-2024, with ESS installations reaching 12.5GW/32.1GWh (vs. 489MW/843MWh in 2017).

**Table 5. Global solar-plus-storage demand estimates**

| | 2020F | 2021F | 2022F | 2023F | 2024F | 2025F |
|---|---|---|---|---|---|---|
| New demand (GW) | 120.0 | 140.0 | 150.0 | 160.0 | 170.0 | 180.0 |
| ESS installations as % of solar energy demand | 1.0 | 1.0 | 2.0 | 5.0 | 5.0 | 10.0 |
| Battery duration (hours) | 2.0 | 2.0 | 2.0 | 3.0 | 3.0 | 4.0 |
| ESS demand (GWh) | 2.4 | 2.8 | 6.0 | 24.0 | 25.5 | 72.0 |

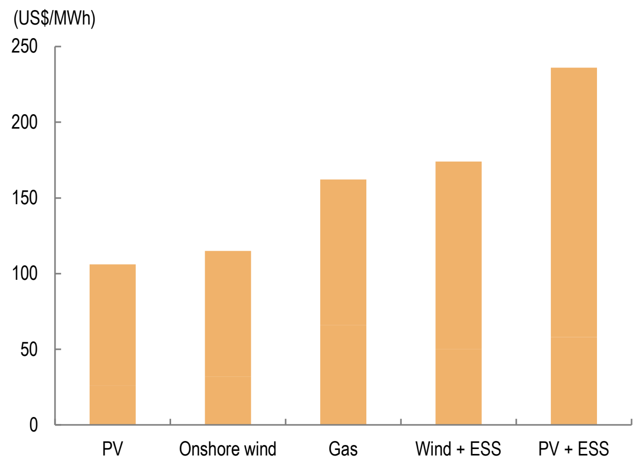
Source: Mirae Asset Daewoo Research estimates

**Figure 24. ESS market outlook by region**




Source: Mirae Asset Daewoo Research estimates

**Figure 34. Estimated power generation cost by source in Australia (1H20)**




Source: BNEF, Mirae Asset Daewoo Research

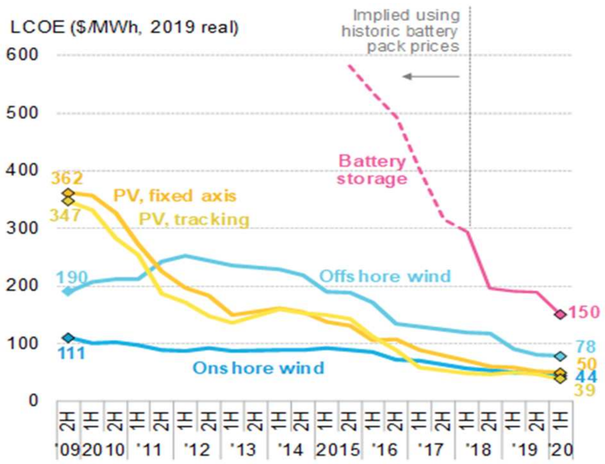
We expect global ESS demand growth to accelerate from 2023, backed by falling battery costs.

A BNEF report notes that ESS power generation costs have nearly halved to US$150/MWh over the past two years. We attribute the faster-than-expected decline to lower battery prices, improvements in battery energy density, and lower per-unit costs amid increasing system size.

We expect the decline in ESS power generation costs to accelerate from 2023 thanks to advances in battery technology spurred by EV market growth. By 2023, we expect battery energy density/cost competitiveness to improve by more than 20% vs. 2020 levels. The growing size of ESS should also lead to a further decline in per-unit costs. In addition, battery duration—which averaged less than one hour when ESS solutions were primarily used for frequency regulation—has been extended to two to four hours to support expanded applications (such as the replacement of peaking power plants). Advances in battery management technology, as well as improvements in system/financing efficiency, should also contribute to cost savings.

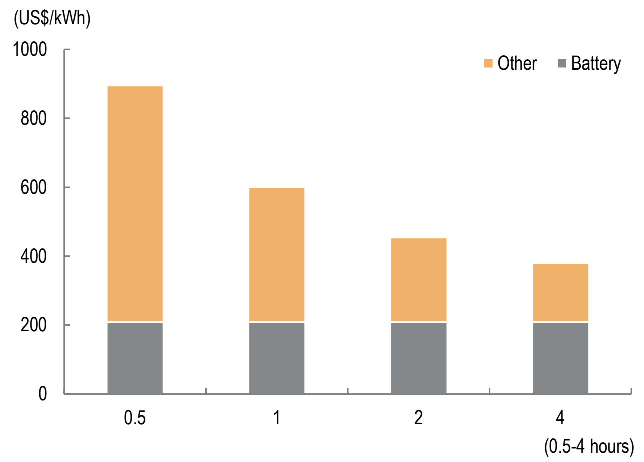
NextEra Energy projects ESS storage costs to fall 16% annually from US$11-17/MWh in 2020 to US$5-9/MWh beyond 2023.

**Figure 35. Estimated ESS power generation costs (BNEF)**



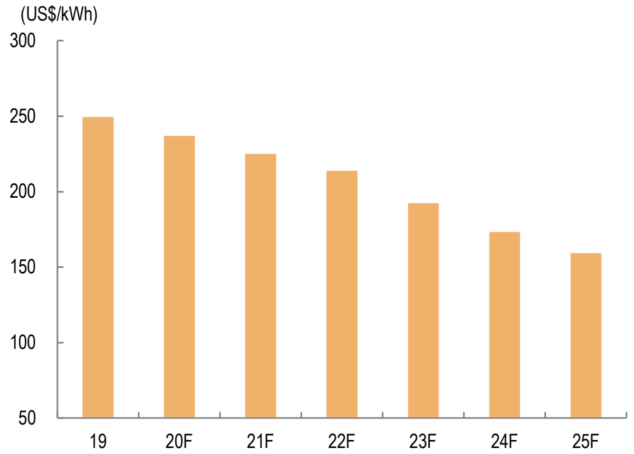

Source: BNEF, Energy Storage News, Mirae Asset Daewoo Research

**Figure 36. Estimated cost of utility-scale ESS installation in the US by battery duration (2018)**



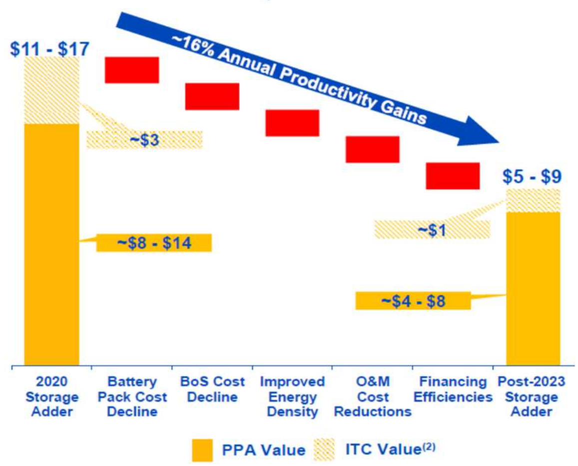

Source: NREL, Mirae Asset Daewoo Research

**Figure 37. Lithium-ion battery price estimates**




Source: Mirae Asset Daewoo Research estimates

**Figure 38. NextEra Energy's ESS cost reduction road map**




Source: NextEra Energy, Mirae Asset Daewoo Research

# IV. EV battery industry outlook

## 1. Highly concentrated around top-tier players

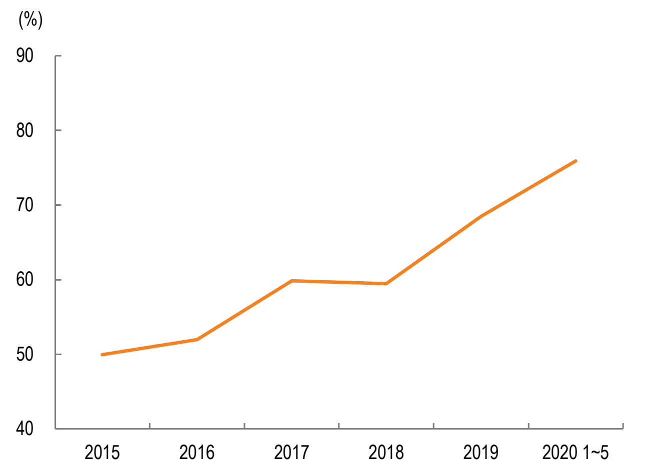
The EV battery industry is highly concentrated, with the top four suppliers—LG Chem, Panasonic, CATL, and Samsung SDI—controlling around 80% of the global market. Notably, domestic firms have been dominant players in the global battery market since the early days of EV market development.

Going forward, the accelerating transition to EVs should drive the rapid expansion of the global battery market. However, there are worries that competition could intensify as latecomers flood the market. The key question, in our view, is how likely latecomers are to succeed—i.e., how high the market entry barriers are and whether they are sustainable. The past five years suggest the battery market has surprisingly high entry barriers.

