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Batteries: Harnessing the Power of the Energy Transition

Nitesh Shah
Director Research, WisdomTree

March 3, 2021

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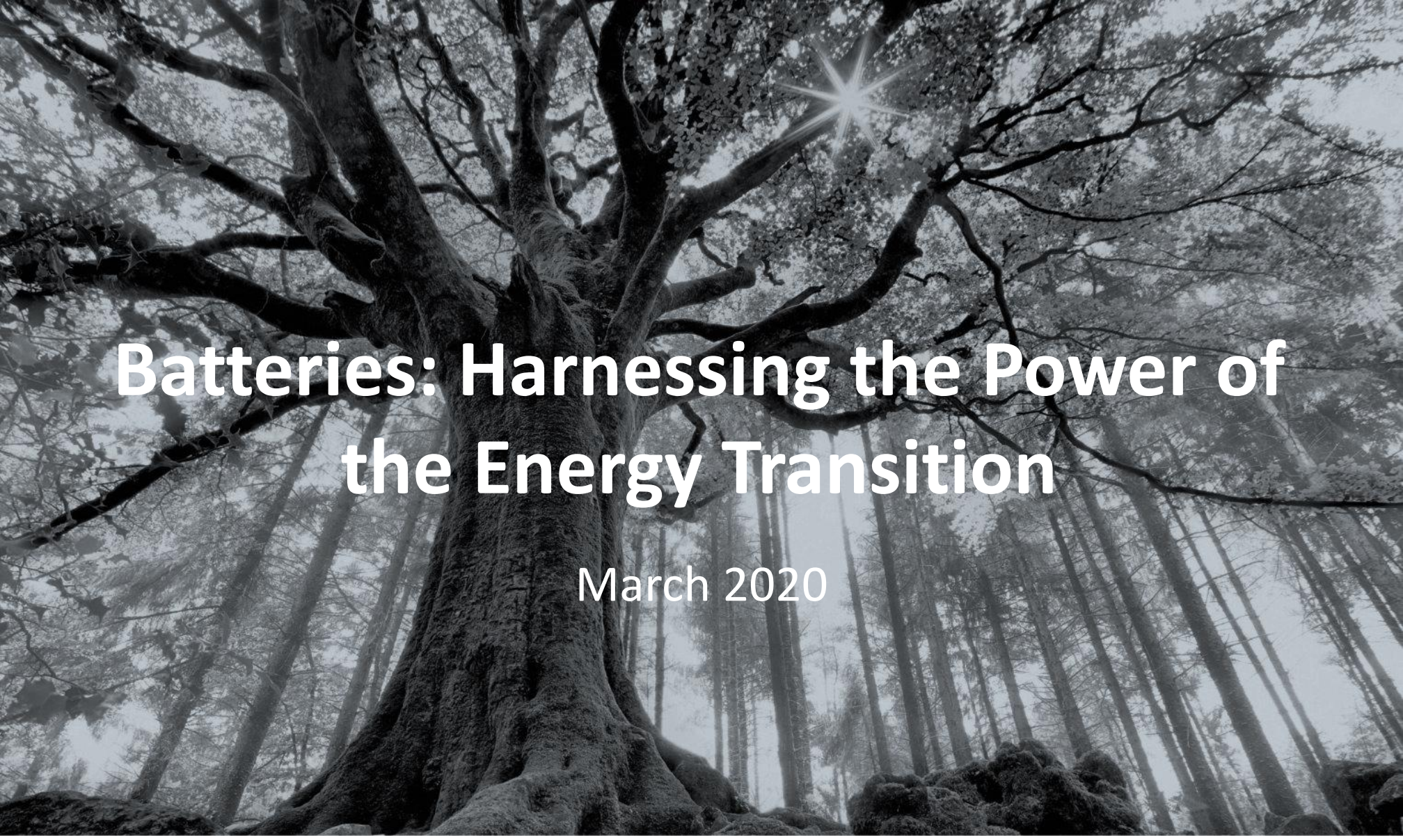


