Copper Demand in Energy Storage

American Copper Council
Annual Spring Meeting 2019
22 May, Seattle

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Agenda

- Executive Summary
- Copper Intensity in Li-ion Cells and Packs
- Copper Demand in Low-Carbon Energy and Mobility Applications
- Impact of Second-Life Batteries on Copper Demand
- Conclusions

Executive Summary

Rising Demand for Energy Storage

- Energy storage – battery technology in particular – is often seen as having great potential to decarbonise power and transport systems. Recent cost reduction of Li-ion batteries has raised penetration levels of electric mobility and stationary energy storage applications.

- Global sales of plug-in electric vehicles (PEVs) hit 2 million in 2018 and the total PEVs on the road reached 5.3 million by the end of 2018.

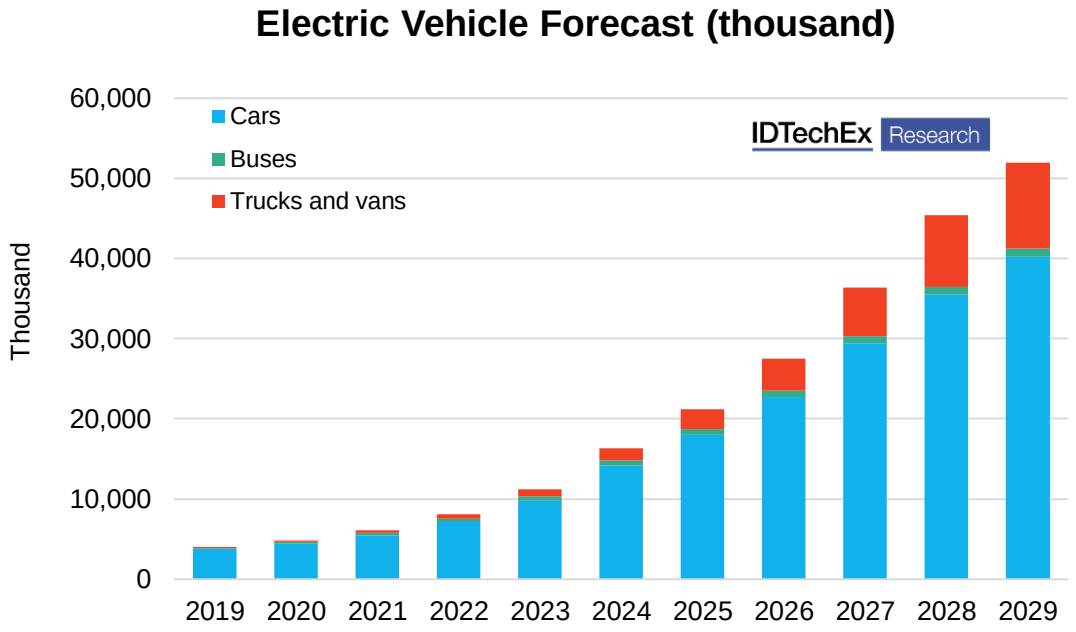
- In IDTechEx's 10-year forecast, the electric vehicle (EV) market including cars, buses and trucks will grow to 52 million annual sales by 2029, driving up demand for batteries to around 3.1 terawatt hours (TWh) per year.

- Widespread EV deployment will lead to a further decrease in Li-ion battery costs, which will spill over to stationary storage systems at household, commercial, industrial and grid levels.

Source: Renault

Electric Vehicle Forecast 2019-2029 - IDTechEx

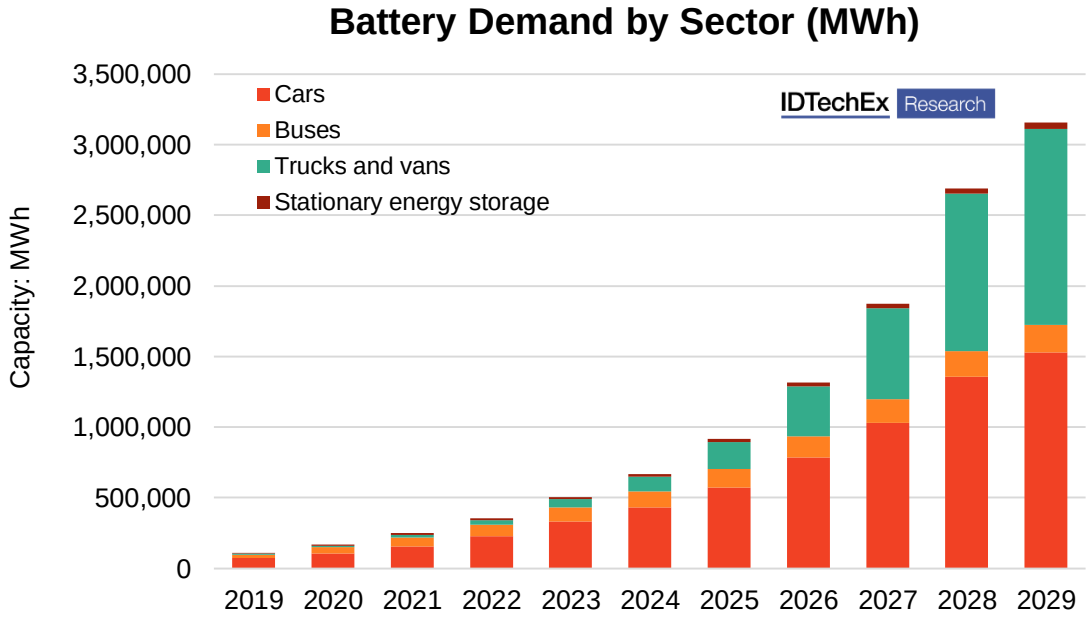
- IDTechEx forecasts that the electric vehicle market (including cars, buses, trucks and vans) will grow from 4 million units sales per year in 2019 to around 52 million by 2029.



Source: IDTechEx

Battery Demand in Mobility and Stationary Storage

- IDTechEx's forecast shows that demand for battery storage in electric mobility and stationary storage will grow from 0.1 terawatt hours (TWh) in 2019 to around 3.2TWh by 2029.
- Batteries will predominantly be deployed in e-mobility applications, especially in cars, buses, trucks and vans.

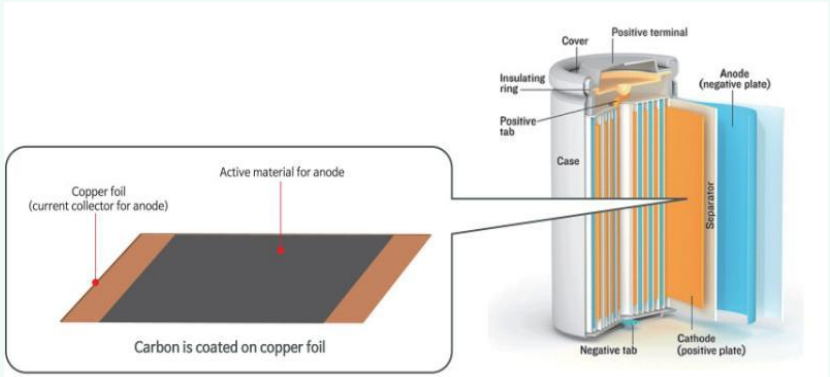


Source: IDTechEx

Copper Content in Li-ion Battery Packs

- Li-ion batteries rely on a number of raw materials not originally present in cars – such as lithium and graphite – but also other materials that may see a significant boost in their demand, like nickel, cobalt, and **copper**.
- Copper is used as anode current collectors for Li-ion cells and cannot be replaced because of corrosion issues. At the pack level, copper is used in electrical interconnects such as busbars, cables and wiring.