China began providing aggressive policy support for the EV industry in 2015, resulting in more than 100 Chinese companies entering the battery market. Many of these companies believed they could easily catch up with market leaders (as was the case with other components), but the industry failed to gain meaningful traction. CATL was the only company to really succeed, while no. 2 player BYD continued to lose market share and no. 3 supplier OptimumNano Energy filed for bankruptcy. Given the growth potential of the EV industry, one would naturally expect at least five to 10 battery makers to be operating in China by now. In the end, however, CATL essentially became the sole supplier in the Chinese market, and the world's top four battery makers now control nearly 80% of the global market.

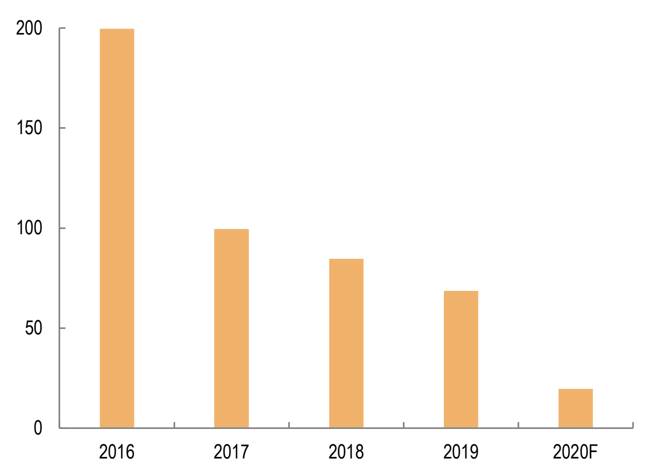
In their rush to improve energy density in order to catch up with market leaders on battery performance, many Chinese latecomers compromised on safety, leading to a large number of EV fire incidents. This, combined with the Chinese government's EV subsidy cuts beginning in 2018, forced industry laggards out of the market.

**Figure 39. Combined M/S of top four global battery suppliers**




Source: SNE Research, Mirae Asset Daewoo Research

**Figure 40. No. of Chinese battery suppliers**




Source: GGII, Gasgoo, Mirae Asset Daewoo Research

## 2. Why making batteries can be challenging

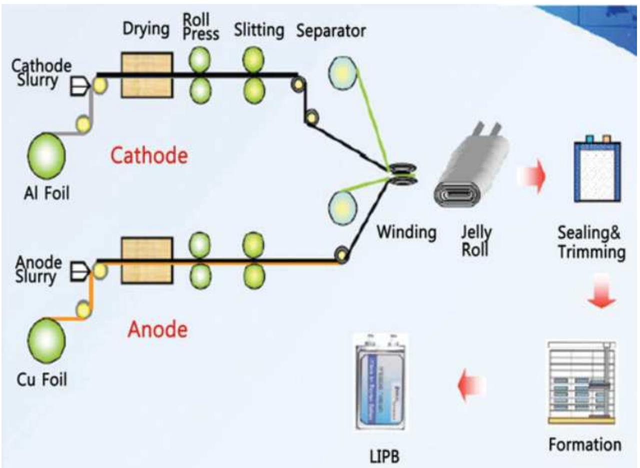
On the face of it, battery manufacturing is a fairly straightforward process: cathode and anode materials are coated in aluminum or copper foil, rolled together with a separator into a case, and injected with electrolytes. The main challenge is finding ways to lower production costs, of which materials account for more than half. To reduce costs, energy density needs to be improved so that more power can be produced from a battery of the same weight. This is why technology matters more than labor when it comes to manufacturing EV batteries.

Density can be improved by increasing nickel content in cathode materials or silicon content in anode materials. But doing so raises complications, including increased flammability, shorter life, and the potential release of gas. Addressing such issues requires new technologies that allow for additional coating or changing conductive materials and additives.

The problem is that most of these technologies relate to materials. Materials technology tends to be complex, making it difficult to copy in a short period of time. In electronic materials, for instance, one can get very different results using the same chemistry. Finding the best solution requires much trial and error.

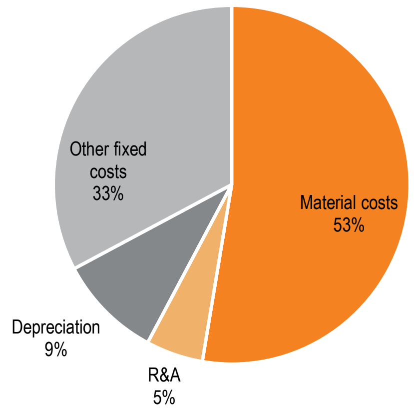
Indeed, LG Chem, despite its decades of experience and status as the world's no. 1 battery manufacturer, struggled to raise the production yield of its European plant to normal levels for roughly a year. Even though the technology was the same, the change in geographical location and slight adjustments to the equipment led to widely different results. Panasonic also wrestled with low production yields for years at its US plant.

**Figure 41. Lithium-ion cell manufacturing process**



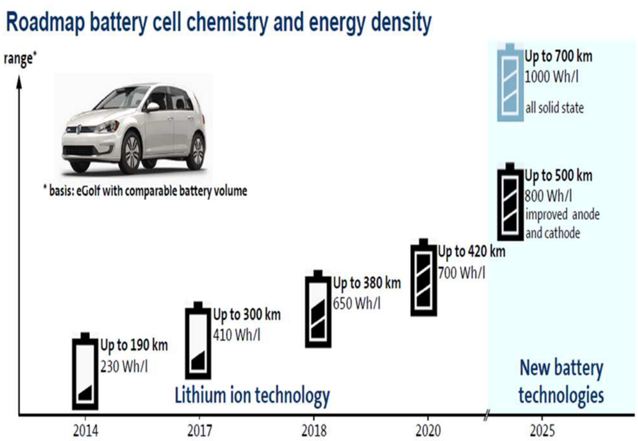

Source: KUBT, Mirae Asset Daewoo Research

**Figure 252. Breakdown of battery manufacturing costs**



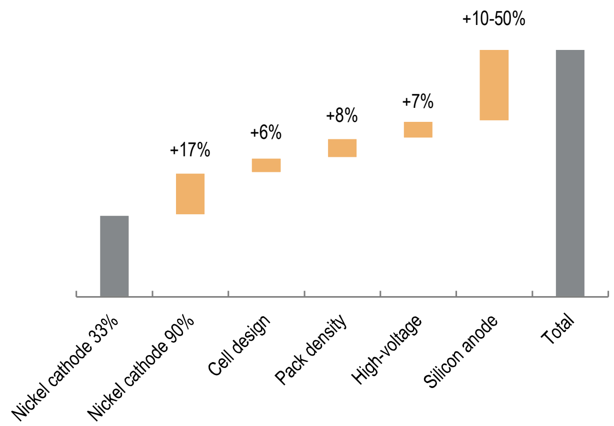

Source: Mirae Asset Daewoo Research estimates

**Figure 43. Volkswagen's battery technology road map**




Source: Volkswagen, Mirae Asset Daewoo Research

**Figure 44. Umicore's solution for improving battery energy density**




Source: Umicore, Mirae Asset Daewoo Research

## 3. Competitiveness gap to widen further

The accelerating innovation in EV batteries—already a highly concentrated segment—should cause the gap between leading players and latecomers to widen even further. As battery contracts are awarded two to three years ahead of new EV model releases, suppliers that fail to win contracts now will find it harder to catch up going forward. Moreover, latecomers are likely having difficulty securing funding and customers during the pandemic.

Notably, industry leaders are speeding up their innovation. The full-fledged expansion of the EV market and Tesla's advance are driving massive R&D investments in battery technologies. Recently, Tesla announced that it would use CATL's lithium iron phosphate (LFP) batteries for some of its EV models. Previously, CATL's LFP batteries were not adopted by automakers because their energy density was equivalent to only around 50% of first-tier nickel cobalt manganese (NCM) battery density levels. However, CATL has raised their relative energy density to 70-80% via cell-to-pack (CTP) technology (which allows cells to be integrated directly into battery packs). CATL's LFP battery packs are more than 20% cheaper than NCM batteries.

There are some concerns that the application of CTP technology and Tesla's adoption of CATL's LFP batteries could hurt suppliers of NCM batteries. However, when considering that the global EV battery market consists of just five or six players, CATL included, heightened competitive pressure is not a cause for concern. Rather, we believe it will motivate other EV battery suppliers to ramp up their innovation efforts.

Indeed, Samsung SDI is working on lowering battery cell production costs by more than 20% by applying lithium nickel cobalt aluminum oxide (NCA) cathodes (which are currently only used for cylindrical batteries) to its large-sized prismatic batteries beginning in 2021. Meanwhile, LG Chem plans to adopt nickel, cobalt, manganese, and aluminum (NCMA) cathodes from 2023 to lower costs by at least 20%. In addition, various battery technologies (e.g., monocrystalline cathode materials and dry battery electrodes) are being explored and developed. Recently, Samsung SDI published a paper on all-solid-state batteries, a next-generation EV battery technology. Although all-solid-state EV batteries are unlikely to be ready for mass production for at least seven years, development of the technology should accelerate, given Samsung SDI's strong commitment and massive investments.

