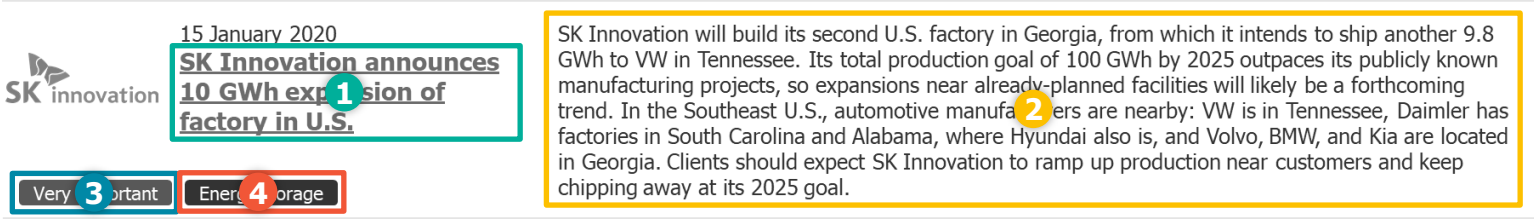
Singapore Battery Consortium

Q2 Newsletter

SINGAPORE BATTERY CONSORTIUM

Understanding curation of recent industry developments and technology news

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



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

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

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

RECENT INDUSTRY DEVELOPMENTS AND TECHNOLOGY NEWS

China extends NEV subsidies in response to the short-term impact of COVID-19 on NEV sales

3 April 2020

China extends NEV subsidies two years, but more policy changes likely to come

Very Important | Energy for mobility

China's plug-in vehicle policies have been among the most important in the world, helping to create the largest market for new energy vehicles. As the automotive industry begins to recover from the worst of the COVID-19 pandemic, China's extension of NEV subsidies is aimed at boosting sales to aid struggling automakers. However, at the same time, officials are discussing cutting other programs – such as the NEV sales mandate and emissions laws – in order to keep the market afloat. Clients should be aware the next year will likely feature ongoing major policy changes to support a struggling automotive sector but understand that 2020 will nonetheless see a drop in NEV sales.

8 April 2020

Corvus Energy expands production capabilities to Canada as part of $16 million investment

Average Importance | Energy storage

The investment in the Richmond BC facility includes expanded production of its 20 MWh to 50 MWh battery pack, Blue Whale. Corvus Energy expects to begin shipping its products from the Richmond plant in 2021. Canada's National Research Council contributed to the investment to drive R&D efforts. Corvus was recently selected by Westcon Power & Automation to supply 1,500 kWh battery packs for a new hybrid vessel. The Canadian facility signals the company's intention to target North American markets, but electrification efforts in marine vessels have historically been driven by policy centered in Europe.

13 April 2020

Northvolt delivers its largest order of battery systems to Epiroc

Low Importance | Energy storage

Following pilot tests of first-generation batteries from Northvolt, Swedish mining equipment company Epiroc will begin implementing Northvolt's second-generation batteries into more underground mining vehicles. By 2025, Epiroc plans to have a fully electric mining vehicle product line. As Northvolt ramps up production capacities for its large-format Li-ion batteries, its early focus on markets like underground mining and forklift vehicles will be a reliable source of early revenue and product testing. New Li-ion battery makers like Romeo Power similarly target industrial transportation. Clients should note that the exact order amount is still unknown; demand is high for Northvolt's battery, but the company may struggle to maintain output.

RECENT INDUSTRY DEVELOPMENTS AND TECHNOLOGY NEWS

Next-generation battery chemistries continue to gain traction with manufacturing plans

13 April 2020

Renault's revised China strategy drops combustion engines

Very Important | Energy for mobility

Renault's China strategy was shaped mostly by financial performance, as its joint venture with Dongfeng had reportedly lost more than $200 million in 2019 alone. That venture focused on combustion vehicles, and Renault's revised strategy in China saw it keep its electric vehicle joint venture with Jiangling Motors – likely influenced by the fact that more than half the world's battery electric vehicles (BEV) were sold in the country. Clients should recognize that other automakers with struggling joint ventures – such as Dongfeng Peugeot Citroën and Changan Ford, which both face overcapacity – could adopt a similar strategy focused on BEVs in part due to financial pressure.

23 April 2020

LBNL paper outlines benefits and challenges of co-locating renewables-plus-storage

Average Importance | Stationary storage

The paper looks at the 4.6 GW of hybrid (co-located renewables and energy storage) capacity in the U.S., which has 14.7 GW in the immediate development pipeline and 69 GW in select interconnection queues. Specifically, the authors highlight the pros of shared incentives, permitting, and interconnection weighed against the cons of reduced operational flexibility and suboptimal siting from mismatches between renewable resources and congested areas of the grid. Critically, there is no clear model for market participation and compensation outside PPAs. Utility-scale storage will continue to grow, but regulations for wholesale market participation must play catch-up.

28 April 2020

Brighsun prepares for production of Li-S battery technology with more than 1,700 cycles

Average Importance | Energy storage

Brighsun New Energy announced it has developed a Li-S battery expected to achieve over 1,000 Wh/kg to soon begin trial production. The battery has a lifetime of 1,700 cycles with 91% retention at a charge rate of 2C and can withstand rates of 5C with a battery life of 1,000 cycles at 74% retention. Brighsun claims it mitigates the low cycle life issues with Li-S batteries by eliminating polysulfide shuttling at the cathode and suppressing dendrite growth on the lithium metal anode. Its parent company, Brighsun EV Group, develops and sells e-buses and EVs in China and Australia. Clients should be skeptical of Brighsun's claims; as seen from Oxis Energy, it likely has separate technologies that optimize either life cycle or energy density.

RECENT INDUSTRY DEVELOPMENTS AND TECHNOLOGY NEWS

Decarbonization pressure and dropping prices have utilities planning large-scale solar-plus-storage projects

29 April 2020

Lincoln cancels Rivian-powered BEV, pushing back electrification program

Very Important | Energy for mobility

The company cited impacts from COVID-19 as the reason for delaying the project, although the announcement mostly speaks to Lincoln and Ford scaling back EV plans. If it were committed, using Rivian's existing platform to underpin the vehicle would be more cost-effective than designing or adapting a new one. Clients should note that other automakers in the U.S. are likely to take a similar approach, as there are no regulatory drivers to make less profitable EVs. In Europe, automakers face costly fines for missing the 95 g/CO2 targets, and in China, they face a penalty for not producing zero-emission vehicles – providing an incentive for automakers to focus on lower-emission vehicles.

7 May 2020

SK Innovation to being construction on second U.S. manufacturing facility in July

Average Importance | Energy storage

SK Innovation will invest $727 million in its second BEV battery plant in Georgia, with an annual capacity of 11.7 GWh. The first facility in Georgia with a planned capacity of 9.8 GWh is on track to open in 2022. The company will spend a total of $1.5 billion on manufacturing in the U.S. Earlier in the year, SK Innovation announced the possibility of building a second plant in Hungary to meet demand in Europe. BEV production is expected to take a hit following COVID-19 for an indeterminate period; furthermore, lax emissions policies in the U.S. and low oil prices will delay BEV adoption rates. Clients should expect a stall in BEV sales that could lead to battery production delays.

21 May 2020

El Paso Electric's grid-scale solar-plus-storage projects show continuing price reductions

Average Importance | Stationary storage

Facing a mandate of power sector decarbonization by 2045, El Paso Electric received approval for two projects due online in the summer of 2022. Notably, the 100 MW solar project has a power purchase agreement (PPA) of $14.99/MWh, one of the lowest prices so far in the U.S. A second project will add 100 MW/50 MWh solar-plus-storage with a price of $20.99/MWh. These projects will help offset 91 MW of capacity from two units at the Rio Grande natural gas steam turbine plant set for retirement in 2022. With the price of solar in the U.S. continuing to fall, clients should start planning for how low energy prices can speed up decarbonization opportunities in industrial sectors.