Li-ion cell: anode current collector

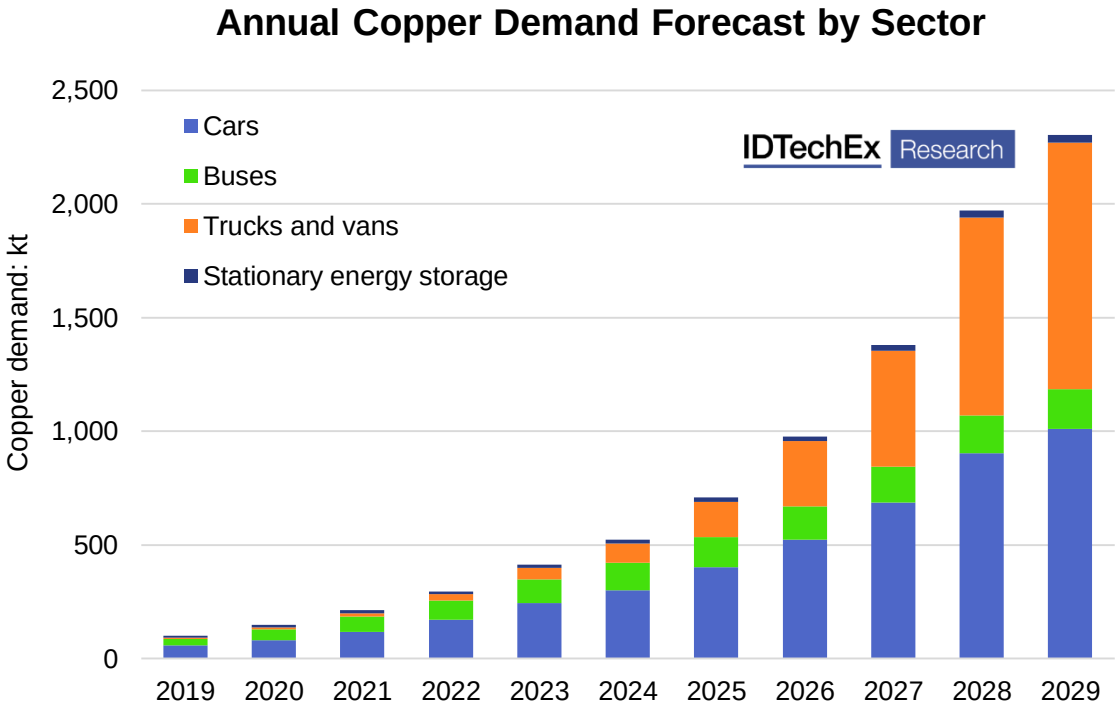


Li-ion battery pack: electrical interconnects

- *Busbars*

- *Cables and Wiring*

Copper Demand in Energy Storage Applications

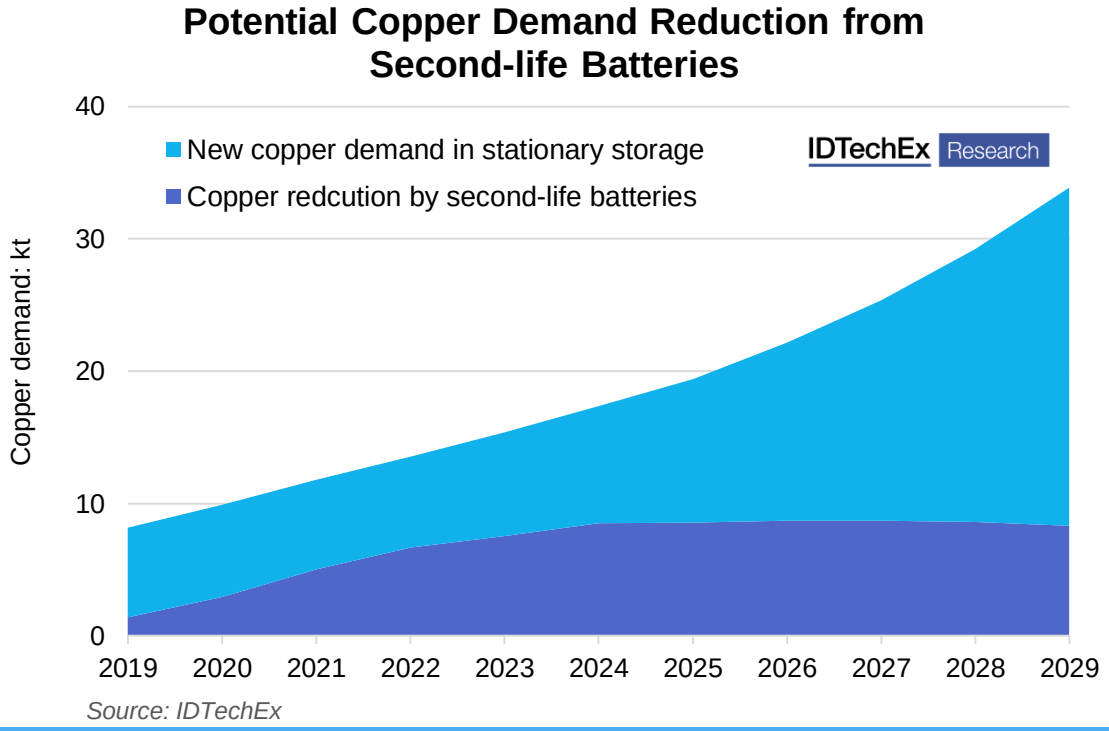


Source: IDTechEx

- IDTechEx's forecasts that energy storage in mobility and stationary storage applications will raise annual copper demand by **2.3 million tonnes by 2029**.
- The total copper demand in energy storage over the next 10 years will total just over 9 million tonnes by 2029.

Second-Life Batteries and Impact on Copper Demand

The deployment of second-life batteries in stationary storage would reduce the copper demand in producing new batteries for the same purposes.



Source: IDTechEx

- In a modest scenario, second-life battery would remain 25% market share of Li-ion batteries in stationary storage in 2029, and that would reduce copper demand in stationary energy storage by **8,300 tonnes per year** by 2029.
- Over the 10 years, second-life batteries could reduce copper demand in stationary storage by **75,000 tonnes by 2029**.

Copper Intensity in Li-ion Battery Cells and Packs

Li-ion Battery: From Cell to Pack

- Li-ion cell
- Battery management system (BMS)
- Thermal management
- Electrical interconnects
- Safety components
- Housing

Battery pack

Note: Battery pack, together with power conditioning systems (PCS) including inverters, battery chargers, energy management systems, consist of a **battery system**.

Source: Yole

Copper Content in Li-ion Battery Packs

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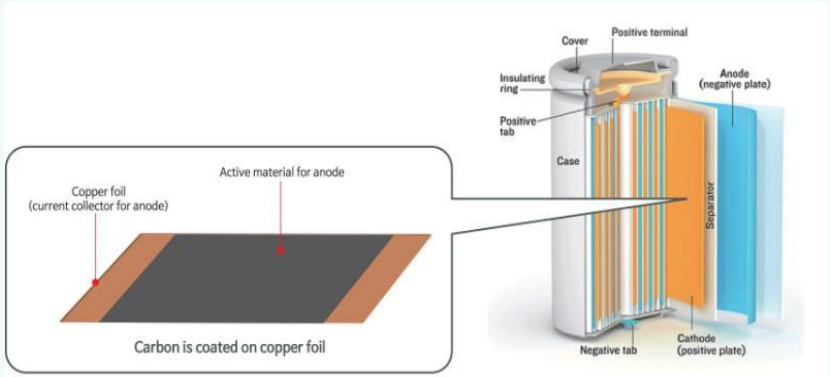
Li-ion cell: anode current collector



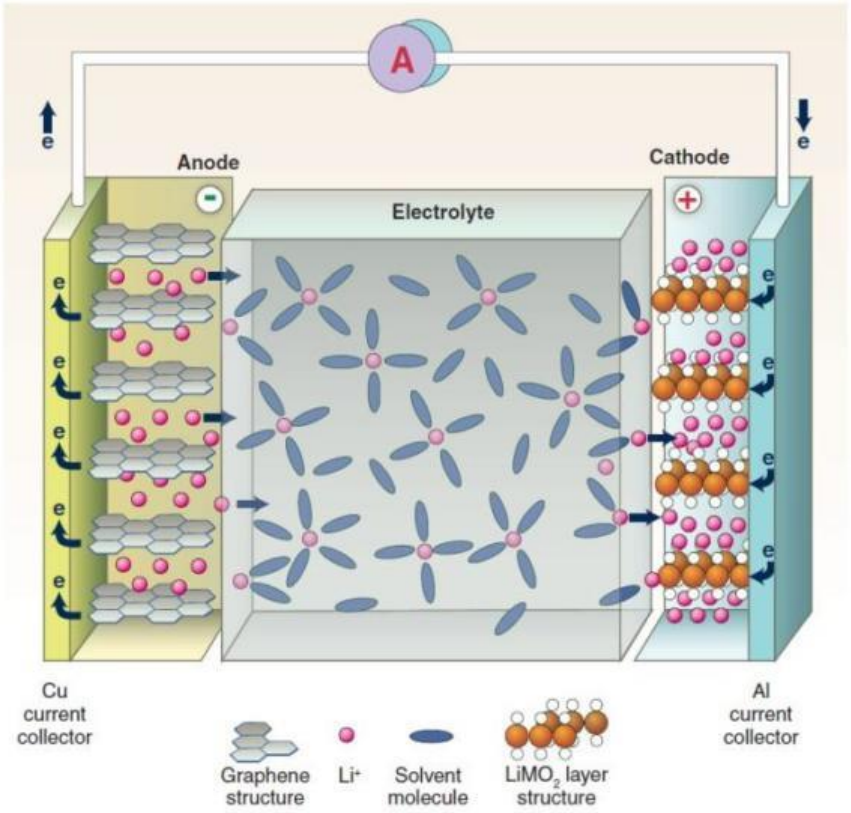
Li-ion battery pack: electrical interconnects