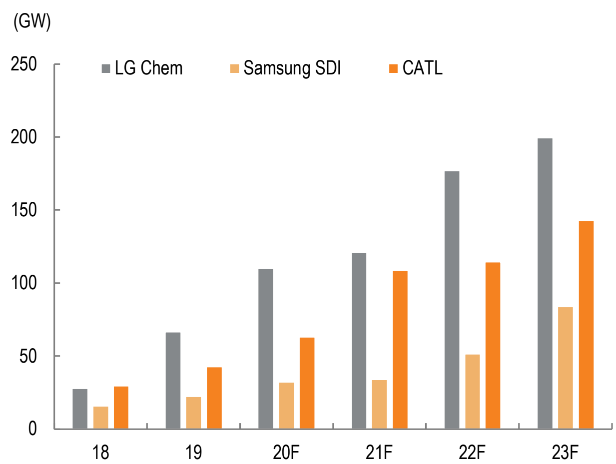
Against this backdrop, market leaders are likely to further widen their lead over latecomers, supported by advances in technology and rapid cost declines. Although there are some new players in Europe (e.g., Northvolt) and China, they should continue to trail market leaders, especially in the race for next-generation EV battery technologies.

Given Tesla's market share gains and the pace of EV battery price declines, it is crucial for conventional automakers to release more compelling EV models in 2022-23 at the latest. Battery contracts should therefore be awarded in 2020-21, and these are likely to go to major suppliers. The concentration of orders among top-tier suppliers should make it more difficult for latecomers to close the competitiveness gap in the next two to three years.

**Figure 45. CATL's CTP-based LFP battery technology**


Source: CATL, Mirae Asset Daewoo Research

**Figure 46. EV battery production capacity by major supplier**




Source: SNE Research, Mirae Asset Daewoo Research

## 4. ESS, another driver of EV battery market growth

Like the EV battery market, the fast-growing ESS battery market should increasingly be led by top-tier players. We forecast global demand for ESS-use lithium-ion batteries to expand sevenfold to 91GWh in 2025 (from 12GWh in 2020). In the US, ESS demand is set to expand particularly rapidly over the next two to three years, and we may see sales overshoot market expectations.

We expect the ESS-use battery market to remain highly concentrated, similar to the EV battery market. And significantly, margins are likely to be high relative to EV battery margins.

ESS-use batteries are dominated by the top five players, which collectively control 70% of the market (as of 2018). Most top-tier EV battery suppliers are also major ESS players; we expect the ESS battery market to be dominated by leading EV battery suppliers in the medium term given: 1) the conservative nature of utility companies/power producers; 2) the need for stable after-sales service/maintenance; and 3) efforts to improve the safety and cost competitiveness (20% reduction by around 2023) of NCM batteries.

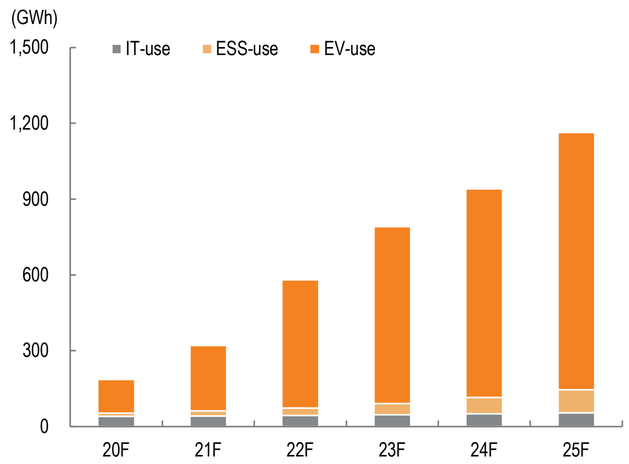
ESS-use battery margins are likely to stay higher than EV battery margins.

Given the conservative nature of power suppliers, we expect batteries with proven track records to be favored over low-priced batteries. In addition, we do not anticipate high price-cutting pressure, as ESS batteries account for just a fraction of total power system costs (whereas EV batteries account for 30-40% of EV costs). Indeed, ESS-use battery prices fell less sharply than expected in 2018-19. We believe this moderate price decline was attributable to tight EV battery supply. In addition, ESS-use battery prices appear slightly higher than EV battery prices.

In our view, winners in the EV battery market will increasingly extend their leadership to the ESS battery market. For lithium-ion batteries, energy density improvement via superior cathode/anode materials is essential to enhancing cost competitiveness. As such, companies with advanced cathode/anode materials technologies and significant production know-how are better positioned to achieve cost reductions.

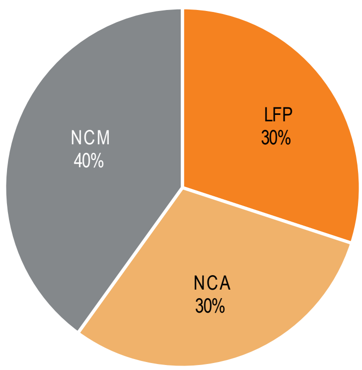
All in all, we expect the ESS-use battery market to follow in the footsteps of the EV battery market and become even more concentrated over the next two to three years.

**Figure 47. Lithium-ion battery market outlook by application**




Source: Mirae Asset Daewoo Research estimates

**Figure 48. ESS-use battery market breakdown (2019)**




Source: SNE Research, Mirae Asset Daewoo Research estimates

## 5. What if Tesla manufactures its own batteries?

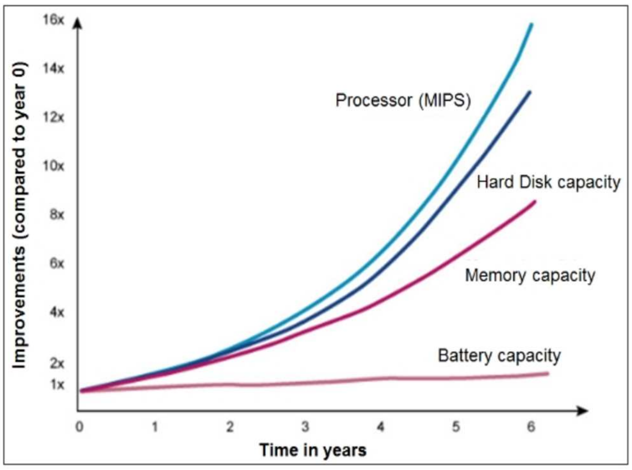
Since Tesla's Battery Day event, battery stocks have slid on concerns that the automaker may start manufacturing its own batteries, taking a big slice of the battery market pie. However, we think top-tier battery firms will eventually benefit from Tesla's move, in light of the following:

1) Tesla will likely help increase the size of the market pie. Currently, global EV market penetration stands at only 3-4%. If Tesla succeeds in driving down battery prices and strengthens its market dominance, other automakers will have to increase EV sales to protect their market shares. They will also need to strengthen their partnerships with existing battery makers (as using Tesla's batteries will likely not be an option).

2) At the Battery Day event, Tesla did not announce any new technologies or patents (but rather focused on improving productivity). Meanwhile, existing battery suppliers are also developing their technologies (e.g., increasing battery size, exploring the use of dry electrodes, etc.). We believe Tesla will help drive overall EV market growth, as it has in the past. Indeed, in 2012, the release of Tesla's cylindrical battery-powered Model S helped accelerate battery manufacturers' and automakers' technology development, leading to a decline in battery prices and eventually boosting market growth.

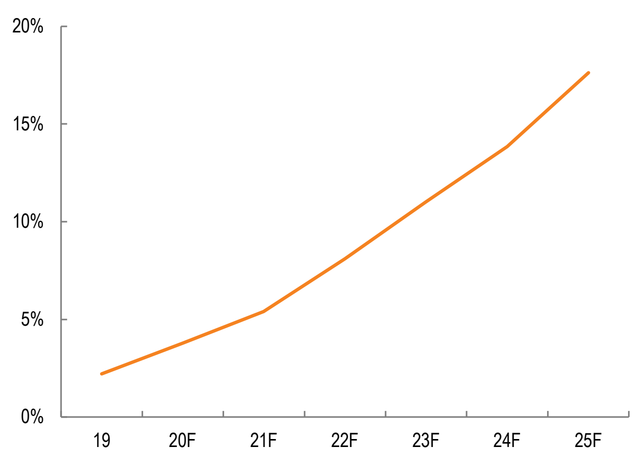
3) Batteries are an industry with high technological barriers to entry. Technological advances have been slow compared with other IT products, and mass production is particularly challenging due to low yields. This is because accumulated experience and know-how are crucial in materials technology—the key technology in battery cell production. Panasonic has been manufacturing batteries for over 20 years, but it took the company several years to secure sufficient yields at its US factory. It took LG Chem more than a year to stabilize yields in Europe. We believe Tesla will choose to collaborate with existing battery makers for cell production, as its goal is to expand the EV market, not to compete with battery firms.

**Figure 26. Pace of battery technology improvement**




Source Battery University, Mirae Asset Daewoo Research

**Figure 27. EV penetration rate**




Source Mirae Asset Daewoo Research estimates

# V. Materials market outlook

## 1. Battery materials market outlook: Elecfoil

We expect the battery-use elecfoil market to see a supply shortage starting in 2022 (based on our utilization assumption of 90%).