RECENT INDUSTRY DEVELOPMENTS AND TECHNOLOGY NEWS

Battery swapping gaining traction with NEV owners in China as industry continues to address long charging times

2 June 2020

NIO announces battery swapping milestone of 500,000 swaps in two years

Average Importance | Energy for mobility

As battery swapping continues to see increasing interest in China, Nio's announcement is a surprising one just two years after its first battery swapping station opened – suggesting that over that time period, it averaged nearly 700 swaps per day. This announcement comes just days after the company announced it had completed its 131st swapping station. Lux continues to view consumer-focused battery swapping as a poor strategy compared to focusing on fleets like taxis, which will have a larger need for quickly adding range and more stable demand. However, clients should view the announcement favorably, as it indicates that Nio's swapping service is popular with consumers.

9 June 2020

AEMO approves Fluence's 500 MW transmission line deferment plan

Average Importance | Stationary storage

The Australian Energy Market Operator (AEMO) approved Fluence Energy's plan to use energy storage to increase the transmission capacity of existing lines between Victoria and New South Wales. Fluence's plan calls for two 250 MW/125 MWh energy storage assets sited at each end of a 500 kV transmission line to reduce capital spend and speed up commissioning relative to upgrading transmission. While AC and DC transmission are the lowest-cost options for moving energy, they are still expensive. Clients should evaluate how energy storage can reduce transmission and interconnection costs, especially as those costs begin to dominate new renewable energy projects.

9 June 2020

Hawaiian Electric procures 2.9 GWh of energy storage in latest round

Average Importance | Stationary storage

Building off of its massive 2018 energy storage procurement round, Hawaiian Electric (HECO) announced that it would deploy another 2.9 GWh on Oahu, Maui, and Hawaii islands. The largest of the 16 projects announced is a 185 MW/565 MWh stand-alone energy storage asset installed by Energy Storage Resources, a San Francisco-based developer. HECO said the latest round of energy storage procurement is meant to support its ambitions of 100% renewable electricity by 2045. Clients should expect the larger energy storage projects of HECO's latest round to be even less expensive than its 2018 installations – a clear sign of the financial strength of solar-plus-storage.

RECENT INDUSTRY DEVELOPMENTS AND TECHNOLOGY NEWS

Application stacking enabling grid-scale storage projects to supplement traditional power infrastructure build outs

9 June 2020

Schmidt Group and Nusaned Investment for JV to manufacture flow batteries in Saudi Arabia

Average Importance | Energy storage

German technology firm Schmidt and Saudi investment arm Nusaned have formed a joint venture to build a vanadium flow battery manufacturing facility in Saudi Arabia with an announced capacity of 3 GWh per year. Schmidt indicated that one possible destination for its Saudi-produced flow batteries is a new purpose-built city and living laboratory, Neom. While Lux had previously identified the suitability of flow batteries over Li-ion batteries in hot environments, clients should still take the announcement with a grain of salt; initial production will be far less than 3 GWh, as Saudi Arabia has yet to deploy significant solar energy to merit widespread buildout of energy storage.

9 June 2020

Great River Energy procures 1 MW/15 MWh long-duration energy storage device from Form Energy

Average Importance | Stationary storage

This represents Form Energy's first commercial application of long-duration energy storage technology, though it's unclear whether the device Great River Energy will install is the aqueous polysulfide-air flow battery system described in 2017. More likely, given the energy storage, this is Form Energy's other technology, an iron-air battery with a replaceable metal electrode. Clients should view this development as an early pilot in long-duration energy storage with a motivated customer and continue to research other technology options to enable similar capabilities.

9 June 2020

Southern California Edison to procure 770 MW of energy storage to replace natural gas peaking plants

Very Important | Stationary storage

California utility Southern California Edison (SCE) announced it would procure 770 MW of Li-ion battery energy storage to be brought online by August 2021. The seven new projects would replace aging natural gas power plants that are being decommissioned due to California's 100% renewable electricity mandate and its tightening water and air quality regulations. Energy storage assets would be co-located with existing natural gas or solar facilities. NextEra Renewable Resources was the leading developer, winning 460 MW of projects. With at least 9,000 MW of energy storage needed to support California's 100% renewable electricity goals, clients should expect many more large energy storage procurements in the near future.

RECENT INDUSTRY DEVELOPMENTS AND TECHNOLOGY NEWS

Decarbonization of electricity is feasible, but remains a major government-level infrastructure initiative

12 June 2020

Lilum plans to continue flight testing after COVID-19 restrictions lift

Average Importance | Energy for mobility

While most aviation companies have slowed activity, Lilium continues work on its first aircraft, slated for commercial flight in 2025. The flight tests are expected to show faster flight speeds and a full transition to air flight. The company recently closed a $240 million funding round and received an additional $35 million investment from Baillie Gifford, a prominent investor in Tesla. Lilium has now raised $375 million to date. The investments will allow the company to continue with business as usual when it can begin testing once again. Clients should recognize that the extra capital comes at an opportune time; further eVTOL investments will likely not be as generous in the coming year.

16 June 2020

B2U Storage Solutions installs largest second-life battery storage project in U.S.

Average Importance | Stationary storage

Solar Electric Solutions, and its affiliate second-life battery company B2U have completed installation of a 1.2 MWh pilot stationary energy storage system using 200 Nissan Leaf batteries. Final target capacity is 17 MWh and will use 2,000 batteries. The battery system is paired with a 8.5 MW solar facility and will provide firm capacity, arbitrage, and ancillary services to Southern California Edison. This is both companies' first second-life battery project. With its low-value LMO cathodes not meriting recycling and large sales volumes, Nissan Leaf batteries are a common second-life battery. Clients should expect second life to play a niche role, especially as more recycling options become available.

16 June 2020

UC Berkeley reports renewables-plus-storage can help U.S. grid reach 90% carbon-free by 2035

Very Important | Stationary storage

A study from the Goldman School of Public Policy at the University of California, Berkeley, found that 90% of the U.S.'s electricity demand in 2035 can be met cost-effectively by scaling wind, solar, and Li-ion battery storage deployments. The study concludes that $1.7 trillion invested into 1,100 GW of new wind and solar, 150 GW of four-hour storage, and modest increases to transmission capacity would result in a 10% reduction in wholesale electricity prices by 2035, compared to a 20% reduction under business as usual. Clients should see this as another data point that decarbonizing the electricity supply is straightforward in the U.S., but decarbonization of other sectors of the economy or in other countries will be much more challenging.

RECENT INDUSTRY DEVELOPMENTS AND TECHNOLOGY NEWS

Large, strategic rounds will continue despite an overall decline in VC investment in 2020

18 June 2020

[Australia proposes new battery performance standard for residential storage installations]

Average Importance | Stationary storage

The Australian Battery Performance Standard (ABPS) project was started in June 2018, with funding from the Australian Renewable Energy Agency (ARENA) and the Victorian government. If Standards Australia approves the new standard, manufacturers and system integrators will have to disclose performance metrics using specific testing protocols and reporting methods designed to inform consumers and enable them to compare expected behavior of systems under the same circumstances. ARENA expects this effort to increase consumer adoption of storage systems; while it is a step in the right direction, it won't significantly contribute to more installations.