- *Busbars*

- *Cables and Wiring*

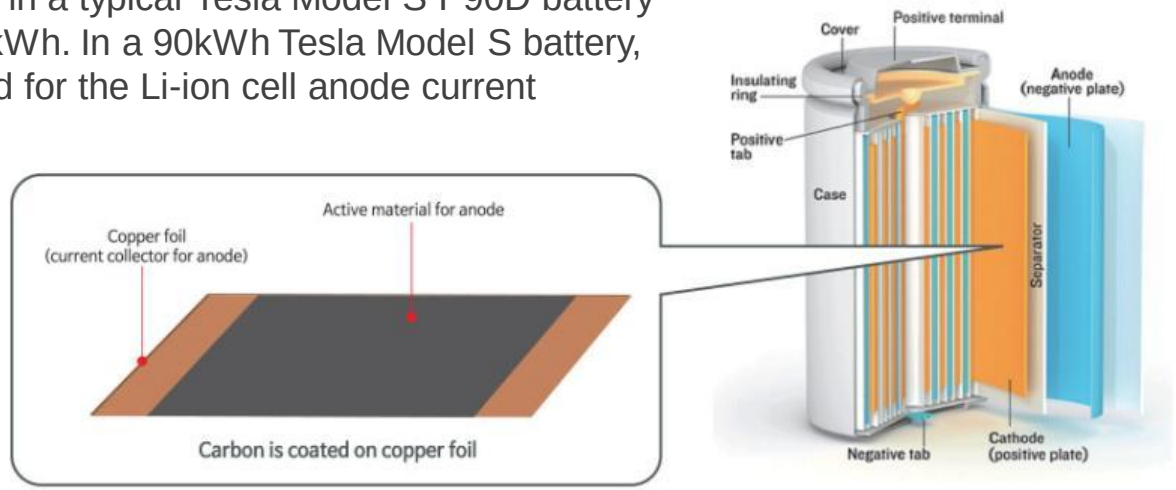
Li-ion Battery Cell Structure

- A Li-ion battery relies on the “rocking chair” principle, which allows lithium ions (Li+) to be reversibly inserted/intercalated into the anode and the cathode.
- The **cathode** is a metal oxide which is coated on an aluminum foil that works as the current collector.
- The **anode** is usually graphite which is coated on a thin copper foil as the current collector.
- The **electrolyte** is a 50:50 organic carbonate mixture with a lithium salt.
- The **separator** is a non conductive membrane that prevents short circuit between the two electrodes.

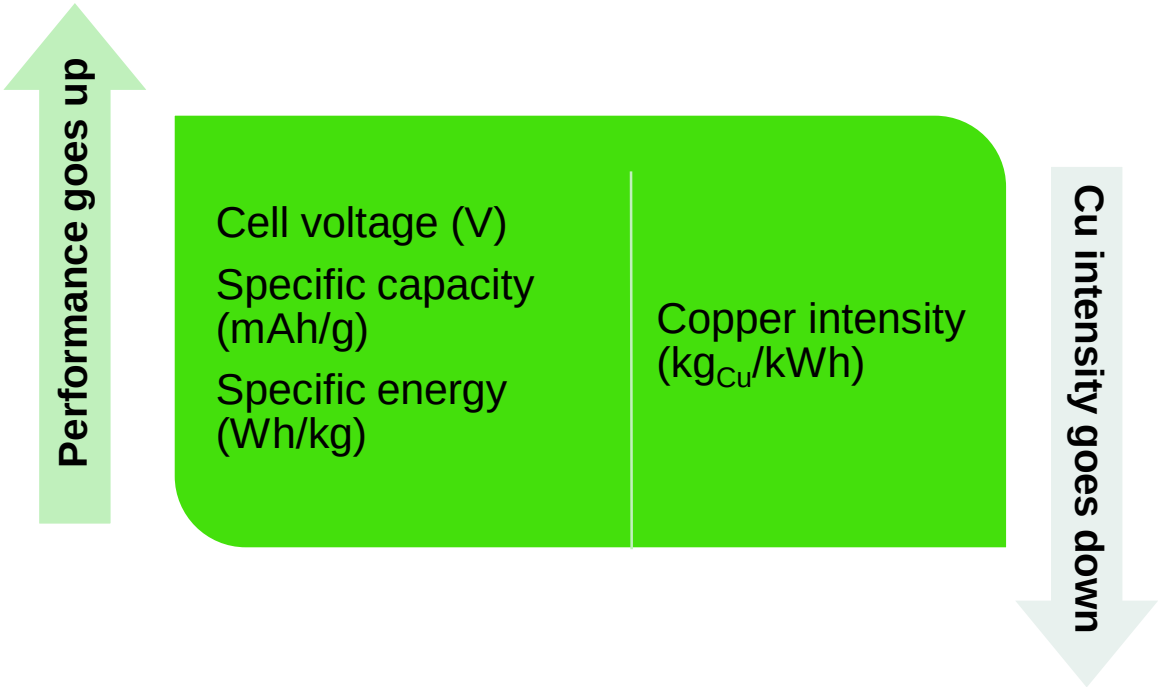


Copper Intensity at Cell Level

- At cell level, copper demand is predominantly in the form of the copper foil which is used as the anode current collector.
- A kilowatt-hour (kWh) is a unit of energy commonly used for electricity and is the main value used to describe the size/capacity of a Li-ion battery.
- A useful metric to define copper demand in Li-ion batteries is **kilograms of copper per kilowatt-hour** (kg_{Cu}/kWh), which is also what we refer to as copper intensity in this study.
- Commercially available copper foil for Li-ion cell anode current collector ranges from 6μm to 20μm in thickness. Copper intensity in a typical Tesla Model S P90D battery cell, for example, is 0.334kg/kWh. In a 90kWh Tesla Model S battery, around 30kg of copper is used for the Li-ion cell anode current collector.



Copper Intensity V.S. Cell Performance

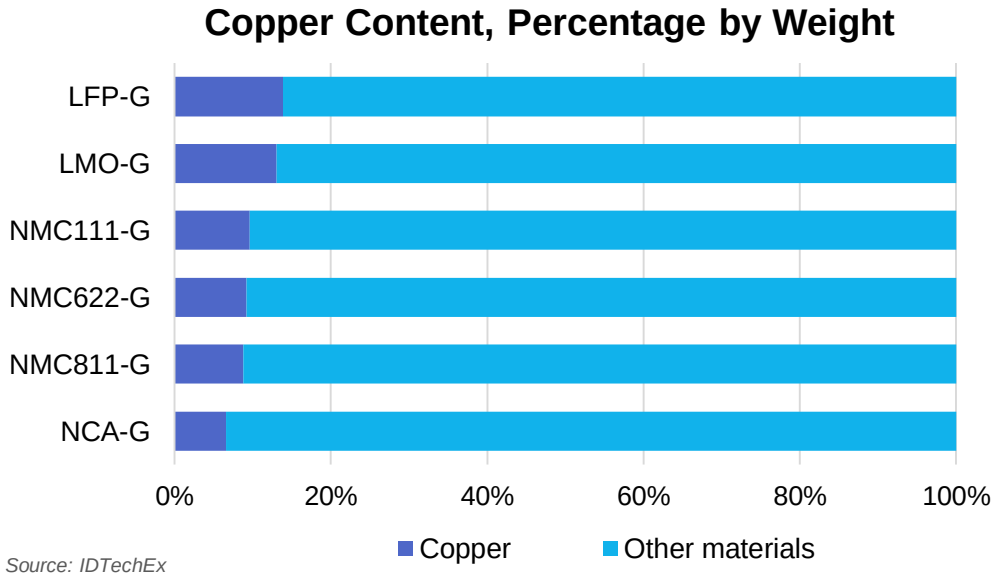


At the cell level, copper foil is needed as the anode current collector.

The more energy-dense a battery cell is, the lower the copper intensity (kg_{Cu}/kWh).