Batteries: Harnessing the Power of the Energy Transition

March 2020

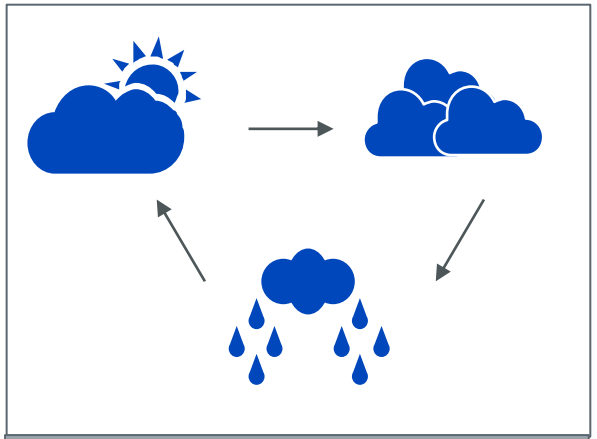
Nitesh Shah

Director, Research, WisdomTree

WisdomTree®

Growth Drivers for Batteries: Tapping into Several Megatrends

To fight climate change, the world needs better technology

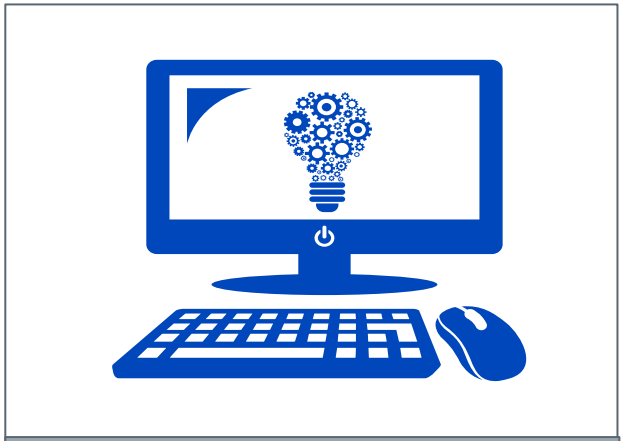


Climate change can threaten our survival

1.5ºC

The United Nations Paris Agreement aims to limit temperature increase to 1.5ºC above pre-industrial levels*