18 June 2020

[Tesla receives electricity generation license in the United Kingdom]

Average Importance | Energy business models

The Office of Gas and Electricity Markets (Ofgem) in the U.K. granted an electricity generation license to Tesla Motors, taking a step closer toward becoming an energy services company in the country. While Tesla doesn't own or operate traditional generation capacity, it offers stationary storage systems for utility-scale and behind-the-meter applications as well as software that can manage and optimize these assets by means of application stacking. Tesla is likely positioning itself to play a role as a virtual power plant (VPP) aggregator in the U.K., a country ripe to take full advantage of VPPs; although Tesla is not alone, it is joining the vast number of players in the country.

19 June 2020

[Volkswagen invests an additional $200 million into QuantumScape]

Average Importance | Energy for mobility

Following its $100 million investment into QuantumScape in 2018, Volkswagen has reinforced its commitment to commercializing a solid-state battery. The new funding will go into further development and support for a pilot production line. Solid-state batteries can offer higher energy densities and improved safety compared to Li-ion batteries with a liquid electrolyte, but they suffer from poor manufacturability, room temperature conductivity, and cycle life. QuantumScape has previously quoted battery performance goals of 400 Wh/kg to 600 Wh/kg with extended cycle life. While Volkswagen has doubled down on its initial investment, it still faces a long and expensive road to commercialization, which we believe won't occur for another 10 years.

RECYCLING & SECOND-LIFE

Recycle or Reuse: The Billion-Dollar Battery Question

End-of-life management of Li-ion batteries is a complex undertaking. With Li-ion battery deployment expected to reach 2,760 GWh in deployments by 2035, major stakeholders are looking to near-term solutions to responsibly and profitably manage end-of-life Li-ion batteries. The two sustainable practices are recycling and second-life use. Partially due to lack of existing Li-ion battery recycling infrastructure, many have defaulted to second-life applications, reusing vehicle packs in stationary storage applications like frequency regulation for the grid or residential solar-plus-storage systems.

LUX TAKE

Currently battery recycling or reuse is more of an obligation than a value-add business opportunity, however after being used in its primary application, many cells still have usable life in them. While both reuse and recycling are mostly underdeveloped and lack scale, the economics of the two are beginning to reveal itself and present their own unique advantages and disadvantages.

Source: BMW

GLOBAL ENERGY STORAGE MARKET

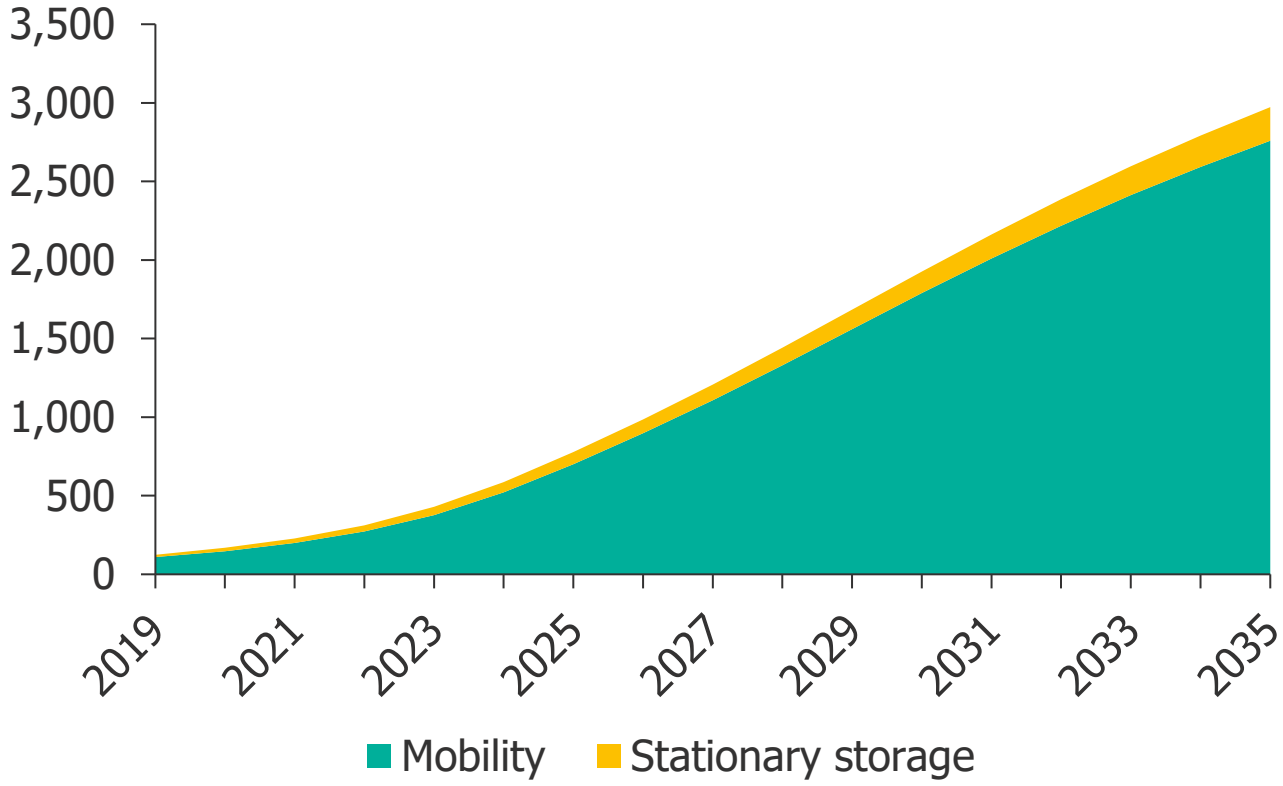
Battery recycling and reuse will become a critical part of the Li-ion value chain as electric vehicles sales increase

Mobility remains the long-term driver of energy storage demand, with a 2035 total market share of 91% by demand at 2,760 GWh. It will also witness the highest compound annual growth rate through 2035 at 22.3%. With the first-generation of electric vehicles set to come offline in coming years, battery makers, automakers, and customers must solve a crucial question of what to do with used batteries.

However, reusing Li-ion cells is not as straightforward as plugging them into new applications. Remaining capacity and performance depend on climate conditions, driving habits, and charging habits. Furthermore, there is a high amount of variance in form factor and chemistry, making grouping old cells together for large projects complicated. The industry is now focused on the potential of recycling and second-life batteries.

Global Energy Storage Market

Energy storage demand (GWh)