Copper Intensity at Cell Level: Different Cell Chemistries

- Lithium nickel cobalt aluminum oxide (NCA), lithium nickel manganese cobalt oxide (NMC), lithium iron phosphate (LFP) and lithium ion manganese oxide (LMO) are the most commonly used cathode materials in energy storage Li-ion batteries. Consumer batteries are beyond the scope of this study.
- In general, as cell performance (e.g. specific energy) goes up, copper intensity in Li-ion cells decreases.



Source: IDTechEx

Different Li-ion Cell Formats

Cylindrical

- ✓ Low-cost option
- ✓ Highly optimized manufacturing process
- ✓ Highest cell-level volumetric efficiency
- ✗ Difficult to cool
- ✗ Packaging efficiency

Used by:

TESLA

Faraday Future

Pouch

- ✓ Highest module design flexibility
- ✓ Highest capacity flexibility
- ✓ Wider supplier selection
- ✗ Poor mechanical containment
- ✗ Good compression control required

Used by:

NISSAN

RENAULT

CHEVROLET

Prismatic

- ✓ Simple, lower-cost manufacturing
- ✓ Easier to cool
- ✗ Poor cell-level energy density
- ✗ Poor flexibility
- ✗ Lifecycle challenges

Used by:

BYD

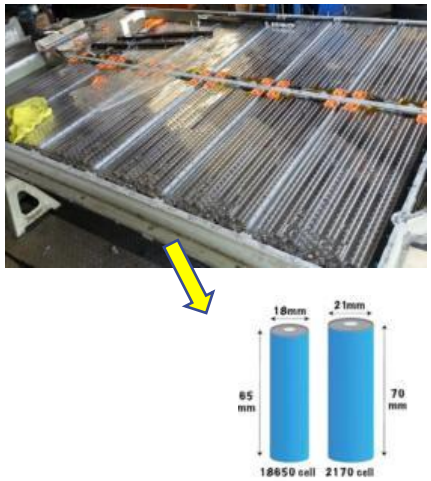
BMW

北汽新能源 BAIC BJEV

EV Battery Models Analysed

Type	Brand	Model	Chemistry	Cell capacity (Ah)	Cell voltage (V)	Energy (kWh)	Configuration	Specific energy (Wh/kg)	Battery supplier
Cylindrical	Tesla	Model S	NCA-Gr	3.2	4	85	96s74p	138	Panasonic
Pouch	Nissan	LEAF	LMO-Gr	32.5	3.75	24	96s2p	88	AESC
Prismatic	BMW	i3	NMC-Gr	94	3.7	33	96s1p	123.6	Samsung SDI

Tesla Model S P85D (cylindrical cell)



Nissan LEAF (pouch cell)

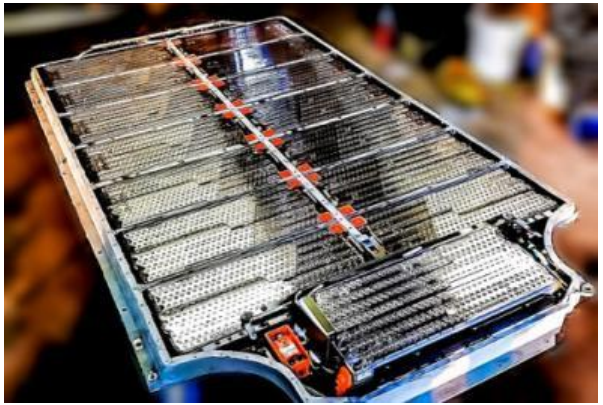
BMW i3 (prismatic cell)

Copper in Tesla Model S Battery Pack

31.48kg copper used in a Tesla Model S battery pack.

Cell: 28.39kg

Electrical interconnects: 3.09kg



Copper in Nissan Leaf Battery Pack

32.83kg copper used in a Nissan Leaf battery pack.

Cell: 27.05kg

Electrical interconnects: 5.78kg

Batteries are Increasing Energy Density

- As cell chemistries (especially cathode) move towards higher energy density, copper intensity (kg/kWh) decreases at cell level.
- For example, moving from NMC111 to NMC811 cathode material will cause a decrease in copper intensity from 0.611 to 0.462kg/kWh at cell level.
- Replacing the existing NMC111 Li-ion cathode to NMC811 will lead to a 24% decrease in copper demand from Li-ion cells.

Power Battery Technology Roadmap

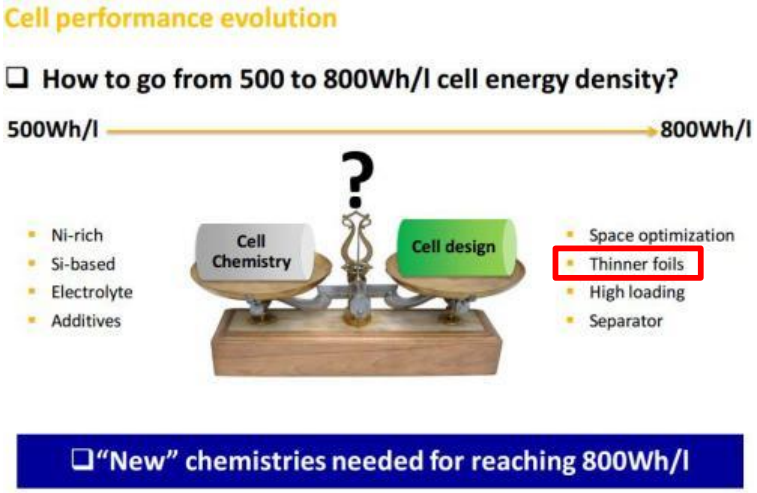
From the general expert team of 13th Five-Year National Key Research and Development Program <New Energy Vehicle>

		2015	2020	2025	2030
EV		promotion	universal		
		150-200 Km	300-400 Km		500-600 Km
cell	specific energy	180 Wh/Kg	300 Wh/Kg	400 Wh/Kg	500 Wh/Kg
	specific power	800 W/Kg	1000 W/Kg	1300 W/Kg	1500 W/Kg
	cycle	2000 weeks	1000 weeks	2000 weeks	2000 weeks
	cost	1.8 yuan/Wh	0.8 yuan/Wh	0.6 yuan/Wh	0.6 yuan/Wh
Battery material	classification	Lithium Ion Battery	New lithium-ion battery		Innovative Lithium-ion battery
	cathode	NMC/NCA	NMC/NCA with more Ni	Lithium-rich manganese-based solid solution	High-energy lithium-rich cathode
	anode	Graphite carbon material	Si/C anode	High-capacity Si/C anode	High-capacity Si/C composites anode
	electrolyte	Carbonate organic electrolyte	High voltage organic electrolyte		Solid electrolyte
	separator	Polyolefin separator	High temperature separator		

Source: Tsinghua University

Inactive Weight

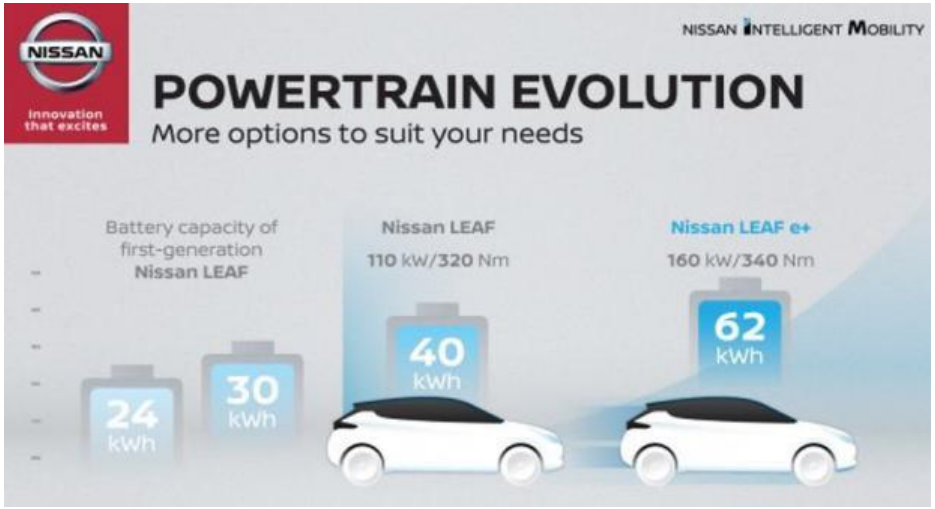
- Reduction of inactive weight is crucial to attain higher performance, as well as lower cost per kWh. Reducing the thickness of copper foil for Li-ion battery current collectors is among one of the trends to improve battery cell energy density.
- Copper foil for Li-ion cell anode current collectors are normally 8-10 microns in existing systems but there are efforts to commercialize thinner foils. Many manufacturers have invested or have already been in the mass-production phase for 6 microns copper foil.
- For example, Chinese copper foil manufacturer Wah Wei Copper Foil Technology have announced that 95% of their production capacity would focus on 6 microns copper foil since 2017.
- Replacing the existing 10 microns copper foil with 6 microns ones will cause copper demand from Li-ion cells to decrease by 40%.