Technology will help us meet this ambitious goal



Technological change is happening quickly

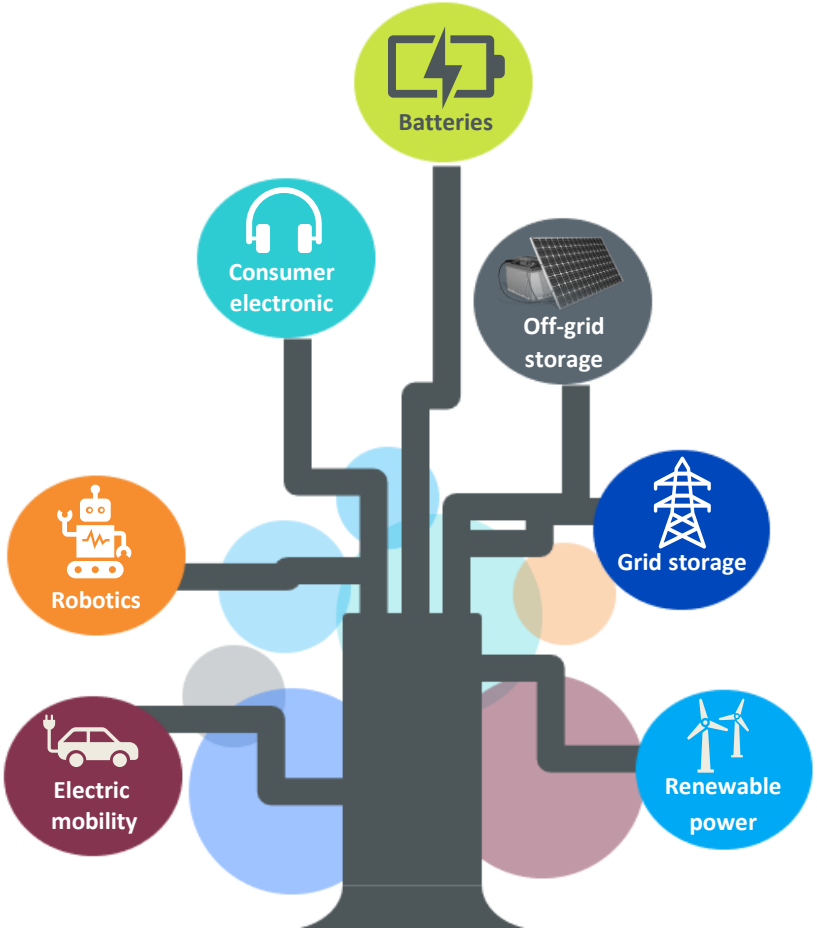
50%

Close to half of all passenger car sales could be electric by 2040 (Wood Mackenzie)

Sources: International Energy Agency 2019, United Nations Climate Change, and WisdomTree
*Intergovernmental Panel on Climate Change (IPCC) stated that in 2017 we were already 1.0ºC above pre-industrial levels

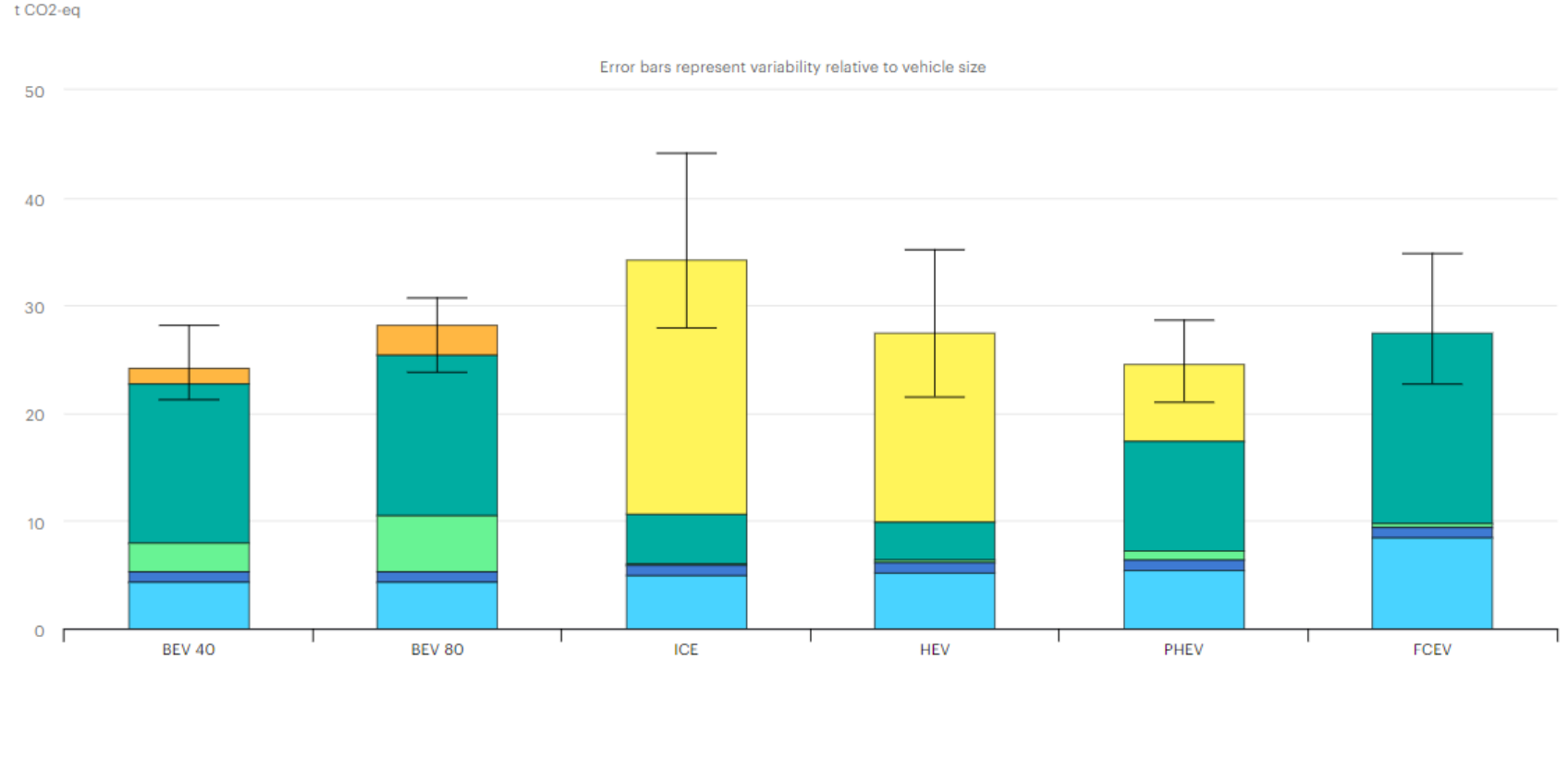
Battery solutions are at the core of this technological change