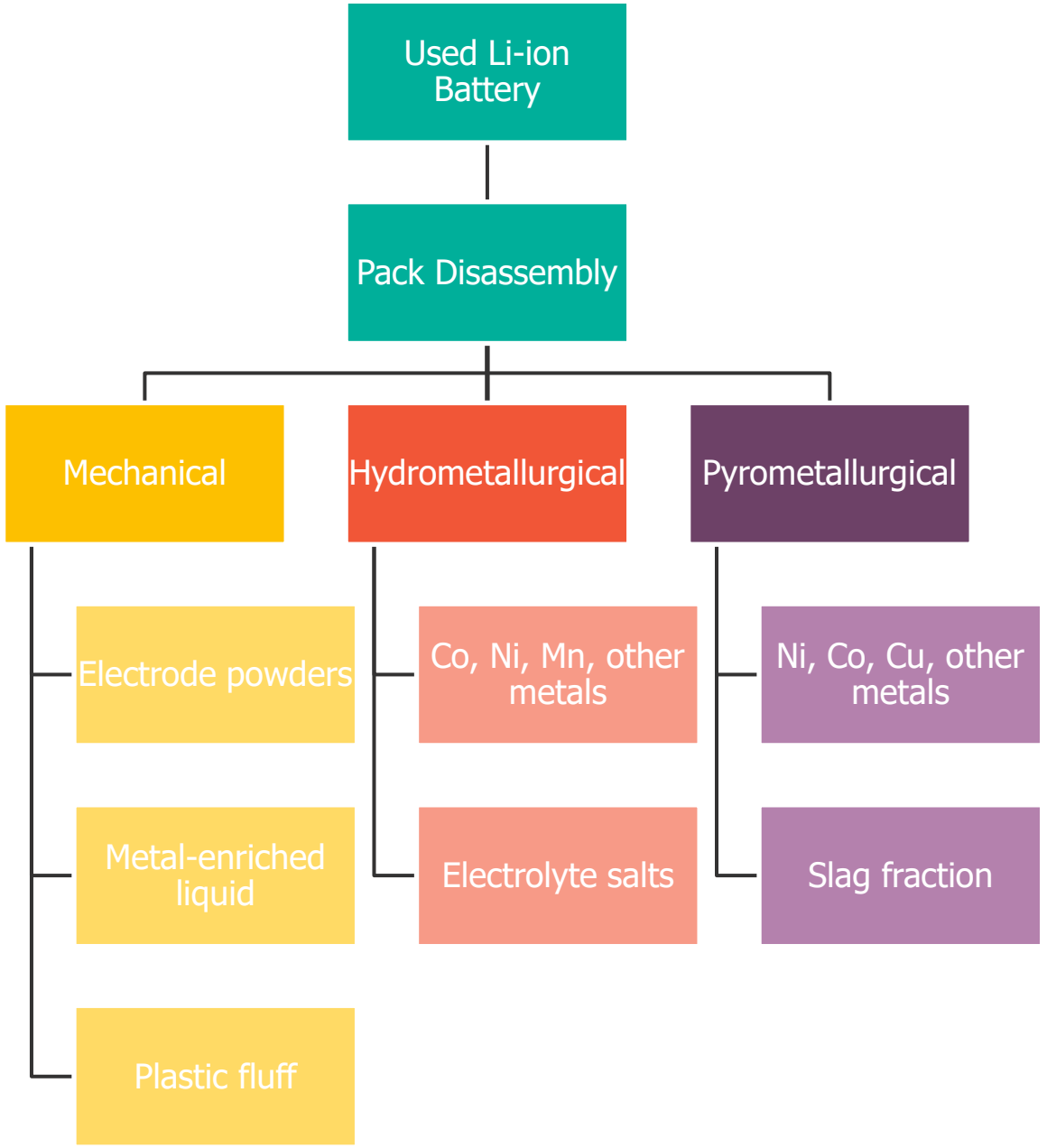
RECYCLING

Li-ion recycling technologies

The value chain of Li-ion battery recycling is intricate due to the different recycling processes available and the different recycling feedstock and end products each process synthesizes. A number of recycling processes exist to recycling used Li-ion batteries, including mechanical, hydrometallurgical, and pyrometallurgical.

The most mature recycling process is pyrometallurgical, which uses high temperatures to smelt the metal components in the Li-ion battery. Hydrometallurgical recycling aims to recover more of the battery by separating metallic and non-metallic components by selectively leaching and precipitating the metal components as metal salts. Mechanical recycling directly recovers the anode and cathode powders and subjects them to a rejuvenation process to be used again in cells.

If the aim is to make recycling a value-add process, the choice of process will depend entirely on the stakeholder and where they sit in the Li-ion battery value chain.



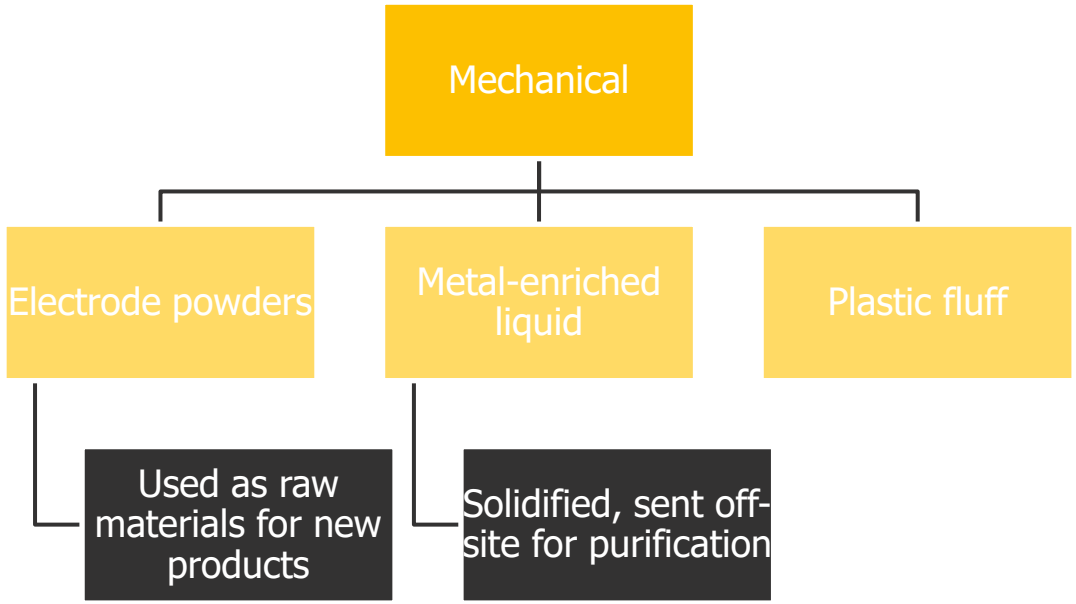
RECYCLING

Mechanical processing can recover valuable cathode materials directly, without separating metals

Mechanical processing involves physically crushing or milling the batteries into fine powder, then mechanically separating those products. Powders can be separated using sieves, manipulating magnetic and electrical properties or a combination of both.

This process can recover materials in their native form – that is, it can directly recover the electrode materials, a potential product value of $\$124/kg_{Co\ eq}$, more valuable than raw metals.

In order to successfully recycling mechanically, the process must sort by battery chemistry to keep the electrode chemistries uniform. Each different battery chemistry would require its own processing line, and is further complicated by electric vehicles that use a combination of chemistries, making it difficult to keep up with changing chemistries.



Summary Information	
Maturity	Less mature
Key players	Retriev Technologies, Onto Technologies
Sorting	Required

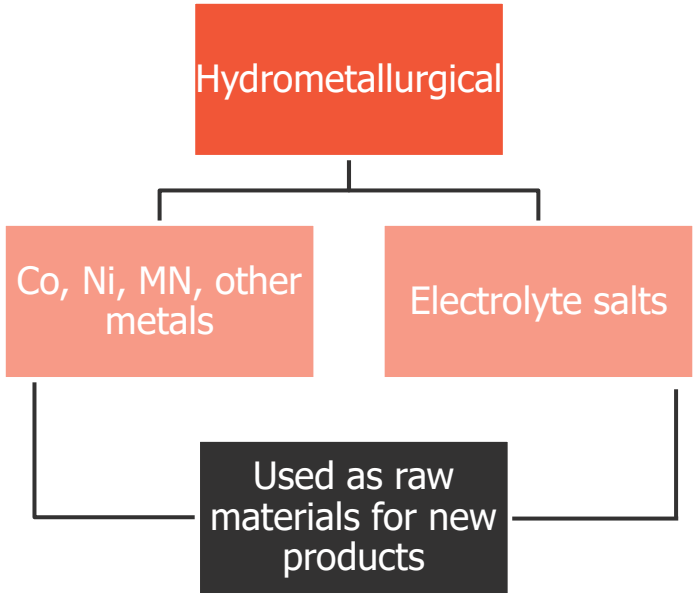
RECYCLING

Hydrometallurgical processing uses acids to dissolve the battery materials at low temperatures

This low-temperature process uses acids to dissolve battery materials into different constituents, ultimately recovering metals and salts, including lithium in the form of LiOH or Li_2Co_3. This process uses chemical leaching to remove these materials, followed by purification of those products, but in creating new end products the ultimate value of the materials created is potentially $\$55/kg_{Co\ eq}$.