Source: Renault

Note: Battery Size (Capacity) is Increasing

- Although several factors might cause copper demand to decrease at the cell and pack level (Kg_{cu}/kWh), this doesn't mean overall copper demand will decline. The automotive sector has been moving towards not only higher energy density, but also higher capacity batteries.
- Many OEMs have announced new EV models with higher capacity batteries. For example, the old Nissan LEAF model only has a 24kWh battery while the latest model LEAF e+ announced at CES 2019 carries a 62kWh battery.
- Although range anxiety cannot be solved by increasing battery capacity alone, we expect battery capacity will increase over the coming years to catch up with the range of gasoline cars, driving up copper demand.



Source: Nissan

Copper Demand in Low-Carbon Energy and Mobility Applications

Energy Storage in Mobility and Energy Applications

- Energy storage technologies will have large potential in the following four sectors across mobility and energy markets:

Cars: electric cars, (plug-in) hybrid electric cars, 48V mild hybrid

Buses: electric buses, fuel cell buses

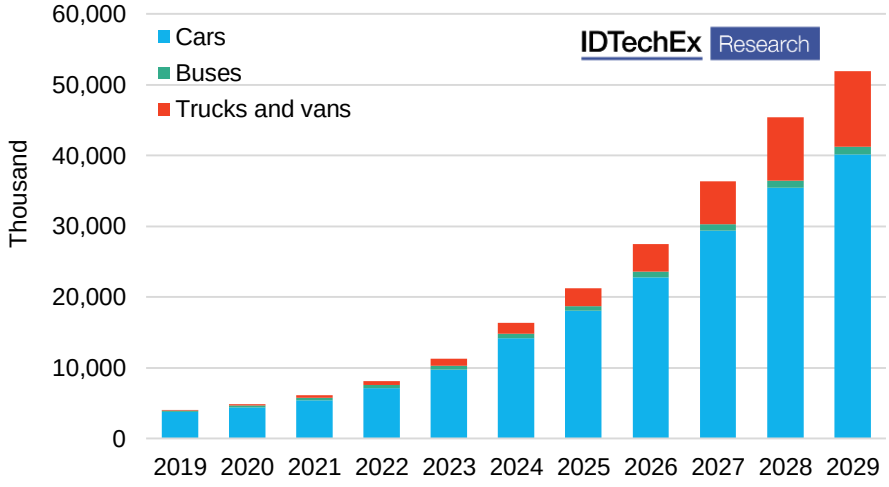
Trucks and vans: Electric trucks and vans, fuel cell trucks

Stationary energy storage

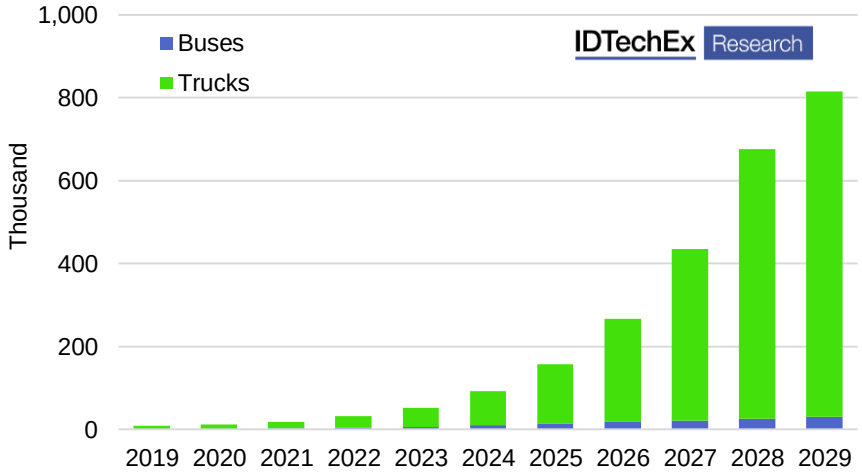
Electric and Fuel Cell Vehicles Forecast 2019-2029

- The electric vehicle market (including cars, buses, trucks and vans) will grow from 4 million units sales per year in 2019 to around 52 million by 2029.
- IDTechEx believes that fuel cells will mainly be deployed in the bus and truck sectors in the next decade with a total market size of just over 800,000 per year by 2029.

Electric Vehicle Forecast (thousand)



Fuel Cell Vehicle Forecast (thousand)

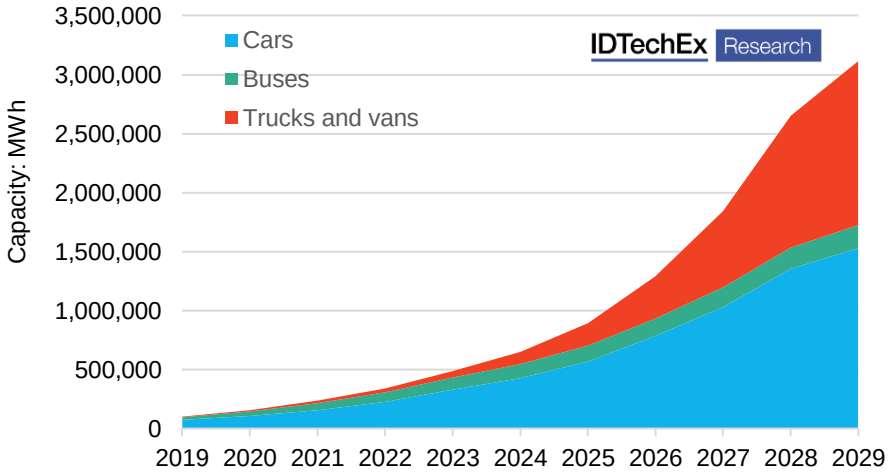


Source: IDTechEx

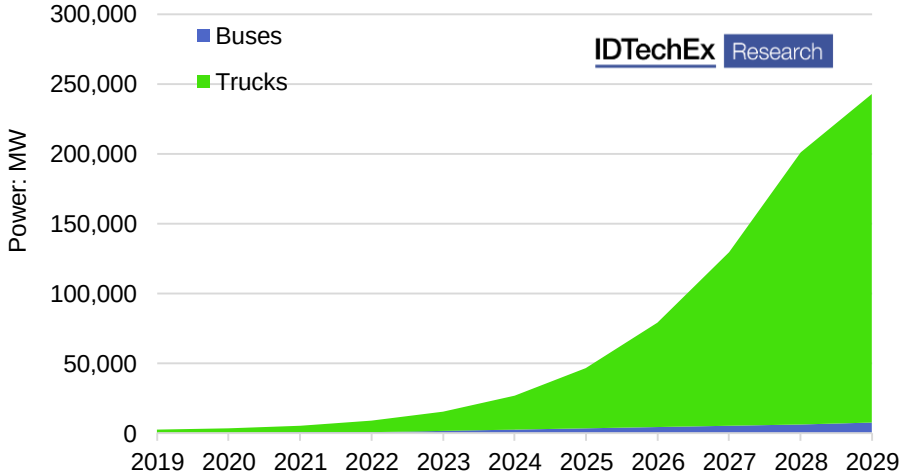
Energy Storage for Electric Mobility Forecast 2019-2029

- Battery demand for electric vehicles including cars, buses, trucks and vans will hit just over 3.1TWh annually by 2029.
- Fuel cells deployed in buses and trucks will reach 243GW per year by 2029.