Batteries are expected to drive innovation and growth in a wide range of sectors



Sources: WisdomTree, Wood Mackenzie.

Comparative life-cycle greenhouse gas emissions over ten year lifetime of an average mid-size car by powertrain



ICE = Internal Combustion Vehicle, BEV 40 = Battery Electric Vehicle (40 kWh), BEV 80 = Battery Electric Vehicle (80 kWh)PHEV = Plug-in Hybrid Electric Vehicle, HEV = Hybrid Electric Vehicle, FCEV = Fuel cell electric vehicle

Source: International Energy Agency, Comparative life-cycle greenhouse gas emissions over ten-year lifetime of an average mid-size car by powertrain, 2018, IEA, Paris https://www.iea.org/data-and-statistics/charts/comparative-life-cycle-greenhouse-gas-emissions-over-ten-year-lifetime-of-an-average-mid-size-car-by-powertrain-2018

Forecasts are not an indicator of future performance and any investments are subject to risks and uncertainties

Storage technology is transforming the energy sector

Better energy storage is fuelling the transition to renewable energy

Slow / declining oil demand growth

Power sector disruption

Decarbonisation policies

Consumer attitudes & behaviour

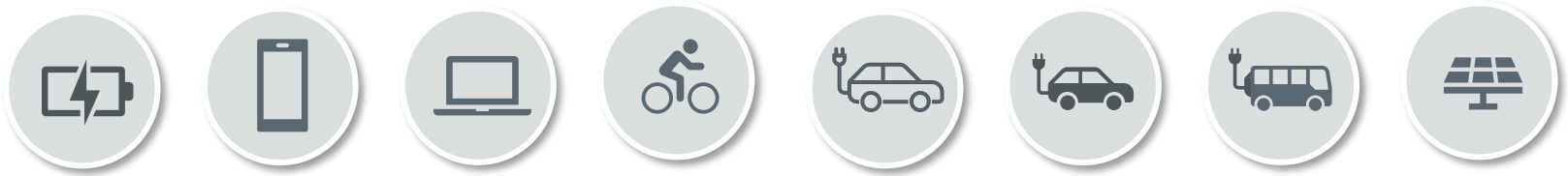
Energy storage

Renewable energy: Solar + battery storage hybrid projects will provide a zero-carbon alternative to oil and natural gas

Source: Wood Mackenzie.

Advancements in battery technology are opening new markets

New applications of evolving technology create diversified growth opportunities



LiB cell	Cell phone	Laptop	E-bike	PHEV	EV	E-bus	ESS
6 Wh	10 Wh	50 Wh	500 Wh	15 kWh	40 kWh	300 kWh	100 MWh

Portable Electronics

- The first LiB was commercialised in 1991 by Sony after 20 years of research.
- Lithium cobalt oxide (LCO) has been the cathode of choice for most applications, including mobile phones, laptops and tablets.