Sorting is desirable, but not required – leaching time, acid concentration, and additives all affect recovered materials and can be optimized for specific chemistries.

Developers are also considering this process as an alternative to pyrometallurgical processing of lead-acid batteries, as it is a potentially lower-cost method due to the lack of environmental compliance requirements.



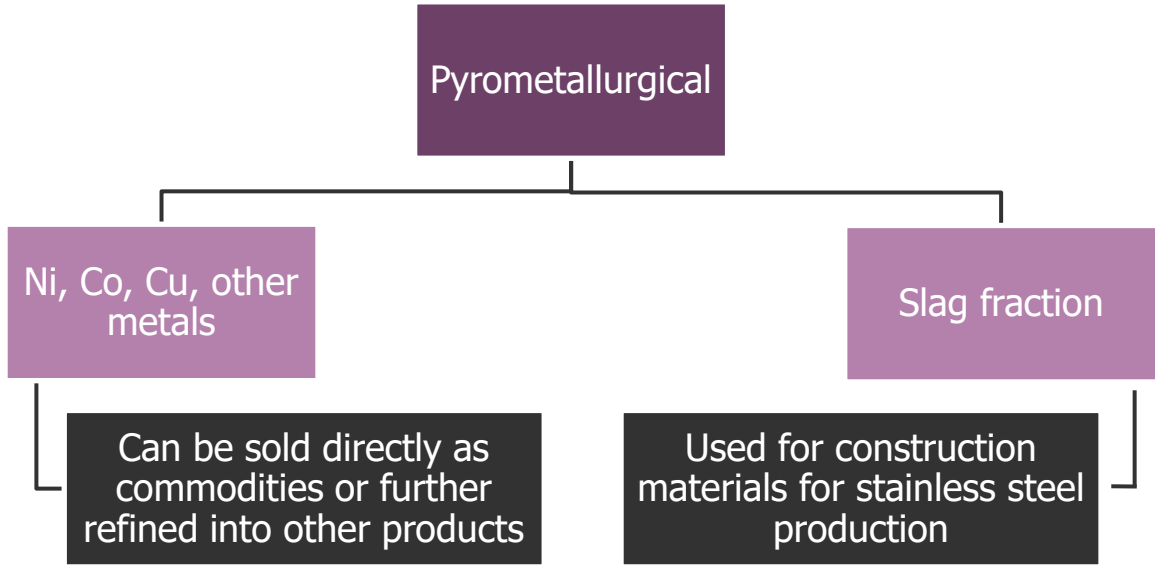
Summary Information	
Maturity	Less mature
Key players	Aqua Metals
Sorting	Not required, but preferred

RECYCLING

Pyrometallurgical processing is the most mature, recovering key metallic elements

Pyrometallurgical processing, or smelting, uses temperatures as high as 1,500 °C to recover metals in their elemental form. Umicore, a major chemicals company that also produces cathode materials, operates one of the largest pyrometallurgical processing plants in the world for Li-ion and NiMH batteries. By reducing the battery to its elemental form, it also results in the lowest valued product at approximately $\$32/kg_{Co\ eq}$.

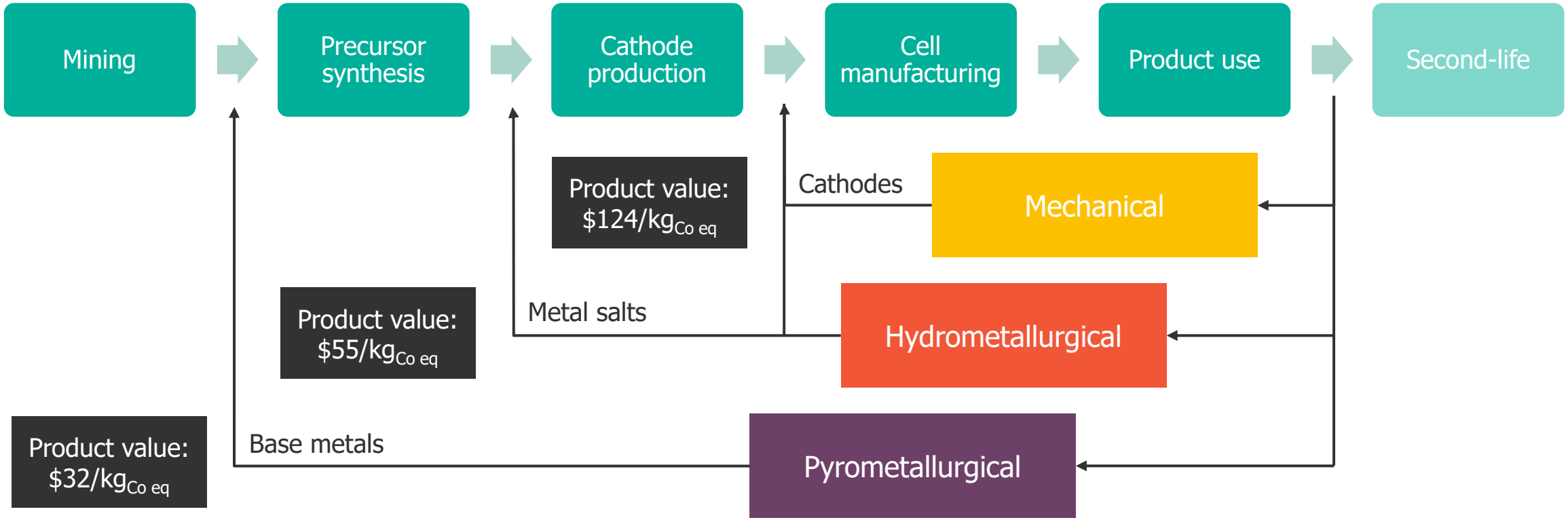
Lead-acid batteries commonly use this recycling process, where most costs come from environmental compliance and energy consumption. Li-ion and NiMH processing also requires full decomposition of volatile organic compounds, and capture of all fluorine products due to environmental concerns.



Summary Information	
Maturity	Most mature
Key players	Umicore
Sorting	Not required