We attribute the tight conditions to: 1) top-tier suppliers' slower-than-expected capacity expansion (no new production lines coming online in 2019); 2) the emergence of large customers such as SK Innovation; and 3) high entry barriers owing to a heavy fixed-cost structure. Notably battery manufacturers enter the elecfoil business by acquiring equity stakes in existing players (e.g., SK Holdings' investment in Wason in 2018 and SKC's investment in KCFT in 2019).

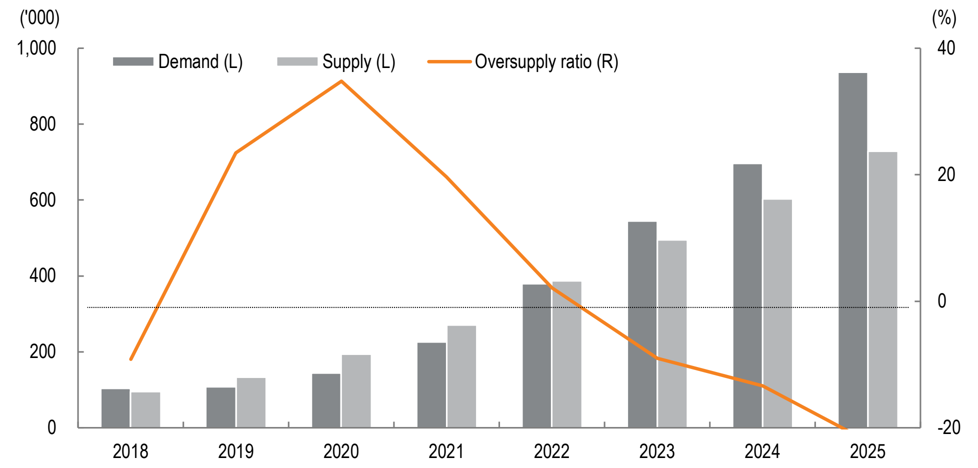
We expect elecfoil suppliers to display solid earnings growth aided by: 1) steady selling prices; and 2) continued customer diversification.

**Table 4. Supply/demand outlook for battery-use elecfoil**

| | 2018 | 2019 | 2020F | 2021F | 2022F | 2023F | 2024F | 2025F |
|---|---|---|---|---|---|---|---|---|
| Battery production capacity (GWh) | | | | | | | | |
| Small batteries | 36 | 36 | 40 | 42 | **44** | 47 | 50 | 55 |
| ESS | 12 | 11 | 12 | 20 | **28** | 43 | 65 | 91 |
| EV batteries | 82 | 89 | 130 | 229 | **426** | 640 | 838 | 1,164 |
| Total | 130 | 136 | 183 | 291 | **498** | 730 | 953 | 1,309 |
| Elecfoil demand (tonnes) | | | | | | | | |
| Small batteries | 29,040 | 28,670 | 31,677 | 32,447 | **33,548** | 34,815 | 36,822 | 39,164 |
| ESS | 9,440 | 8,867 | 9,730 | 15,224 | **21,618** | 32,357 | 47,355 | 65,007 |
| EV batteries | 65,568 | 70,353 | 102,121 | 178,013 | **323,827** | 477,045 | 612,003 | 833,093 |
| Total | 104,048 | 107,890 | 143,528 | 225,683 | **378,992** | 544,217 | 696,180 | 937,264 |
| Elecfoil usage (tonnes/GWh) | 800 | 792 | 784 | 776 | **761** | 746 | 731 | 716 |
| Elecfoil capacity (tonnes) | | | | | | | | |
| Iljin Materials | 17,000 | 25,000 | 35,000 | 55,000 | **65,000** | 75,000 | 85,000 | 95,000 |
| KCFT (LS Mtron) | 19,000 | 19,500 | 29,500 | 39,500 | **59,500** | 79,500 | 99,500 | 119,500 |
| Wason (Lingbao) | 15,000 | 23,000 | 35,000 | 47,000 | **67,000** | 87,000 | 107,000 | 127,000 |
| Chang Chun CCP | 12,500 | 22,000 | 28,000 | 38,000 | **58,000** | 78,000 | 98,000 | 118,000 |
| Nuode | 17,500 | 23,000 | 38,000 | 48,000 | **68,000** | 88,000 | 108,000 | 128,000 |
| Doosan Solus | 0 | 0 | 0 | 10,000 | **20,000** | 30,000 | 40,000 | 70,000 |
| Other | 24,000 | 35,500 | 49,500 | 62,500 | **92,500** | 112,500 | 132,500 | 152,500 |
| Total | 105,000 | 148,000 | 215,000 | 300,000 | **430,000** | 550,000 | 670,000 | 810,000 |
| Elecfoil supply (tonnes; 90% utilization) | | | | | | | | |
| Iljin Materials | 15,300 | 22,500 | 31,500 | 49,500 | **58,500** | 67,500 | 76,500 | 85,500 |
| KCFT (LS Mtron) | 17,100 | 17,550 | 26,550 | 35,550 | **53,550** | 71,550 | 89,550 | 107,550 |
| Wason (Lingbao) | 13,500 | 20,700 | 31,500 | 42,300 | **60,300** | 78,300 | 96,300 | 114,300 |
| Chang Chun CCP | 11,250 | 19,800 | 25,200 | 34,200 | **52,200** | 70,200 | 88,200 | 106,200 |
| Nuode | 15,750 | 20,700 | 34,200 | 43,200 | **61,200** | 79,200 | 97,200 | 115,200 |
| Doosan Solus | 0 | 0 | 0 | 9,000 | **18,000** | 27,000 | 36,000 | 63,000 |
| Other | 21,600 | 31,950 | 44,550 | 56,250 | **83,250** | 101,250 | 119,250 | 137,250 |
| Total | 94,500 | 133,200 | 193,500 | 270,000 | **387,000** | 495,000 | 603,000 | 729,000 |
| Oversupply (%) | -9.18 | 23.46 | 34.82 | 19.64 | **2.11** | -9.04 | -13.38 | -22.22 |

Source: Mirae Asset Daewoo Research

**Figure 28. Medium/long-term supply/demand outlook for battery-use elecfoil: Need for additional capacity to arise in 2022**



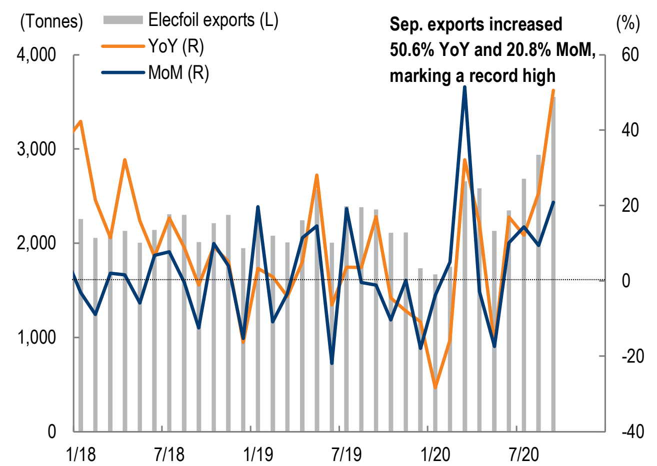

Source: Mirae Asset Daewoo Research

**Table 5. Battery-use elecfoil supply contracts**

| | Customer | Period | Volume (tonnes) | Value (Wbn) |
|---|---|---|---|---|
| Iljin Materials | Samsung SDI | 2019-23 (5 years) | 60,000 | 800 |
| KCFT | LG Chem | 2020-23 (4 years) | 60,000 | 800 |
| Doosan Solus | LG Chem | 2021-25 (5 years) | 30,000 | 400 |
| Doosan Solus | SK Innovation | 2021-24 (4 years) | 6,000 | 100 |
| Iljin Materials | Samsung SDI | 2020-25 (6 years) | 30,000 | 400 |

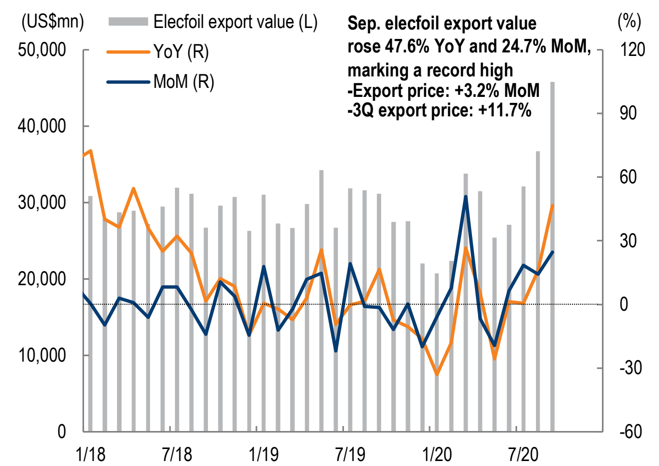
Source: Dart, media reports, Mirae Asset Daewoo Research