Electric Vehicles

- Early electric vehicles used LCO chemistries however there is now competition between a range of LiB cathode chemistries.
- Consumers demand longer ranges and the larger capacities to achieve this require more lithium.

Energy Storage

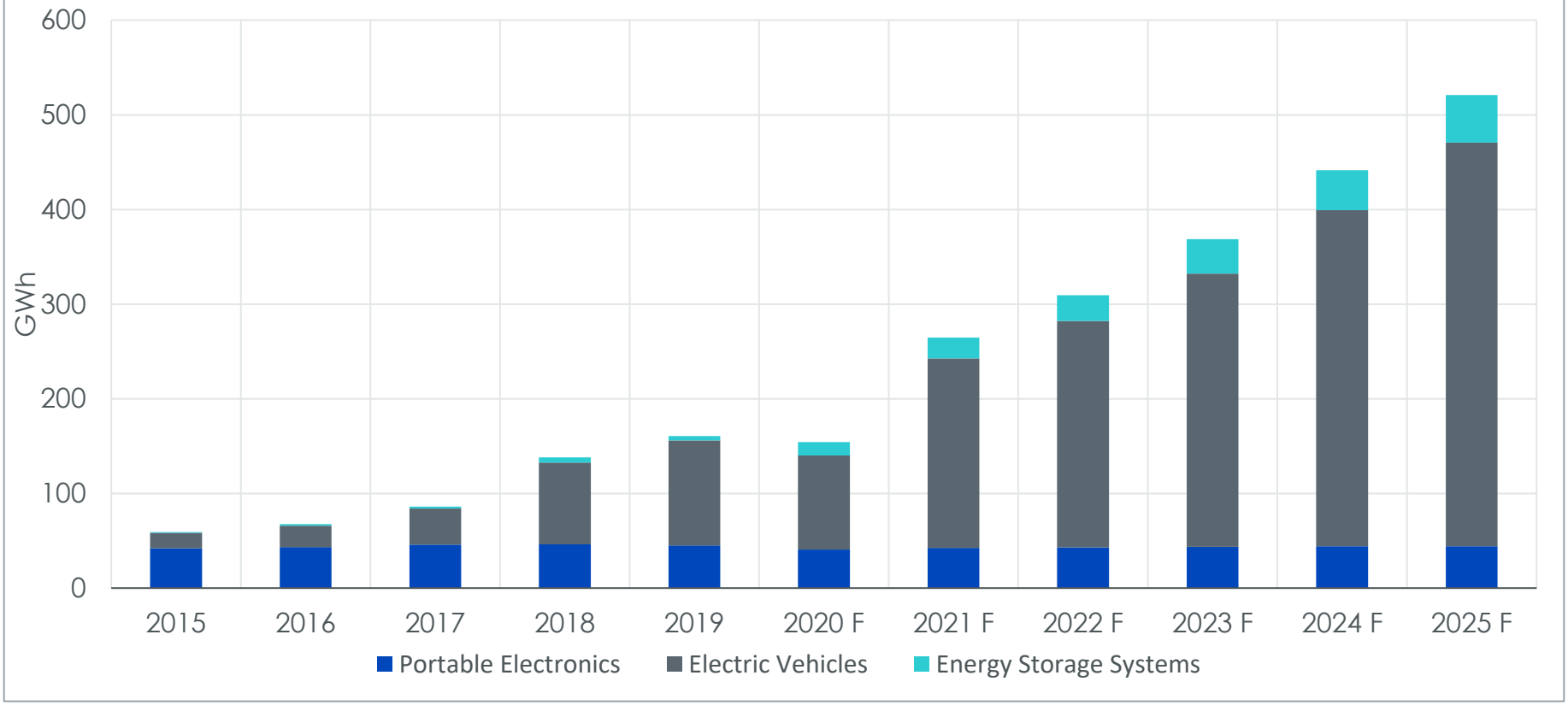
- With LiB successfully demonstrated in EVs, their use for energy storage systems has been a natural progression.
- The flexibility and simplicity of LiB energy storage systems (ESS) makes them ideal for supporting renewables to deliver flexible power and distributed power.