RECYCLING

The cathode is the key material when making recycling a value-add process



SECOND-LIFE

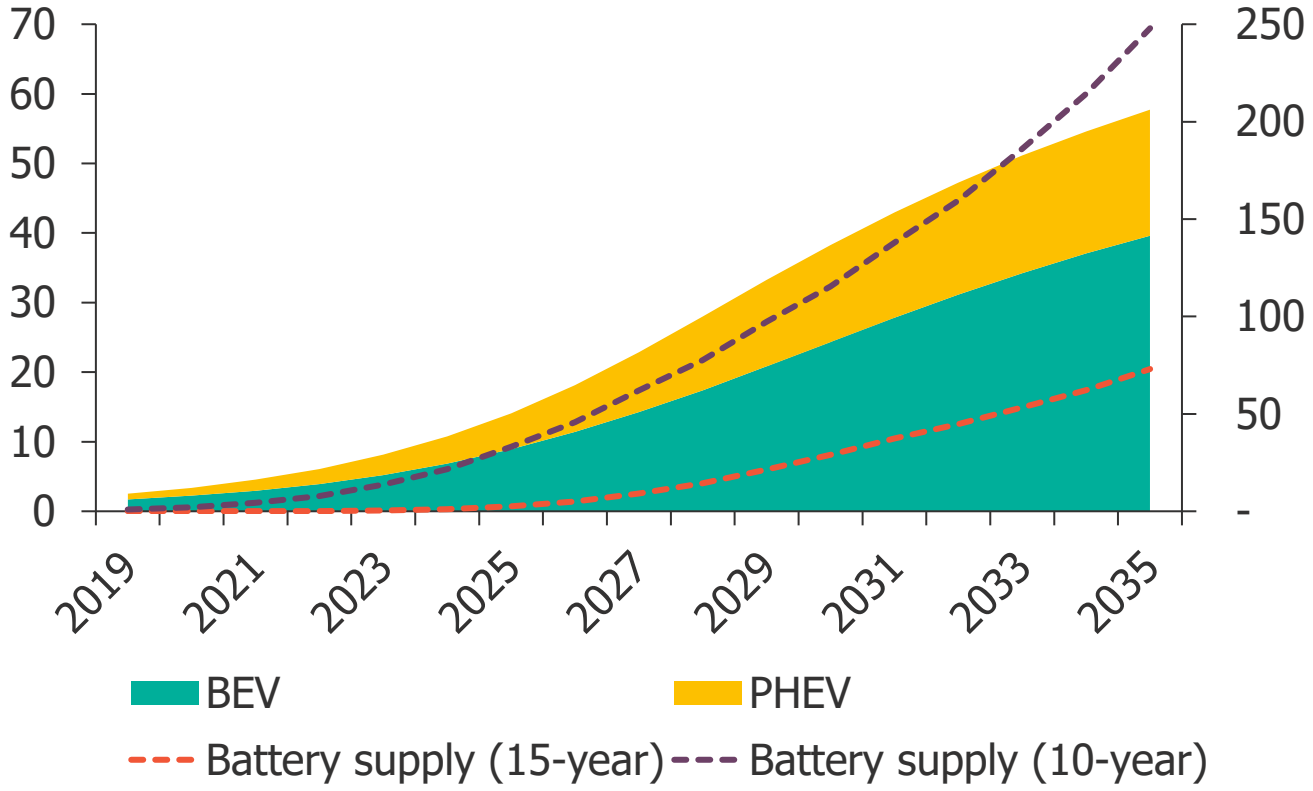
When assuming a conventional 15-year service life for EVs, second-life battery supply will reach 73 GWh in 2035

The electrification of mobility presents the largest source of second-life batteries. Within this segment, light-duty plug-in hybrid electric vehicles (PHEV) and battery electric vehicles (BEV) are the larges source of demand. The tipping point for plug-in vehicles is expected to occur between 2035 and 2040, where nearly 58 million new vehicles will be sold. But leading up to that point, several PHEV and BEV will be coming offline.

When assuming a 15-year service life, second-life battery supply will reach 73 GWh by 2035. However, when assuming a 10-year service life, second-life battery supply more than triples to 248 GWh of supply. With such a significant amount of batteries, it remains key to identifying the best second-life use cases and opportunities.

Global Second-Life Battery Supply

Plug-in sales (million); second-life supply (GWh)



SECOND-LIFE

Residential systems used to increase solar self-consumption are more profitable than new cells

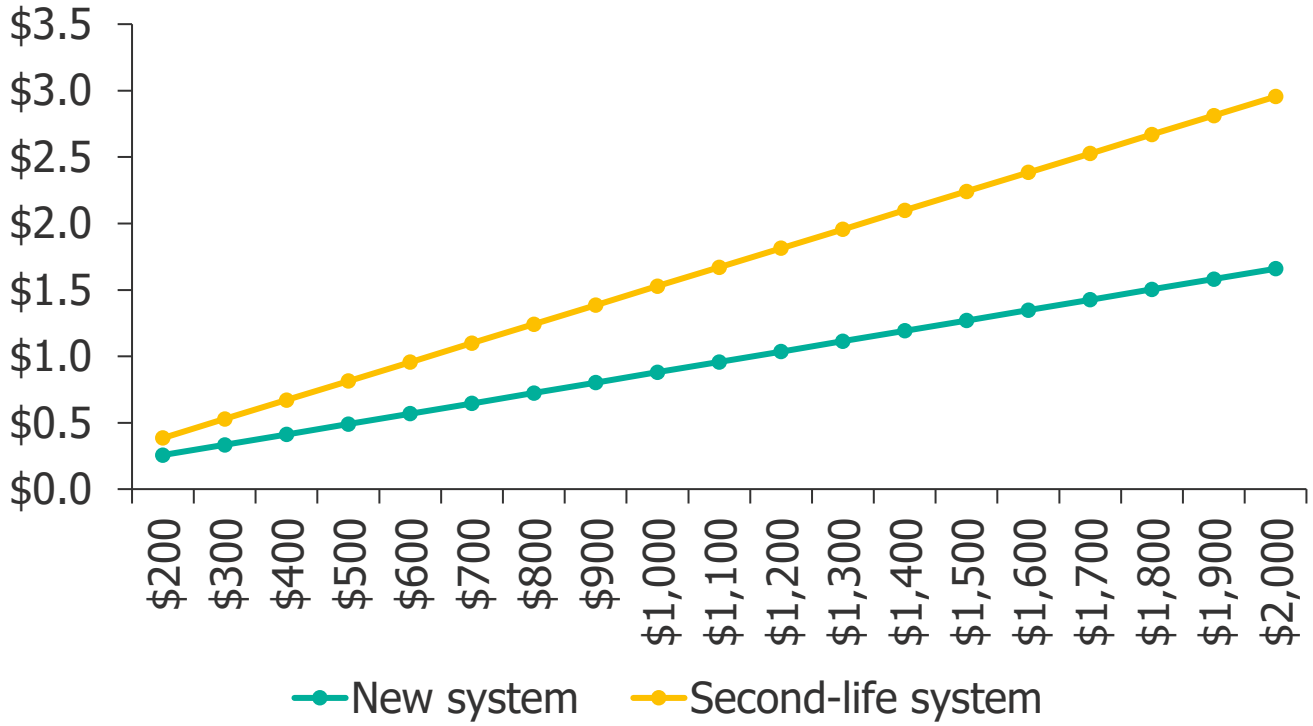
New residential systems require a peak electricity retail price of $0.77/kWh to be profitable, while second-life systems are not profitable with electricity prices below $1.04/kWh. However, each of these values are unrealistically high for peak retail rates, and neither case makes economic sense. The peak electricity retail price will also largely depend on region.

While the total system cost of a second-life is lower than a new cell system, the lower efficiency and cycle life of the battery offset the benefits, and even in 2025 a system with new cells will be more economical.

Assumptions	New System	Second-Life
System size	7 kWh	11.2 kWh
Service life	4745 cycles	3650 cycles

Second-life Residential Systems

Peak electricity price ($/kWh); system costs ($/kWh)



Note: $/kWh for second-life systems are normalized to account for usable capacity, allowing for more direct comparison to new systems

SECOND-LIFE

Second-life batteries are competitive in demand response applications due to infrequent cycling