Battery Demand for Electric Vehicles (MWh)

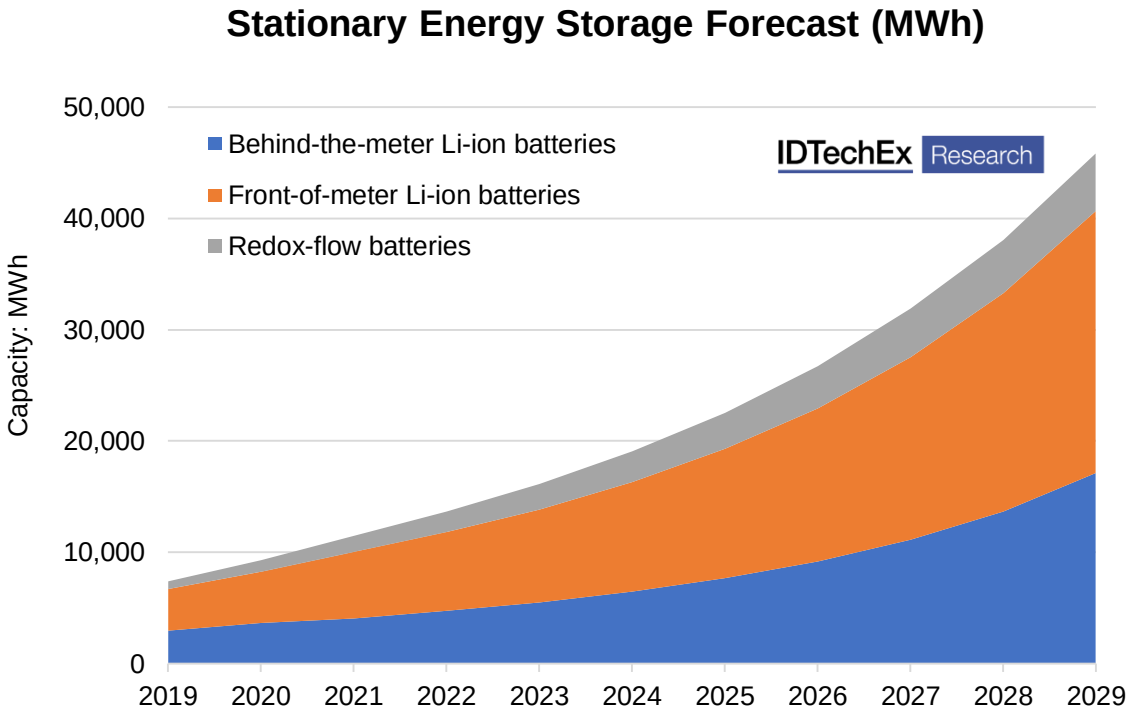


Fuel Cell Demand for Buses and Trucks (MW)



Source: IDTechEx

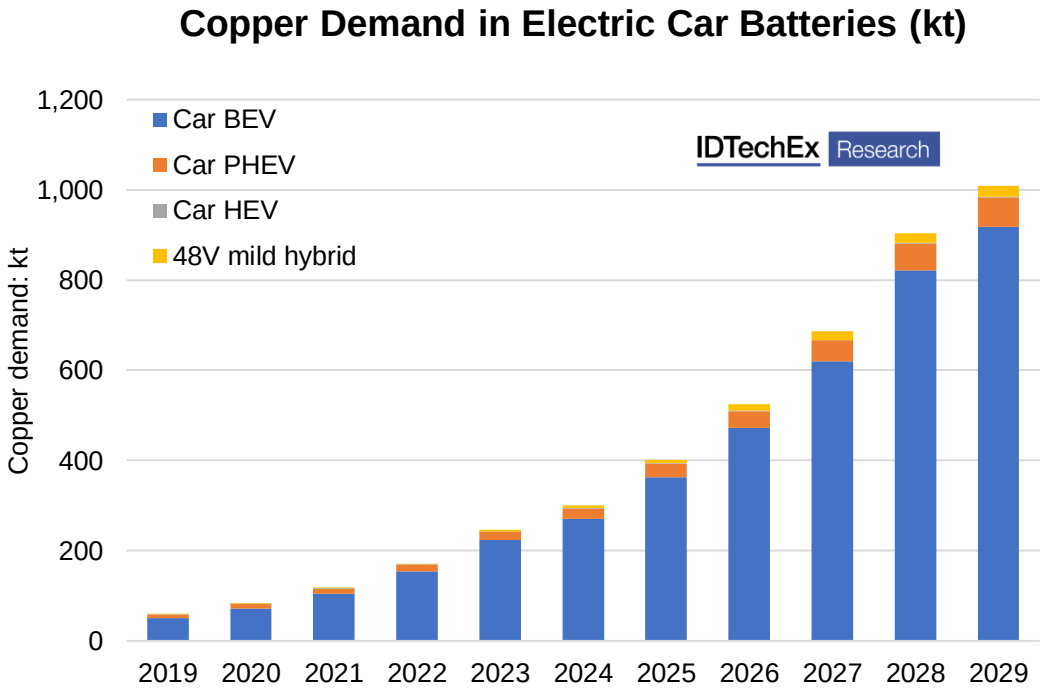
Stationary Energy Storage Forecast 2019-2029



Source: IDTechEx

- IDTechEx forecasts that Li-ion batteries and redox flow batteries will dominate the stationary energy storage market in the next decade.
- Demand for Li-ion batteries in behind-the-meter and front-of-meter applications will grow from 6.7GWh in 2019 to 40.7GWh by 2029.
- Demand for redox-flow batteries will increase steadily from 0.7GWh in 2019 to 5.2GWh by 2029.

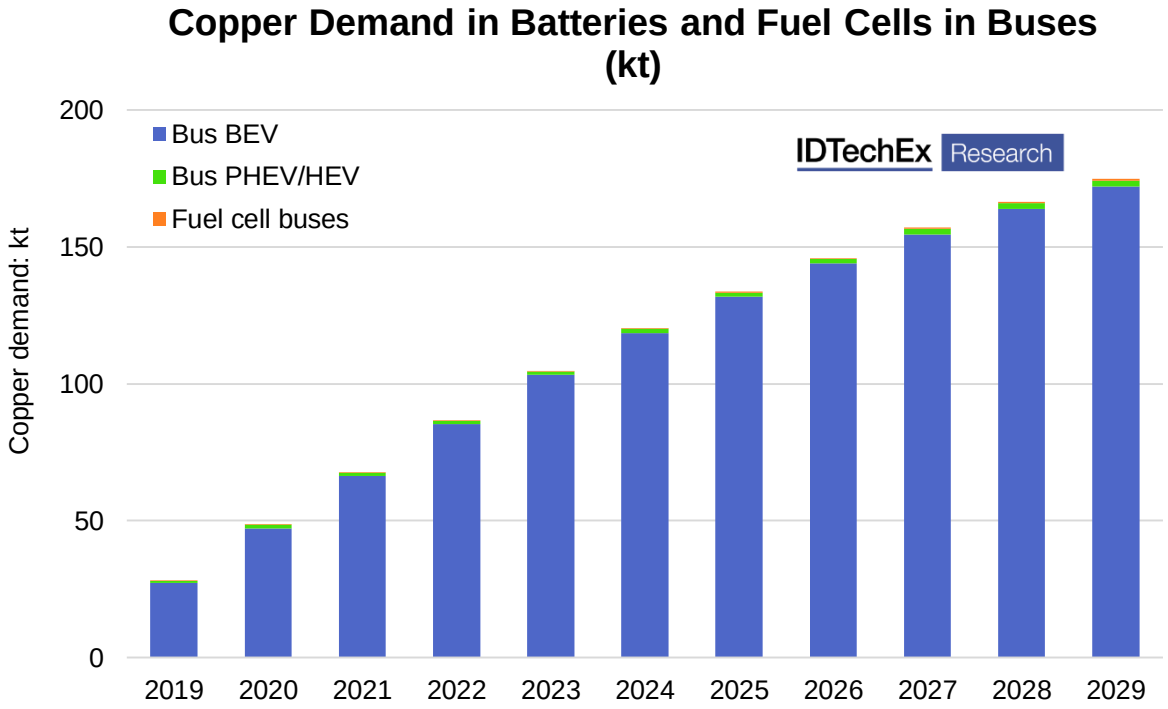
Copper Demand in Electric Car Batteries 2019-2029



Source: IDTechEx

- Using IDTechEx's analysis of copper intensity as well as the forecasted market share of different battery cell chemistries in the four electric car categories, the electrification in the electric car sector will raise annual copper demand in energy storage from 58,000 tonnes in 2019 to over **1 million tonnes by 2029**.