Source: Wood Mackenzie.
Please Note: LiB - Lithium ion Batteries; LCO - Lithium Cobalt Oxide, EV - Electric Vehicle, PHEV - Plug-in Hybrid Electric Vehicle, ESS – Energy Storage System.

Electric vehicles are expected to drive battery growth

Electric vehicles have already taken over portable electronics as main source of demand

Total storage demand by sector



Source: WisdomTree, Wood Mackenzie, forecasts from 2020.

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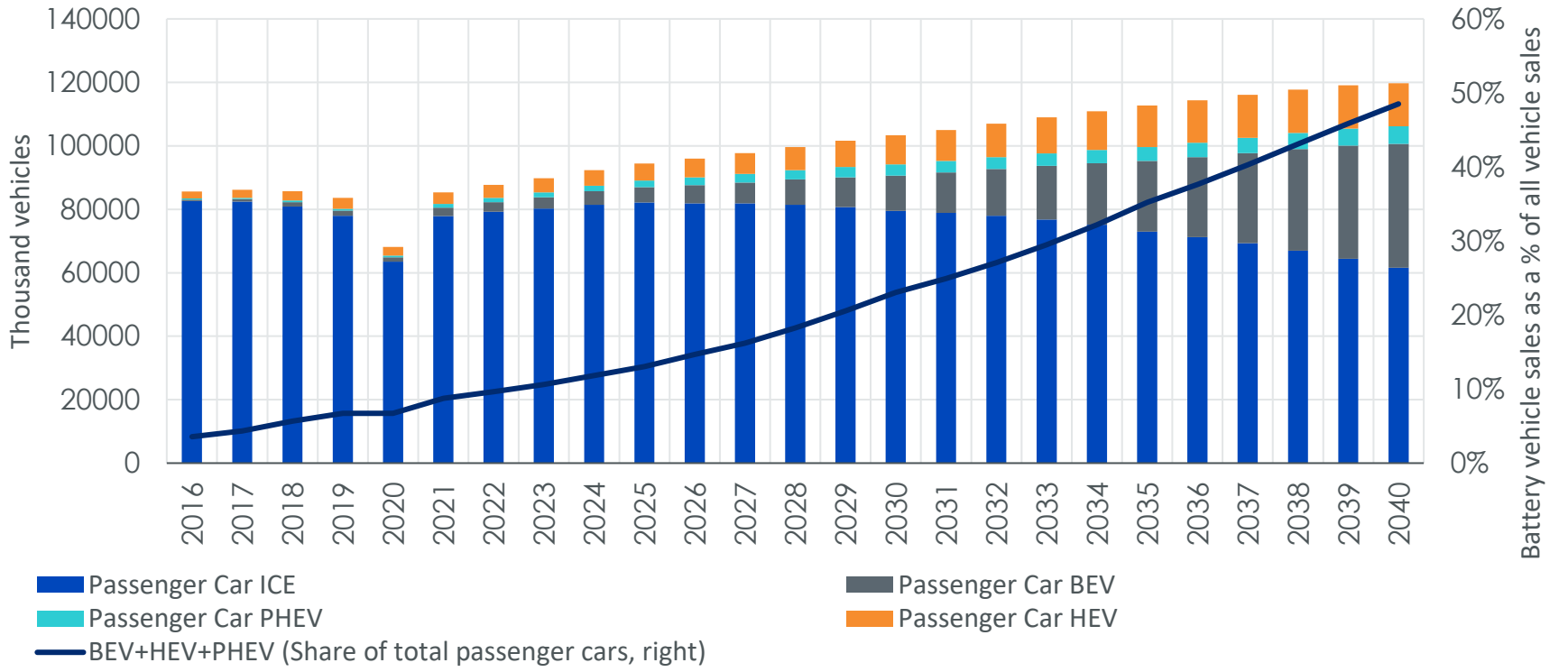
Electric vehicles are expected to drive battery growth

As a proportion of all car sales, BEV + PHEV car sales likely to grow from 5% to 50%

Global passenger car sale forecasts



ICE = Internal Combustion Vehicle, BEV = Battery Electric Vehicle, PHEV = Plug-in Hybrid Electric Vehicle, HEV = Hybrid Electric Vehicle, PC = Passenger Cars

Source: WisdomTree, Wood Mackenzie, forecasts from 2020.