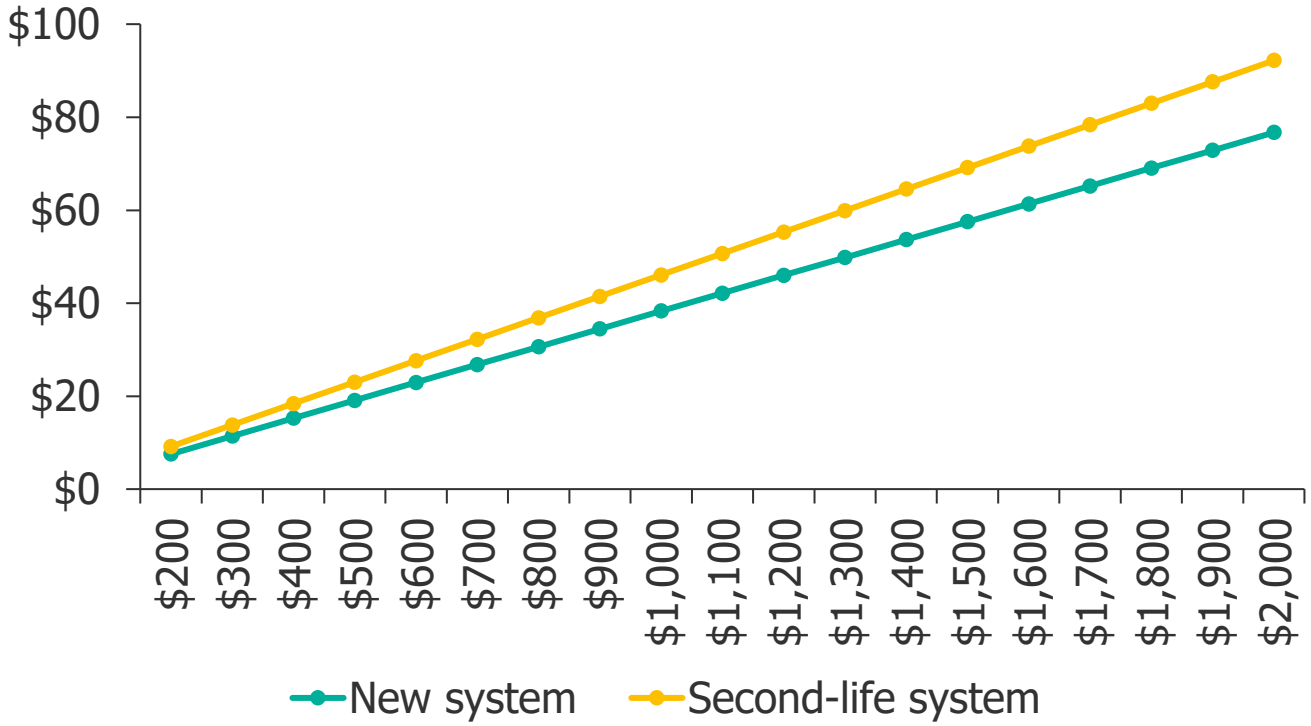
Due to infrequent cycling, lower system costs in second-life battery systems make up for shorter cycle life and poorer system efficiency. Demand response payments, which are paid in available capacity for a duration of time, are typically less than $10/kW-month.

Demand response applications are very site specific, dependent on duration, load profile, and cycles per year. More frequent cycling applications may better utilize new cells in this case.

Assumptions	New System	Second-Life
System size	8.125 MWh	13 MWh
Service life	13 years	10 years
Cycles per year	20	20

Second-life Demand Response

Demand response capacity payment ($/kW-month); system costs ($/kWh)



Note: $/kWh for second-life systems are normalized to account for usable capacity, allowing for more direct comparison to new systems

SECOND-LIFE

New cells should be used for demand charge reduction in commercial and industrial applications

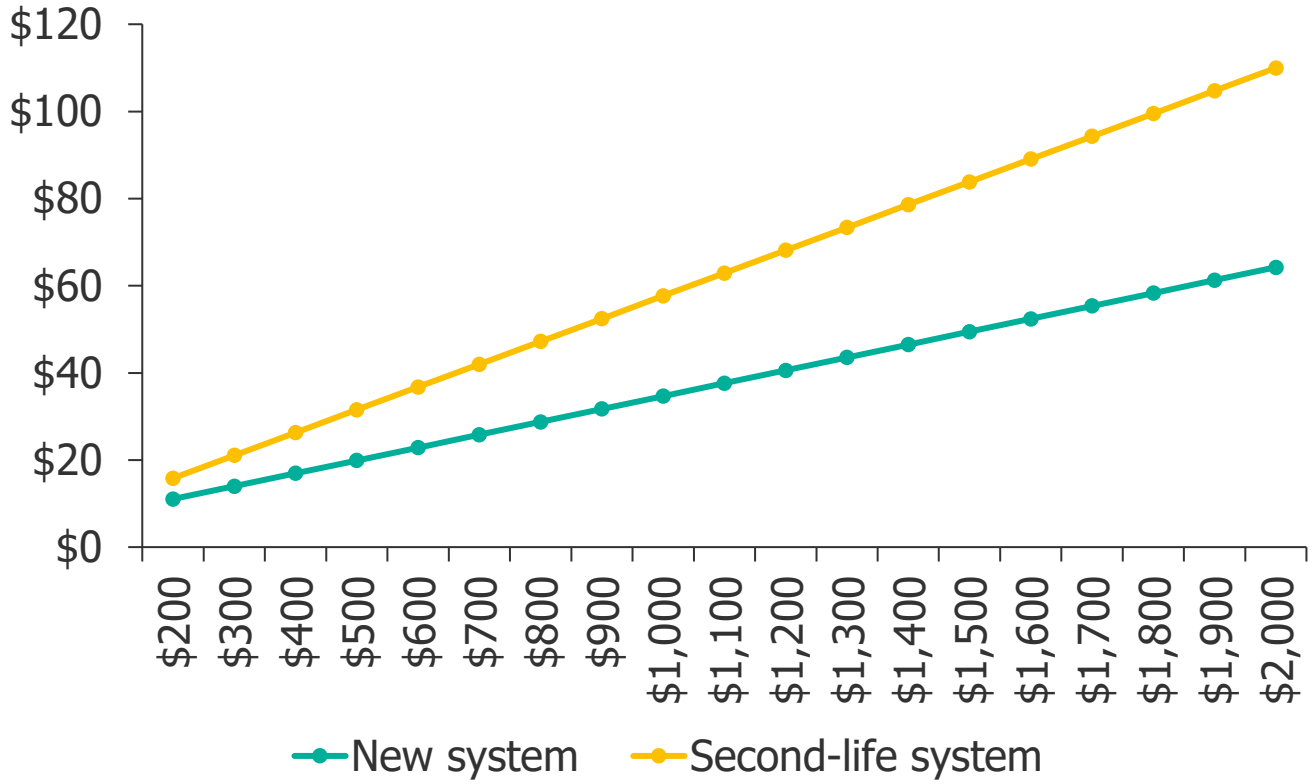
As is the case with residential systems, required daily cycling leads to limited economic payback in second-life battery systems. This is primarily due to the poor system efficiency and limited service life that is assumed of second-use batteries.

Based on the analysis, second-life battery systems are generally a decade behind to new cell systems in terms of potential demand charge reduction pricing to reach profitability. This highlights how poor second-life systems perform in this specific application. Demand charges on a customers electricity bill are also very dependent upon load profiles of the facility in question.

Assumptions	New System	Second-Life
System size	75 kWh	120 kWh
Service life	4745 cycles	3650 cycles
Demand reduced	40 kW	40 kW

Second-life Demand Charge Reduction

Demand charge ($/kW); system costs ($/kWh)



Note: $/kWh for second-life systems are normalized to account for usable capacity, allowing for more direct comparison to new systems

SECOND-LIFE

Peaker plant replacement and energy arbitrage fall short of profitability for both systems