**Figure 29. Elecfoil export volume trend**




Source: Trass, Mirae Asset Daewoo Research

**Figure 30. Elecfoil export value trend**




Source: Trass, Mirae Asset Daewoo Research

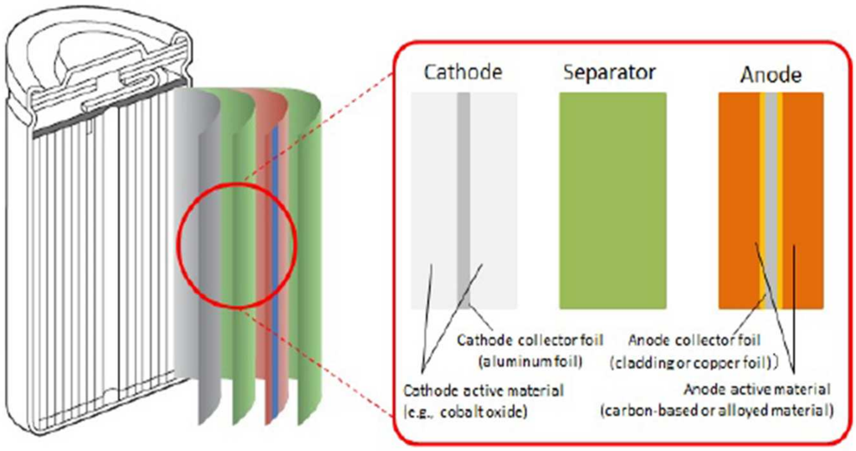
**Reducing elecfoil thickness from 8㎛ to 6㎛ results in a 3-5% increase in battery capacity**

Elecfoil thickness is a key focus of manufacturers, as a decline in thickness leads to a corresponding increase in anode active material content and improvement in battery capacity. We estimate reducing elecfoil thickness from 8㎛ to 6㎛ leads to a 3-5% increase in battery capacity.

Going forward, we expect battery capacity to improve on the back of thinner battery-use elecfoil. Based on current production facilities, major Korean companies are poised to take the lead in the production of premium elecfoil (6㎛ or thinner), having secured medium- and long-term supply contracts for the equipment (titanium drums) needed to produce high-end products.

Amid a steady shift to thinner elecfoil, we expect leading players to maintain their technology lead over latecomers. Top-tier players should also be able to defend selling prices thanks to an improved product mix; note that as elecfoil becomes thinner, the amount of elecfoil used (tonnes per GWh) decreases, but the T value (selling price minus production cost and copper price) increases. Contrary to market concerns, we believe the competitive threat (in terms of technology, market share, and ASP) from new entrants is limited.

**Figure 31. A decline in elecfoil thickness leads to an increase in active material content**




Source: Media reports, Mirae Asset Daewoo Research

## 2. Battery materials market outlook: Separators

Among battery materials, separators should see the tightest supply conditions in the medium to long term, with SNE Research projecting the supply shortage ratio at 35% in 2022. Accordingly, we expect separator suppliers (particularly top-tier ones) to seek to expand capacity in earnest. Amid weak market conditions over the past two to three years, suppliers have been conservative toward capacity additions. (Given the high proportion of fixed costs, separator oversupply could lead to sharp margin deterioration.)

With a number of countries implementing subsidies since the COVID-19 outbreak, the global separator market is in the midst of an unexpected boom. Of note, separators should maintain solid selling prices relative to other materials, given their nature as a commodity material and the supply shortage stemming from the sudden market upturn. Going forward, we expect separator supply/demand conditions to remain tight, given: 1) the time needed for capacity additions to catch up with market growth; and 2) the shortage in supply.

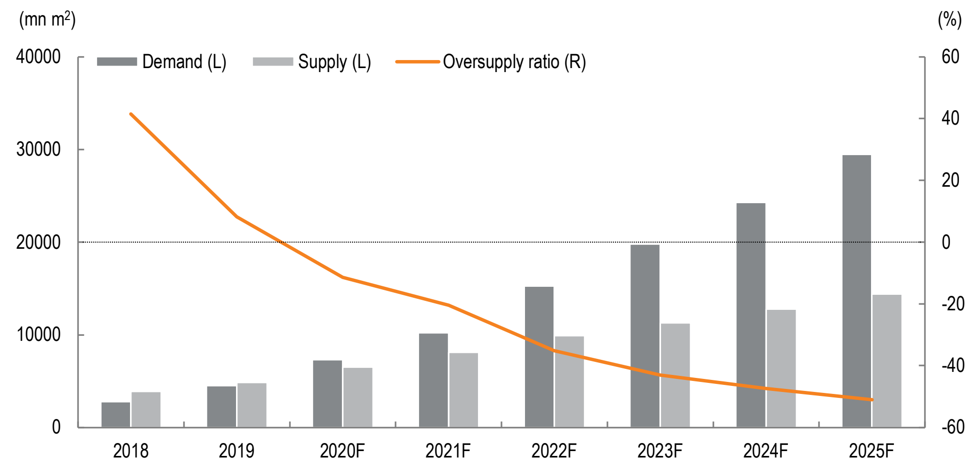
Among battery materials suppliers, separator makers boast the highest OP margin (around 30% for top-tier suppliers).

Suppliers of other materials need to steadily execute capex in excess of their annual EBITDA, which is why many battery-related companies have sought external financing (including rights offerings, CB issuance, subsidiary listings, and borrowing) since 2019. Separator suppliers, however, can fully finance capex with their EBITDA. Indeed, for Yunnan Energy New Material, 2020F and 2021F capex/EBITDA ratios stand at only 74% and 63%, respectively.

For EV battery-use separators, suppliers cannot obtain customer approval without mass production facilities. As separators are critical to battery stability, the approval process takes up to two years, and vendor changes are not common. Due to high supply/demand uncertainties, battery cell makers typically sign medium/long-term supply contracts.

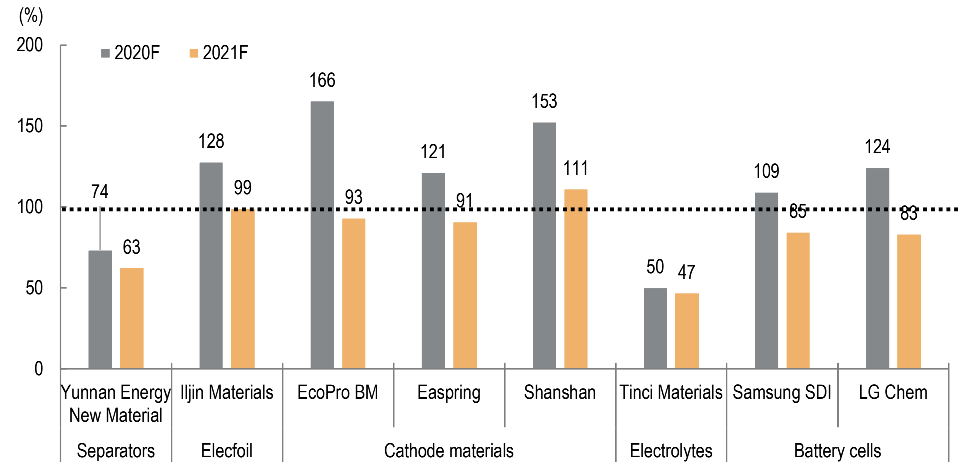
Of note, the separator business requires massive production facilities, which incur high depreciation expenses. However, this is favorable for top-tier suppliers, as new entrants face huge initial capex requirements and are likely to incur massive losses in the event of weak utilization or yields.