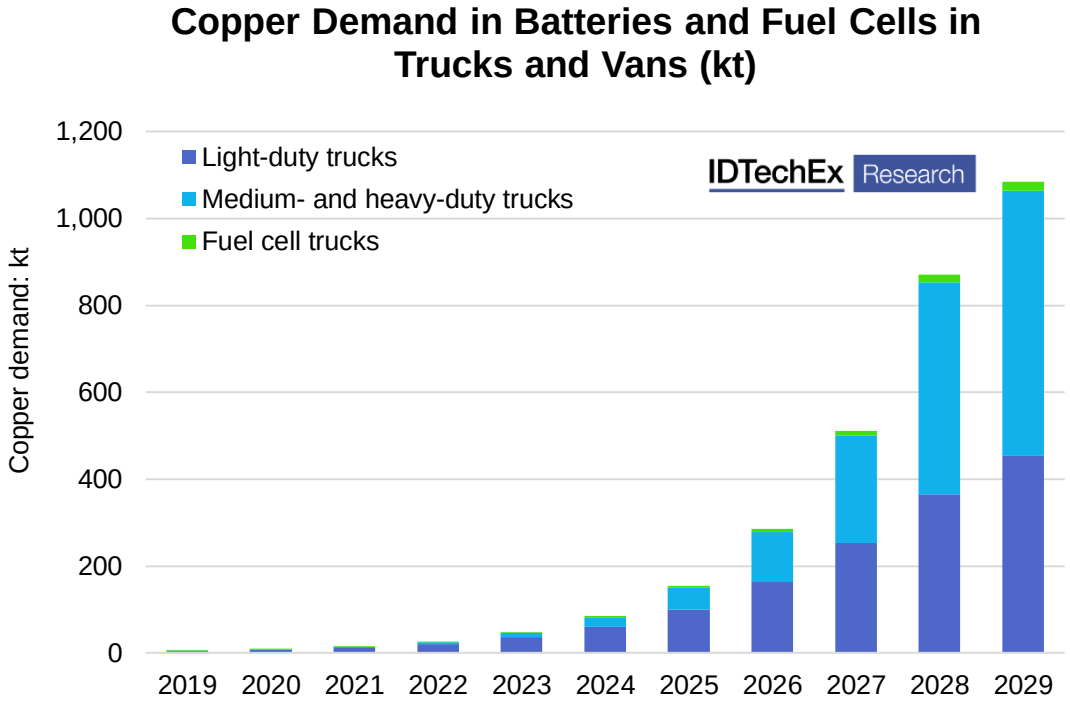
Copper Demand in Batteries and Fuel Cells in Buses 2019-2029



Source: IDTechEx

- IDTechEx forecasts that batteries and fuel cells for the bus sector will raise annual copper demand in energy storage by 175,000 tonnes by 2029.
- The increase in copper demand is mainly caused by the market penetration of pure electric buses.

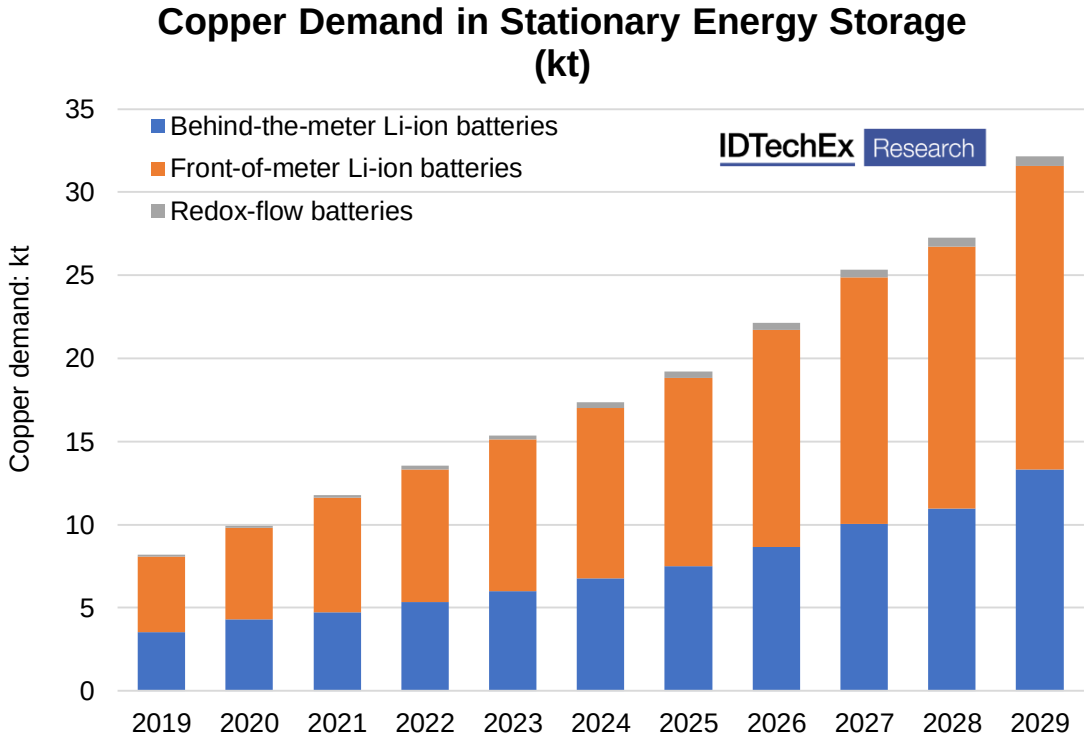
Copper Demand in Batteries and Fuel Cells in Trucks and Vans 2019-2029



Source: IDTechEx

- IDTechEx forecasts that the deployment of batteries and fuel cells in trucks and vans will raise annual copper demand by 1.1 million tonnes by 2029.

Copper Demand in Stationary Energy Storage 2019-2029



Source: IDTechEx

- IDTechEx forecasts that copper demand in stationary storage will predominantly come from Li-ion batteries over the next decade.
- The total annual copper demand from Li-ion and redox flow batteries for stationary storage will grow from 8,200 tonnes in 2019 to 33,900 tonnes by 2029.

Impact of Second-Life Batteries on Copper Demand

Redefining the ‘End-of-life’ of EV Batteries

- Consumer batteries such as those used in power tools, mobile phones and laptops are normally recycled/disposed after their service life – that’s what we normally refer to as the ‘end-of-life’ of the batteries.

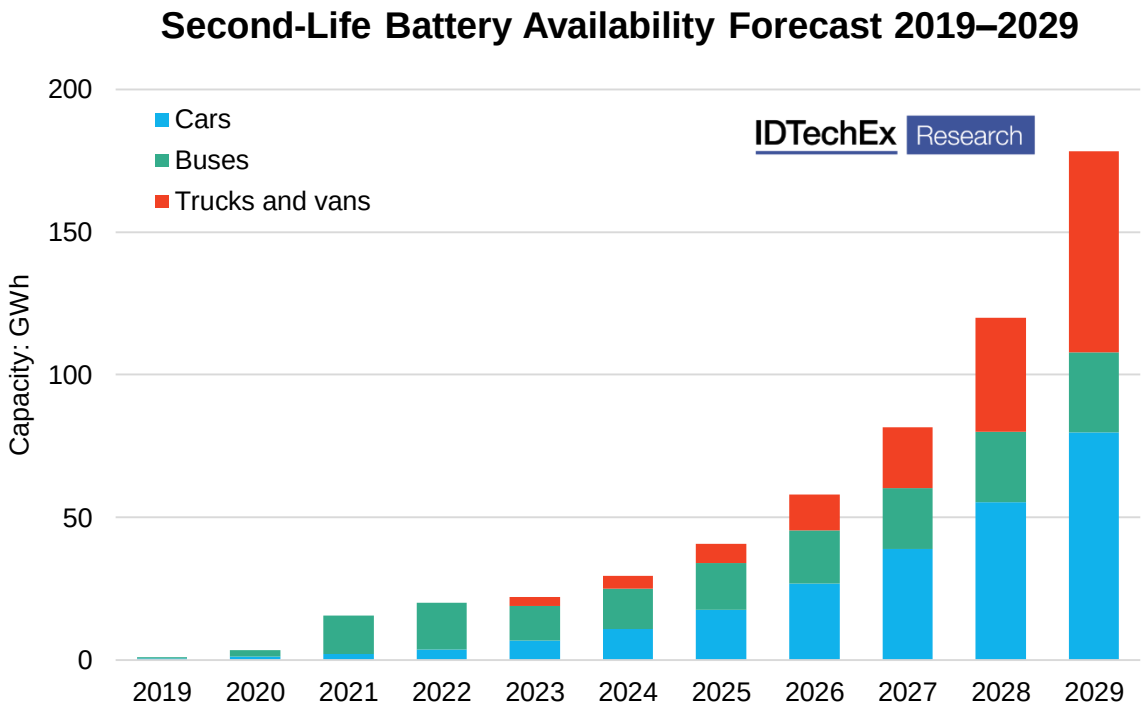
- However, retired car batteries that are no longer suitable for electric cars could still hold sufficient capacity for second- or even third-life applications (cascaded use).

- The ‘end-of-life’ of an electric car battery needs to be redefined as they could be further used, for example, for another 10 years or even longer in various post-vehicle applications before they are finally recycled/disposed.