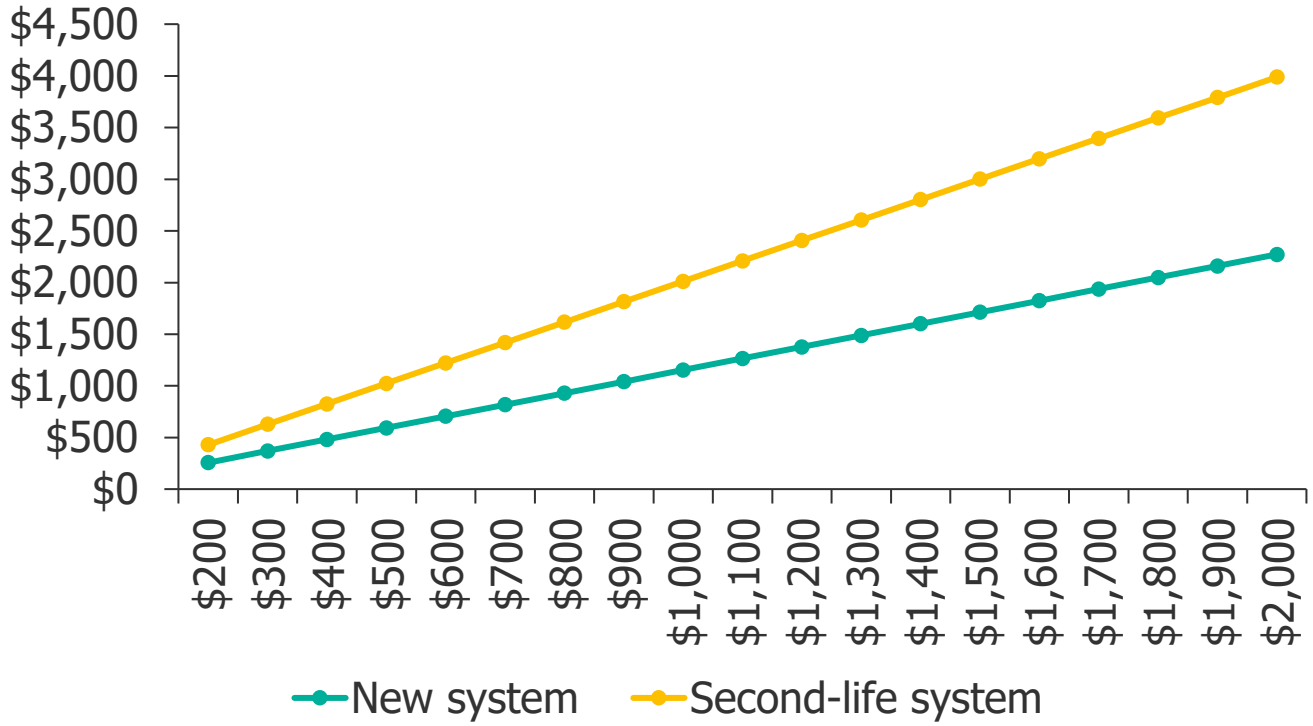
Reaching a 15% internal rate of return requires selling electricity back to the grid at $1,340/MWh in second-life battery systems and nearly $1,000/MWh in new systems – both of which are well above typical wholesale electricity prices of $100/MWh. Peaker plants, due to a relatively low utilization rate and predictable demand, are well suited for application stacking to bring down costs.

Peaker plants face a higher profitability threshold than many other applications, in part due to a low utilization rate, where neither new or second-life battery systems can reach profitability alone.

Assumptions	New System	Second-Life
System size	200 MWh	320 MWh
Operational	22 years	17 years
Charging price	$30/MWh	$30/MWh

Second-life Demand Charge Reduction

Price sold back to the grid ($/MWh); system costs ($/kWh)



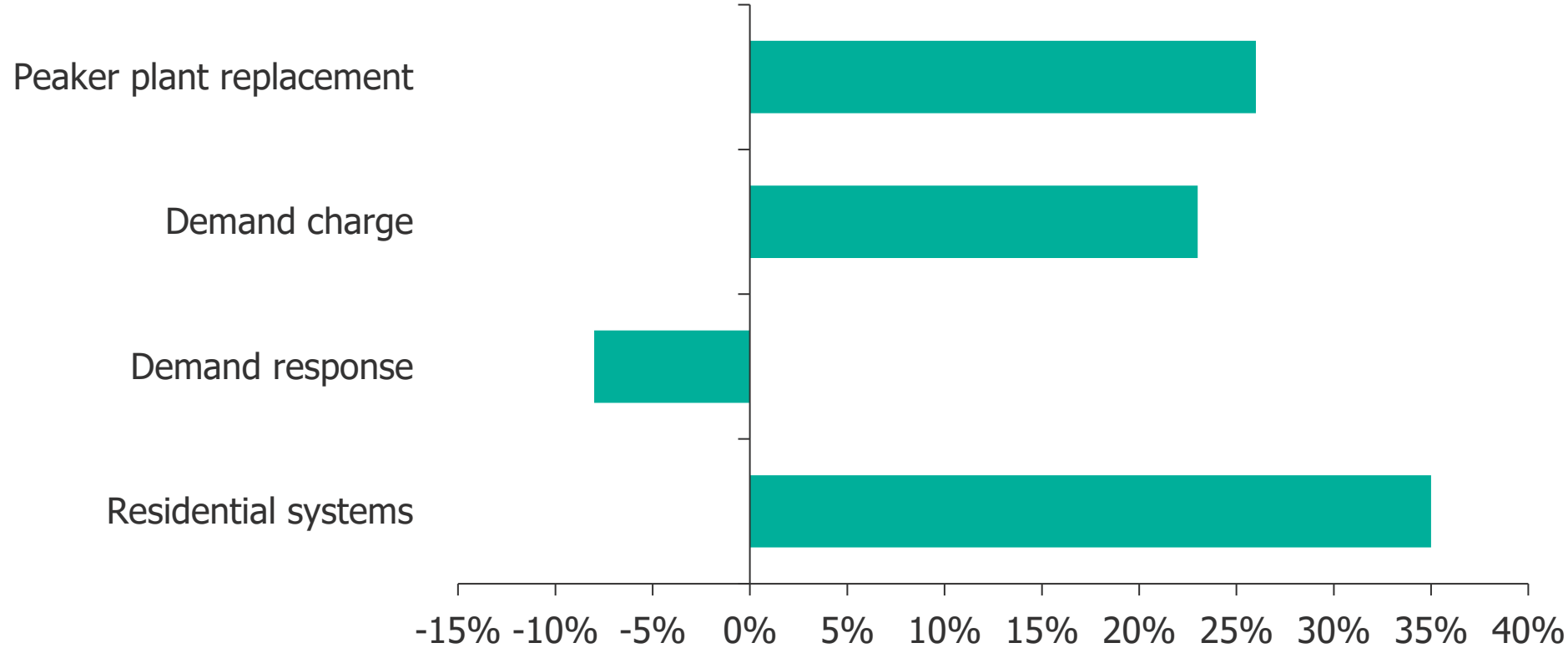
Note: $/kWh for second-life systems are normalized to account for usable capacity, allowing for more direct comparison to new systems

SECOND-LIFE

Most applications will provide higher returns using new sells, which could lead to more battery recycling

Costs of Ownership of Second-Life Systems

Relative costs compared to new systems



Source: Umicore

RECYCLING & SECOND-LIFE

Making dollars and sense of battery recycling and reuse

While second-life reuse of Li-ion batteries in stationary storage applications may have been an early solution to managing end-of-life PHEV and BEV batteries, it is highly unlikely to continue due to technical challenges and unfavorable costs compared to new cell systems.

It is absolutely critical for the automotive and Li-ion battery industry to develop a recycling value chain that can profitably recover Li-ion battery material. If the battery industry fails to put in place the infrastructure to manage this growing waste stream in the coming years, it is extremely likely that it will be compelled to by regulators, without regard for profitability.

Recycling will become a vital component of the Li-ion battery value chain over the next five years. While it will take time for end-of-life cell volumes to grow to make recycling profitable, it will take most of that time to develop the necessary processes and partnerships to build out a robust collection and materials recovery network central to a successful recycling business. It is critical to begin building a recycling strategy now.

INNOVATE SMARTER & GROW FASTER

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BOSTON NEW YORK AMSTERDAM SINGAPORE TOKYO

Lux Research

www.luxresearchinc.com
www.luxresearchinc.com/blog
info@luxresearchinc.com
@LuxResearch
Lux Research, Inc.
Lux Research