**Figure 32. Battery-use separator supply/demand analysis: Tightest supply among battery materials**




Source: Mirae Asset Daewoo Research

**Figure 33. Capex/EBITDA ratio comparison: Separators are a high-margin material**



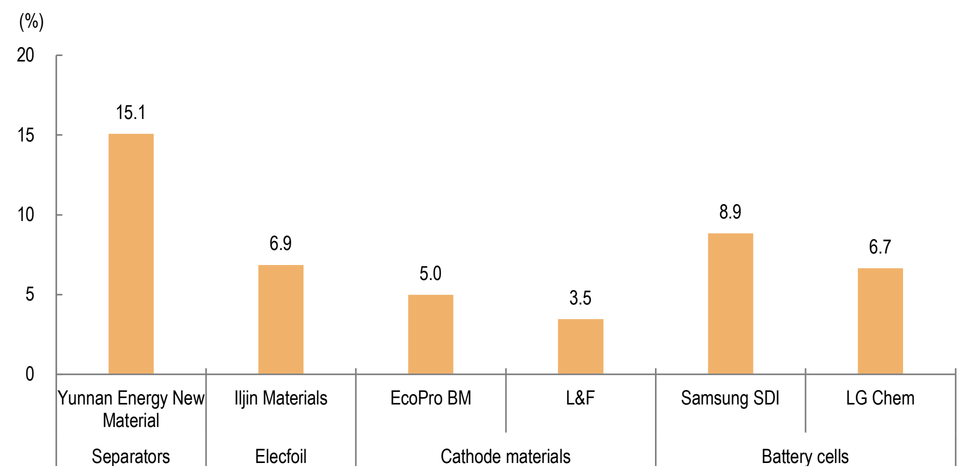

Source: WISEfn, Mirae Asset Daewoo Research

**Table 6. Capex/EBITDA ratio forecasts** (Wbn, %)

| | | EBITDA | | | | Capex | | | | Capex/EBITDA (%) | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 2018 | 2019 | 2020F | 2021F | 2018 | 2019 | 2020F | 2021F | 2018 | 2019 | 2020F | 2021F |
| Separators | Yunnan Energy New Material | 160 | 246 | 314 | 410 | 231 | 357 | 231 | 257 | 145 | 145 | 74 | 63 |
| Elecfoil | Iljin Materials | 77 | 90 | 109 | 157 | 119 | 132 | 139 | 156 | 154 | 147 | 128 | 99 |
| Cathode materials | EcoPro BM | 72 | 61 | 94 | 159 | 73 | 182 | 156 | 148 | 101 | 297 | 166 | 93 |
| | Easpring | 69 | 11 | 71 | 108 | 9 | 75 | 86 | 98 | 13 | 671 | 121 | 91 |
| | Shanshan | 178 | 150 | 202 | 267 | 298 | 323 | 308 | 297 | 168 | 215 | 153 | 111 |
| Electrolytes | Tinci Materials | 41 | 52 | 179 | 178 | 129 | 46 | 90 | 84 | 316 | 89 | 50 | 47 |
| Battery cells | Samsung SDI | 1,652 | 1,484 | 1,670 | 2,256 | 2,146 | 1,898 | 1,826 | 1,910 | 130 | 128 | 109 | 85 |
| | LG Chem | 3,515 | 2,581 | 4,328 | 5,479 | 4,219 | 6,238 | 5,383 | 4,568 | 120 | 242 | 124 | 83 |

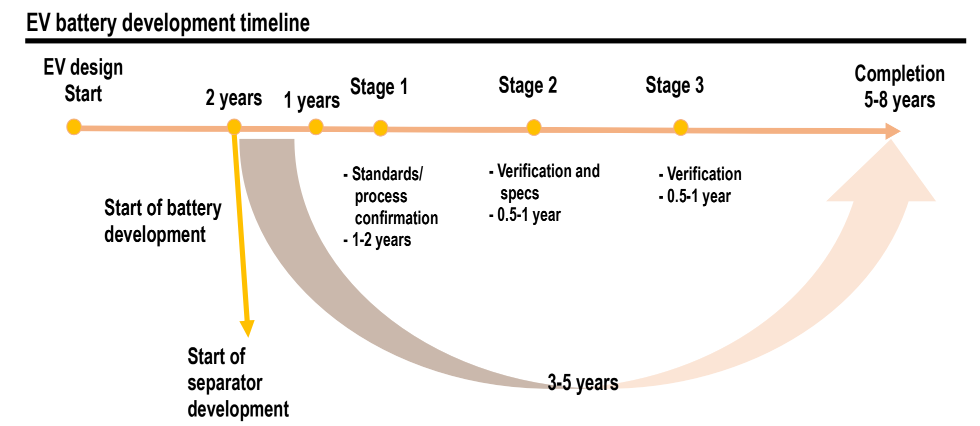
Source: WISEfn, Mirae Asset Daewoo Research

**Figure 34. Depreciation expenses as % of total expenses**




Source: Mirae Asset Daewoo Research

**Figure 35. Customer approval process for EV battery-use separators takes longer than that for IT-use separators**




Source: SNE Research, Mirae Asset Daewoo Research

## 3. Battery materials market outlook: Battery-use cathode materials

The technological landscape for battery-use cathode materials is changing. Contrary to initial expectations that NCM would become the norm, the cathode materials market is becoming diversified, with companies increasingly opting for NCA, NCMA, and LFP. Leading the change are the no. 2-4 (in terms of production capacity) EV battery cell makers.

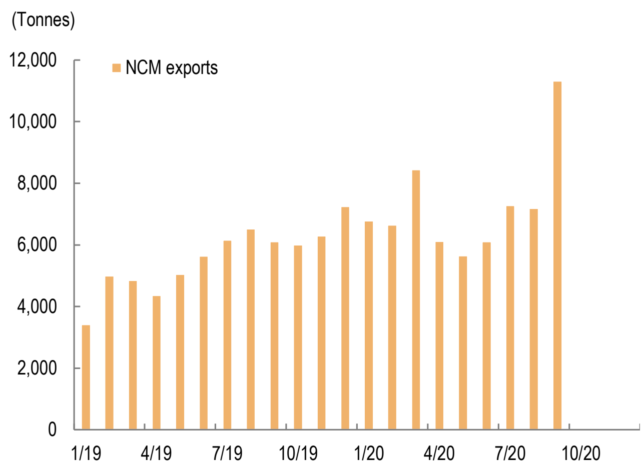
If NCM 811 were to become the standard, LG Chem—as the no. 1 player with the largest production capacity—would reap the biggest benefits over the medium and long term. Accordingly, we believe the company's rivals are seeking to differentiate their formulations to overcome their lack of economies of scale.

For instance, Samsung SDI established a joint venture with EcoPro BM and is set to apply NCA cathode materials to mid/large-sized prismatic batteries in 2021. SK Innovation also entered a medium/long-term contract with EcoPro BM to secure core-shell-gradient (CSG) cathode materials. And CATL recently signed a deal to supply Tesla with cobalt-free LFP batteries.

**Figure 36. Latecomers differentiating their formulations in effort to beat economies of scale**

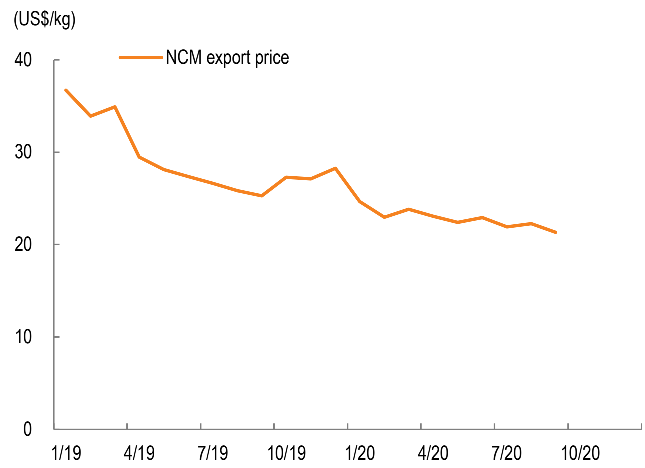

Source: Mirae Asset Daewoo Research

**Figure 37. NCM export volume trend**




Source: TRASS, Mirae Asset Daewoo Research

**Figure 38. NCM export price trend**



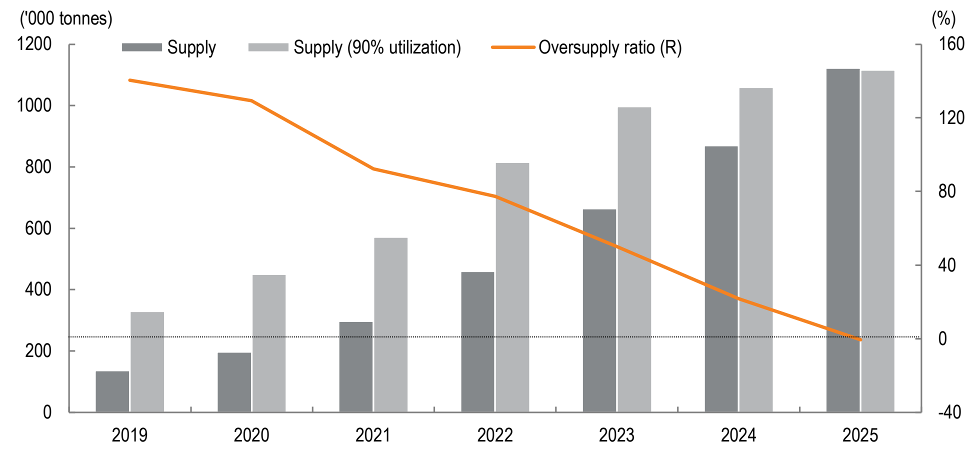

Source: TRASS, Mirae Asset Daewoo Research

### Oversupplied cathode materials market → Focus on differentiation through specialty products

Assuming an NCM market share of 75%, EV (BEV+PHEV) sales volume of 98.45mn units, and a capacity utilization rate of 90%, we estimate NCM demand at 886,000 tonnes and supply volume at 99.7mn tonnes in 2023. Given that global NCM suppliers have aggressively expanded production capacity over the past two to three years, we expect the NCM segment to be oversupplied through 2023.

Accordingly, we think companies that have secured medium/long-term supply contracts for specialty products have higher visibility on earnings growth. We recommend focusing on companies that are pursuing product differentiation through specialty products (NCA, CTP-based LFP, and NCMA) and securing stable demand through medium/long-term contracts or joint venture partnerships.