End-of-service ≠ End-of-life

Main Players in Second-Life Batteries

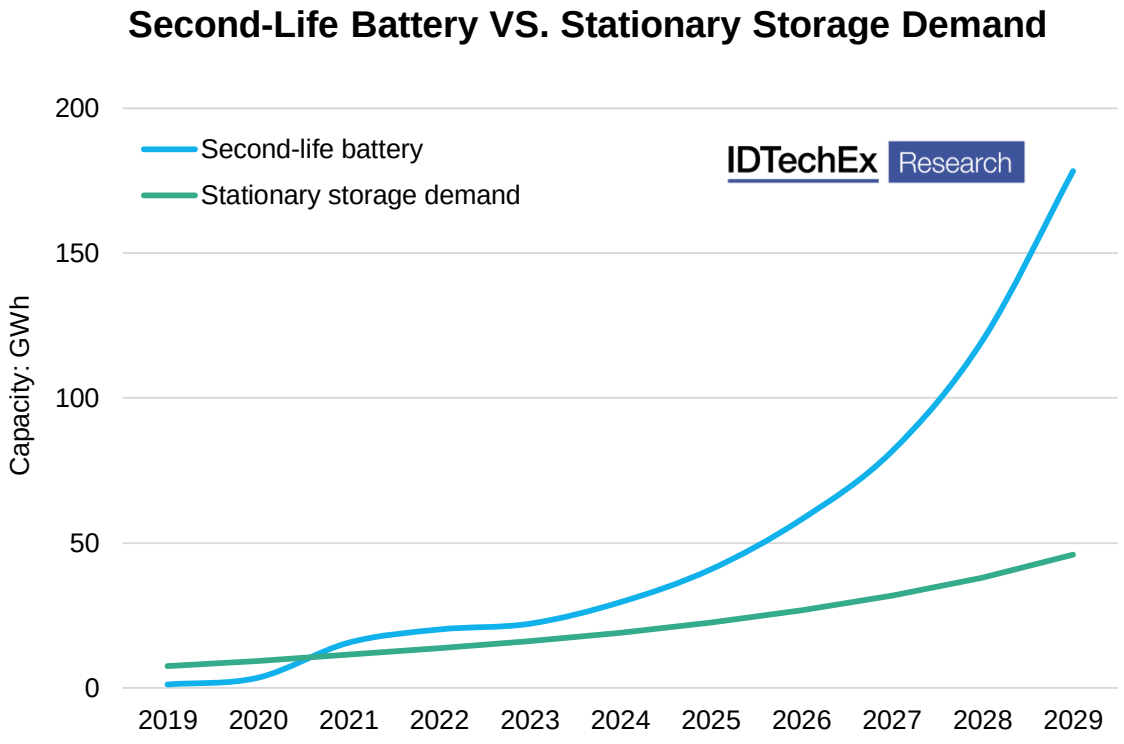
Available Second-Life Battery Capacity



Source: IDTechEx

- By 2029, available storage capacity from second-life batteries will hit **178 GWh** per year.
- Available second-life battery capacity is a portion of retired EV batteries because some of those batteries are not suitable for second-life, e.g. battery damage, premature degradation and low residual capacity.

Second-Life Battery Demand



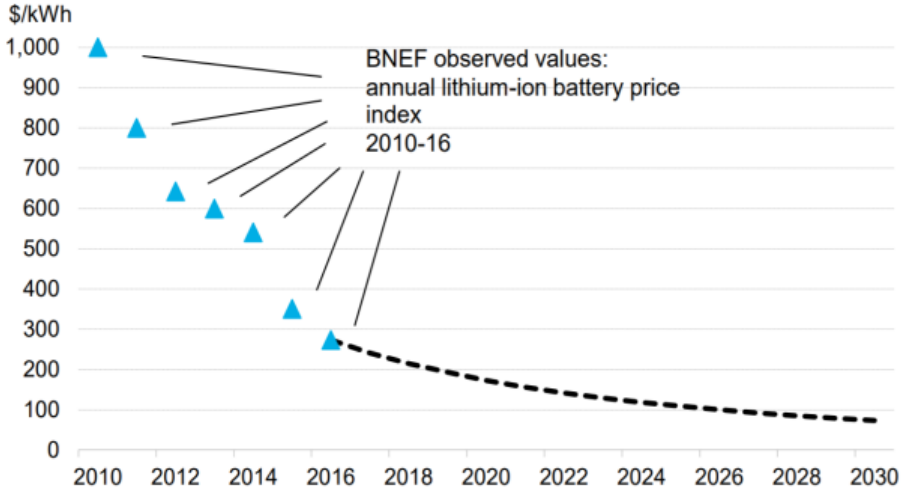
Source: IDTechEx

- In theory, second-life battery availability will be large enough to cover the total stationary energy storage demand after 2020 and there will be an over-supply of second-life batteries.
- However, the actual deployment of second-life batteries in stationary energy storage depends on many factors such as repurposing cost, new battery price and raw material price.

New Li-ion Battery Price is Decreasing

- Li-ion battery price has decreased from $1,000/kWh in 2010 to around $200/kWh in 2018, thanks to the technology improvements and economics of scales. According to BNEF's forecast, Li-ion battery price will drop further to below $100/kWh by 2030.
- The decrease in Li-ion battery price will put threat to second-life battery deployment. Currently the repurposing cost of second-life batteries is around $75-100/kWh according to IDTechEx's interviews with major industrial players.
- Second-life batteries will have cost advantage over new Li-ion batteries in the next 3-5 years but will gradually become less attractive as new battery price drop close to $100/kWh.
- IDTechEx believes that second-life battery market share in stationary storage will increase until 2024 and decrease afterwards to around 25% in 2029.

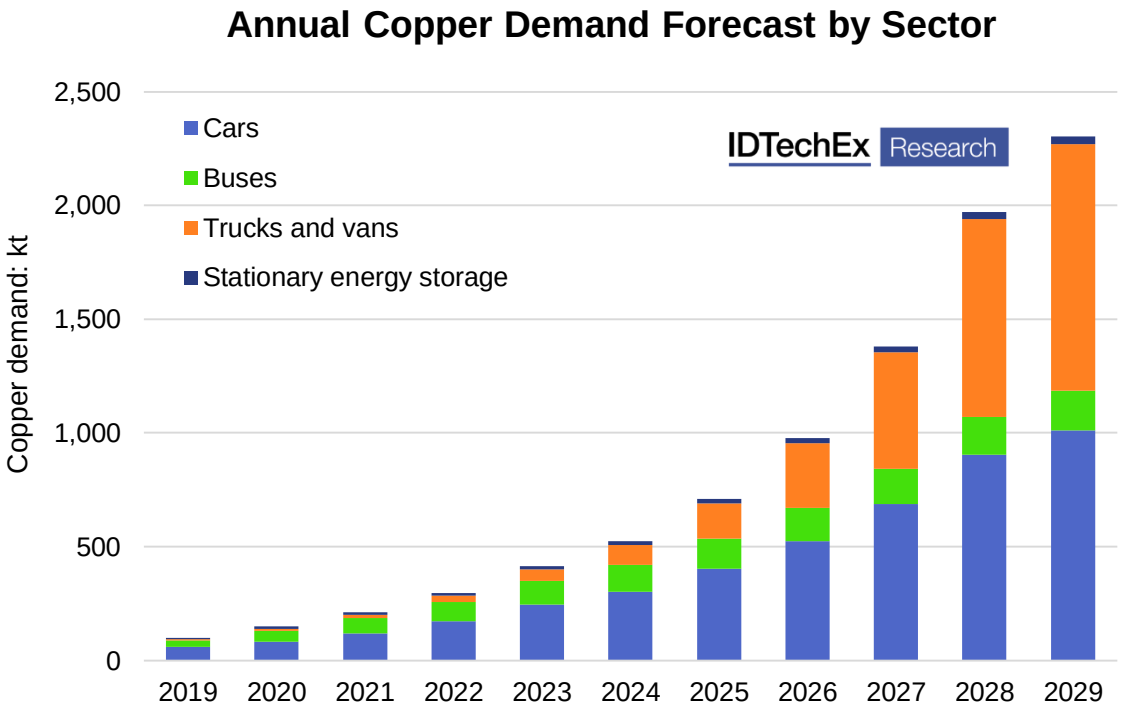
Li-ion Battery Price Forecast



Sources: BNEF

Conclusions

Copper Demand in Energy Storage Applications



Source: IDTechEx

- IDTechEx forecasts energy storage in mobility and stationary storage applications will raise annual copper demand by **2.3 million tonnes by 2029**.
- The total copper demand in energy storage over the next decade will total just over 9 million tonnes by 2029.