**Figure 39. EV-use NCM supply/demand analysis**




Source: Mirae Asset Daewoo Research

**Table 7. Cathode material supply/demand based on global EV sales volume**

| | 2019 | 2020F | 2021F | 2022F | 2023F | 2024F | 2025F |
|---|---|---|---|---|---|---|---|
| EV sales volume ('000 units) | 2,115 | 3,029 | 4,587 | 7,095 | 9,845 | 12,887 | 16,622 |
| EV battery shipment volume (MWh) | 88,830 | 130,243 | 229,327 | 425,688 | 639,900 | 837,683 | 1,163,573 |
| Demand for EV battery-use cathode materials (tonnes/'000 units) | 190,350 | 272,601 | 412,789 | 638,532 | 886,015 | 1,159,869 | 1,496,022 |
| Cathode material market breakdown (%) | | | | | | | |
| NCM | 72 | 72 | 72 | 72 | 75 | 75 | 75 |
| NCA | 17 | 17 | 18 | 19 | 19 | 19 | 19 |
| LFP | 6 | 6 | 6 | 6 | 6 | 6 | 6 |
| Other | 5 | 5 | 4 | 3 | 0 | 0 | 0 |
| Cathode material demand by type (tonnes) | | | | | | | |
| **NCM** | **137,052** | **196,273** | **297,208** | **459,743** | **664,511** | **869,902** | **1,122,017** |
| NCA | 32,360 | 46,342 | 74,302 | 121,321 | 168,343 | 220,375 | 284,244 |
| LFP | 11,421 | 16,356 | 24,767 | 38,312 | 53,161 | 69,592 | 89,761 |
| Other | 9,518 | 13,630 | 16,512 | 19,156 | 0 | 0 | 0 |
| **Global NCM production capacity** | **366,000** | **500,000** | **635,000** | **906,000** | **1,108,000** | **1,177,000** | **1,240,000** |
| NCM supply volume (95% utilization) | 329,400 | 450,000 | 571,500 | 815,400 | 997,200 | 1,059,300 | 1,116,000 |
| NCM excess supply (%) | 140 | 129 | 92 | 77 | 50 | 22 | -1 |

Source: Mirae Asset Daewoo Research

# VI. TIGER KRX Secondary Battery K-New Deal ETF

## Providing diversified exposure to the battery supply chain

Holdings of the TIGER KRX Secondary Battery K-New Deal ETF include: 1) three battery cell companies; 2) three battery-grade copper foil makers; 3) two cathode materials suppliers; and 4) two electrolyte producers.

The three battery manufacturing constituents of the ETF—LG Chem (051910 KS), Samsung SDI (006400 KS), and SK Innovation (096770 KS)—enjoy competitive advantages over foreign competitors in terms of production capacity, chemistry, and customer base. Moreover, they are better positioned to benefit from surging EV sales in Europe (triggered by increased government subsidies intended to stimulate demand amid the COVID-19 pandemic), given their high exposure to the region. We believe these three battery makers will see their earnings expand, backed by growing EV sales in Europe.

The battery-grade copper foil manufacturers held by the ETF are SKC (011790 KS), Iljin Materials (020150 KS), and Doosan Solus (336370 KS). The global market is dominated by a small number of top-tier firms, with high fixed costs raising high barriers to entry. Tesla's plan to produce batteries in-house is also good news for copper foil makers, as it points to the potential emergence of a major new customer. Looking ahead, supply will likely tighten going forward, which is why battery makers are entering into medium/long-term supply contracts and making equity investments in copper foil manufacturers.

The cathode materials suppliers are POSCO Chemical (003670 KS) and EcoPro BM (247540 KQ). As the NCM cathode market will likely remain oversupplied over the medium to long term, differentiation in chemistry/technology (customized for specific customers) is important. Notably, POSCO Chemical, a key supplier to LG Chem, is capable of manufacturing next-generation cathode materials (NCMA). Meanwhile, EcoPro BM should benefit from the medium/long-term growth of Samsung SDI, as it is the battery maker's primary supplier of NCA cathode materials. Going forward, Korean cathode materials players should build on their dominant positions in NCMA and NCA and take the lead in the development of next-generation cathode materials (monocrystalline, etc.).

Electrolyte producers Chunbo (278280 KQ) and Foosung (09337 KS) are also constituents of the ETF. As electrolytes are a commoditized product with a number of suppliers globally, securing captive customers and cost competitiveness is key. Looking ahead, we believe that Chunbo, a manufacturer of electrolyte additives such as $LiPO_2F_2$ (P) and LiFSI (F), will be able to maintain cost competitiveness on the back of its core technologies.

**Table 8. TIGER KRX Secondary Battery K-New Deal ETF constituents** (W)

| Ticker | Company | Country | Weight (%) | P/E (x) | | EV/EBITDA | | P/B (x) | | ROE (%) | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | 2020F | 2021F | 2020F | 2021F | 2020F | 2021F | 2020F | 2021F |
| 096770 KS | SK Innovation | Korea | 25.7 | - | 23.9 | -55.5 | 9.8 | 0.8 | 0.8 | -9.4 | 3.2 |
| 006400 KS | Samsung SDI | Korea | 25.6 | 54.2 | 27.2 | 19.0 | 13.8 | 2.2 | 2.1 | 4.2 | 7.8 |
| 051910 KS | LG Chem | Korea | 22.5 | 38.2 | 26.0 | 12.3 | 10.0 | 2.6 | 2.4 | 6.8 | 9.1 |
| 003670 KS | POSCO Chemical | Korea | 6.7 | 99.5 | 40.6 | 39.2 | 24.0 | 4.7 | 4.3 | 4.9 | 11.0 |
| 011790 KS | SKC | Korea | 6.0 | 19.6 | 19.8 | 12.9 | 10.1 | 1.5 | 1.4 | 8.5 | 7.3 |
| 247540 KQ | EcoPro BM | Korea | 4.5 | 62.2 | 36.6 | 32.9 | 20.0 | 6.5 | 5.6 | 11.7 | 17.9 |
| 020150 KS | Iljin Materials | Korea | 3.3 | 32.7 | 23.0 | 17.7 | 12.4 | 3.1 | 2.7 | 9.8 | 12.4 |
| 278280 KQ | Chunbo | Korea | 2.3 | 51.3 | 34.6 | 32.4 | 21.1 | 6.4 | 5.6 | 14.0 | 17.8 |
| 093370 KS | Foosung | Korea | 1.7 | 187.6 | 26.9 | 24.5 | 13.3 | 4.0 | 3.5 | 2.2 | 13.6 |
| 336370 KS | Doosan Solus | Korea | 1.6 | 27.4 | 19.2 | 12.4 | 10.2 | 6.8 | 5.2 | 22.3 | 27.1 |

Source: Bloomberg, Mirae Asset Daewoo Research

# VII. Risks

## Policy changes, delays to battery cost reductions, and growing competition

Risk factors include policy changes in major economies, delays to battery cost reductions, and potentially intensifying competition.

EVs are still more expensive to make than conventional vehicles, which is why policy supports (government subsidies, etc.) have a major impact on demand. In China, larger-than-expected subsidy cuts have led to oversupply across the supply chain amid plunging demand. In Europe, a sharp increase in subsidies has fueled EV demand.

Fortunately, the impact of subsidies on demand is decreasing as EV manufacturing costs have declined markedly. Moreover, the EV industry is anticipated to continue to grow even after subsidy cuts, given governments' commitment to nurturing the industry over the medium term.

Another factor that may negatively affect ETF performance is a potential delay to battery cost reductions. Mass-producing EV batteries using new technologies has always been a challenging task. Accordingly, further cost reductions may take longer than expected, despite the ongoing efforts by top-tier battery suppliers and Tesla. That said, given that battery prices have already fallen markedly, and factoring in fuel cost savings, an additional 20-30% fall in costs will likely be enough to make EVs truly competitive. Aside from battery cost reductions, achieving economies of scale in EV production should also help lower overall EV production costs.

The possibility of intensifying competition is a common risk for growth industries. However, we note that highly competitive companies tend to continue growth over the medium term even in the face of temporary oversupply. We believe that Korean battery manufacturers and materials suppliers will continue to remain dominant players, particularly given that the EV battery industry is characterized by high technological barriers to entry.

# Appendix 1

## Important disclosures and disclaimers

**Disclosures**
As of the publication date, Mirae Asset Daewoo Co., Ltd. and/or its affiliates do not have any special interest with the subject company and do not own 1% or more of the subject company's shares outstanding

**Analyst certification**
The research analysts who prepared this report (the "Analysts") are registered with the Korea Financial Investment Association and are subject to Korean securities regulations. They are neither registered as research analysts in any other jurisdiction nor subject to the laws or regulations thereof. Each Analyst responsible for the preparation of this report certifies that (i) all views expressed in this report accurately reflect the personal views of the Analyst about any and all of the issuers and securities named in this report and (ii) no part of the compensation of the Analyst was, is, or will be directly or indirectly related to the specific recommendations or views contained in this report. Mirae Asset Daewoo Co., Ltd. ("Mirae Asset Daewoo") policy prohibits its Analysts and members of their households from owning securities of any company in the Analyst's area of coverage, and the Analysts do not serve as an officer, director, or advisory board member of the subject companies. Except as otherwise specified herein, the Analysts have not received any compensation or any other benefits from the subject companies in the past 12 months and have not been promised the same in connection with this report. Like all employees of Mirae Asset Daewoo, the Analysts receive compensation that is determined by overall firm profitability, which includes revenues from, among other business units, the institutional equities, investment banking, proprietary trading, and private client divisions. At the time of publication of this report, the Analysts do not know or have reason to know of any actual, material conflict of interest of the Analyst or Mirae Asset Daewoo except as otherwise stated herein.

**Disclaimers**
This report was prepared by Mirae Asset Daewoo, a broker-dealer registered in the Republic of Korea and a member of the Korea Exchange. Information and opinions contained herein have been compiled in good faith and from sources believed to be reliable, but such information has not been independently verified and Mirae Asset Daewoo makes no guarantee, representation or warranty, express or implied, as to the fairness, accuracy, completeness, or correctness of the information and opinions contained herein or of any translation into English from the Korean language. In case of an English translation of a report prepared in the Korean language, the original Korean language report may have been made available to investors in advance of this report.
The intended recipients of this report are sophisticated institutional investors who have substantial knowledge of the local business environment, its common practices, laws, and accounting principles, and no person whose receipt or use of this report would violate any laws or regulations or subject Mirae Asset Daewoo or any of its affiliates to registration or licensing requirements in any jurisdiction shall receive or make any use hereof.
This report is for general information purposes only and is not and shall not be construed as an offer or a solicitation of an offer to effect transactions in any securities or other financial instruments. The report does not constitute investment advice to any person, and such person shall not be treated as a client of Mirae Asset Daewoo by virtue of receiving this report. This report does not take into account the particular investment objectives, financial situations, or needs of individual clients. The report is not to be relied upon in substitution for the exercise of independent judgment. Information and opinions contained herein are as of the date hereof and are subject to change without notice. The price and value of the investments referred to in this report and the income from them may depreciate or appreciate, and investors may incur losses on investments. Past performance is not a guide to future performance. Future returns are not guaranteed, and a loss of original capital may occur. Mirae Asset Daewoo, its affiliates, and their directors, officers, employees, and agents do not accept any liability for any loss arising out of the use hereof.
Mirae Asset Daewoo may have issued other reports that are inconsistent with, and reach different conclusions from, the opinions presented in this report. The reports may reflect different assumptions, views, and analytical methods of the analysts who prepared them. Mirae Asset Daewoo may make investment decisions that are inconsistent with the opinions and views expressed in this research report. Mirae Asset Daewoo, its affiliates, and their directors, officers, employees, and agents may have long or short positions in any of the subject securities at any time and may make a purchase or sale, or offer to make a purchase or sale, of any such securities or other financial instruments from time to time in the open market or otherwise, in each case either as principals or agents. Mirae Asset Daewoo and its affiliates may have had, or may be expecting to enter into, business relationships with the subject companies to provide investment banking, market-making, or other financial services as are permitted under applicable laws and regulations.
 For further information regarding company-specific information as it pertains to the representations and disclosures in this Appendix 1, please contact compliance@miraeasset.us.com or +1 (212) 407-1000.

**Distribution**
United Kingdom: This report is being distributed by Mirae Asset Securities (UK) Ltd. in the United Kingdom only to (i) investment professionals falling within Article 19(5) of the Financial Services and Markets Act 2000 (Financial Promotion) Order 2005 (the "Order"), and (ii) high net worth companies and other persons to whom it may lawfully be communicated, falling within Article 49(2)(A) to (E) of the Order (all such persons together being referred to as "Relevant Persons"). This report is directed only at Relevant Persons. Any person who is not a Relevant Person should not act or rely on this report or any of its contents.
United States: Mirae Asset Daewoo is not a registered broker-dealer in the United States and, therefore, is not subject to U.S. rules regarding the preparation of research reports and the independence of research analysts. This report is distributed in the U.S. by Mirae Asset Securities (USA) Inc., a member of FINRA/SIPC, to "major U.S. institutional investors" in reliance on the exemption from registration provided by Rule 15a-6(b)(4) under the U.S. Securities Exchange Act of 1934, as amended. All U.S. persons that receive this document by their acceptance hereof represent and warrant that they are a major U.S. institutional investor and have not received this report under any express or implied understanding that they will direct commission income to Mirae Asset Daewoo or its affiliates. Any U.S. recipient of this document wishing to effect a transaction in any securities discussed herein should contact and place orders with Mirae Asset Securities (USA) Inc. Mirae Asset Securities (USA) Inc. accepts responsibility for the contents of this report in the U.S., subject to the terms hereof, to the extent that it is delivered to a U.S. person other than a major U.S. institutional investor. Under no circumstances should any recipient of this research report effect any transaction to buy or sell securities or related financial instruments through Mirae Asset Daewoo. The securities described in this report may not have been registered under the U.S. Securities Act of 1933, as amended, and, in such case, may not be offered or sold in the U.S. or to U.S. persons absent registration or an applicable exemption from the registration requirements.
Hong Kong: This report is distributed in Hong Kong by Mirae Asset Securities (HK) Limited, which is regulated by the Hong Kong Securities and Futures Commission. The contents of this report have not been reviewed by any regulatory authority in Hong Kong. This report is for distribution only to professional investors within the meaning of Part I of Schedule 1 to the Securities and Futures Ordinance of Hong Kong (Cap. 571, Laws of Hong Kong) and any rules made thereunder and may not be redistributed in whole or in part in Hong Kong to any person.
All other jurisdictions: Customers in all other countries who wish to effect a transaction in any securities referenced in this report should contact Mirae Asset Daewoo or its affiliates only if distribution to or use by such customer of this report would not violate applicable laws and regulations and not subject Mirae Asset Daewoo and its affiliates to any registration or licensing requirement within such jurisdiction.

## Mirae Asset Daewoo International Network

**Mirae Asset Daewoo Co., Ltd. (Seoul)**
One-Asia Equity Sales Team
Mirae Asset Center 1 Building
26 Eulji-ro 5-gil, Jung-gu, Seoul 04539
Korea

Tel: 82-2-3774-2124

**Mirae Asset Securities (HK) Ltd.**
Units 8501, 8507-8508, 85/F
International Commerce Centre
1 Austin Road West
Kowloon
Hong Kong
Tel: 852-2845-6332

**Mirae Asset Securities (UK) Ltd.**
41st Floor, Tower 42
25 Old Broad Street,
London EC2N 1HQ
United Kingdom

Tel: 44-20-7982-8000

**Mirae Asset Securities (USA) Inc.**
810 Seventh Avenue, 37th Floor
New York, NY 10019
USA

Tel: 1-212-407-1000

**Mirae Asset Wealth Management (USA) Inc.**
555 S. Flower Street, Suite 4410,
Los Angeles, California 90071
USA

Tel: 1-213-262-3807

**Mirae Asset Wealth Management (Brazil) CCTVM**
Rua Funchal, 418, 18th Floor, E-Tower Building
Vila Olimpia
Sao Paulo - SP
04551-060
Brazil
Tel: 55-11-2789-2100

**PT. Mirae Asset Sekuritas Indonesia**
Equity Tower Building Lt. 50
Sudirman Central Business District
Jl. Jend. Sudirman, Kav. 52-53
Jakarta Selatan 12190
Indonesia
Tel: 62-21-515-3281

**Mirae Asset Securities (Singapore) Pte. Ltd.**
6 Battery Road, #11-01
Singapore 049909
Republic of Singapore

Tel: 65-6671-9845

**Mirae Asset Securities (Vietnam) LLC**
7F, Saigon Royal Building
91 Pasteur St.
District 1, Ben Nghe Ward, Ho Chi Minh City
Vietnam

Tel: 84-8-3911-0633 (ext.110)

**Mirae Asset Securities Mongolia UTsK LLC**
#406, Blue Sky Tower, Peace Avenue 17
1 Khoroo, Sukhbaatar District
Ulaanbaatar 14240
Mongolia

Tel: 976-7011-0806

**Mirae Asset Investment Advisory (Beijing) Co., Ltd**
2401B, 24th Floor, East Tower, Twin Towers
B12 Jianguomenwai Avenue, Chaoyang District
Beijing 100022
China

Tel: 86-10-6567-9699

**Beijing Representative Office**
2401A, 24th Floor, East Tower, Twin Towers
B12 Jianguomenwai Avenue, Chaoyang District
Beijing 100022
China

Tel: 86-10-6567-9699 (ext. 3300)

**Shanghai Representative Office**
38T31, 38F, Shanghai World Financial Center
100 Century Avenue, Pudong New Area
Shanghai 200120
China

Tel: 86-21-5013-6392

**Ho Chi Minh Representative Office**
7F, Saigon Royal Building
91 Pasteur St.
District 1, Ben Nghe Ward, Ho Chi Minh City
Vietnam

Tel: 84-8-3910-7715