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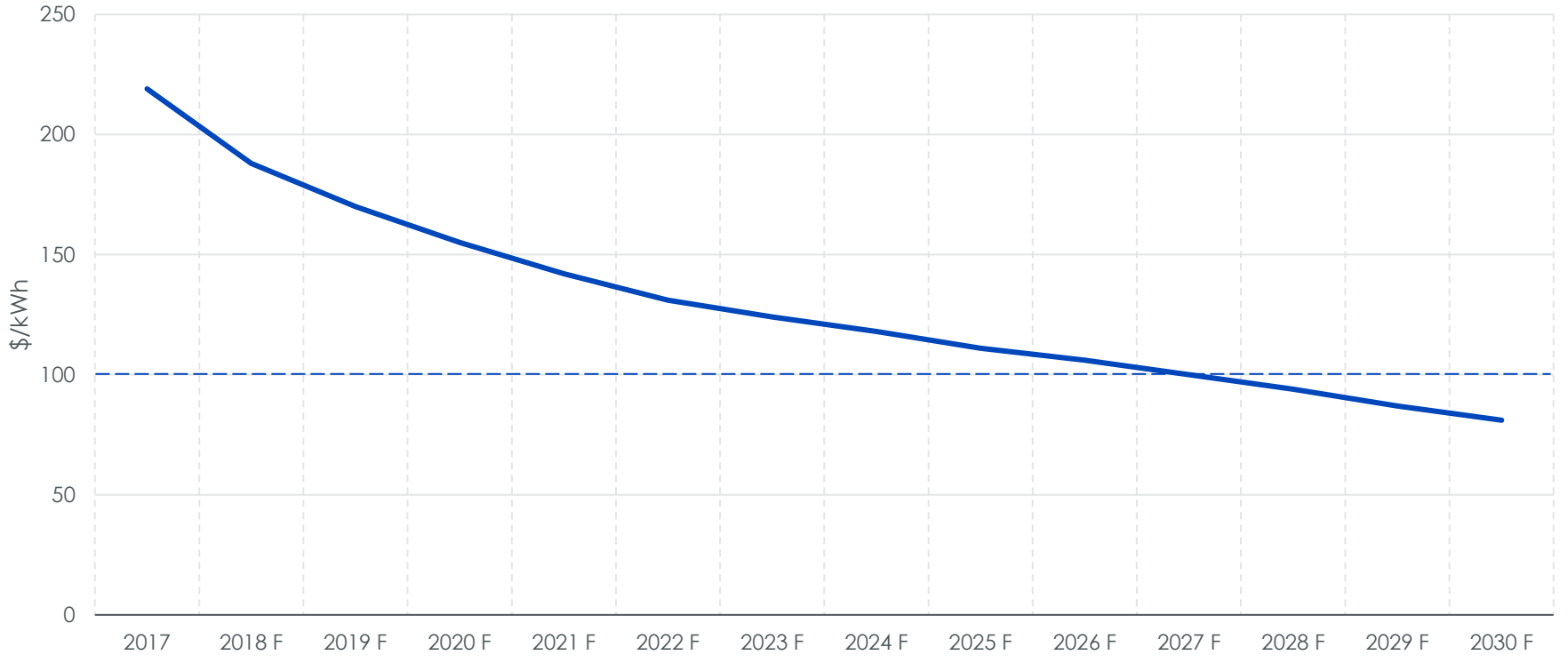
Falling costs are enabling the adoption and growth of batteries

Battery costs could halve in the next decade

Lithium-ion Battery Cost Forecasts

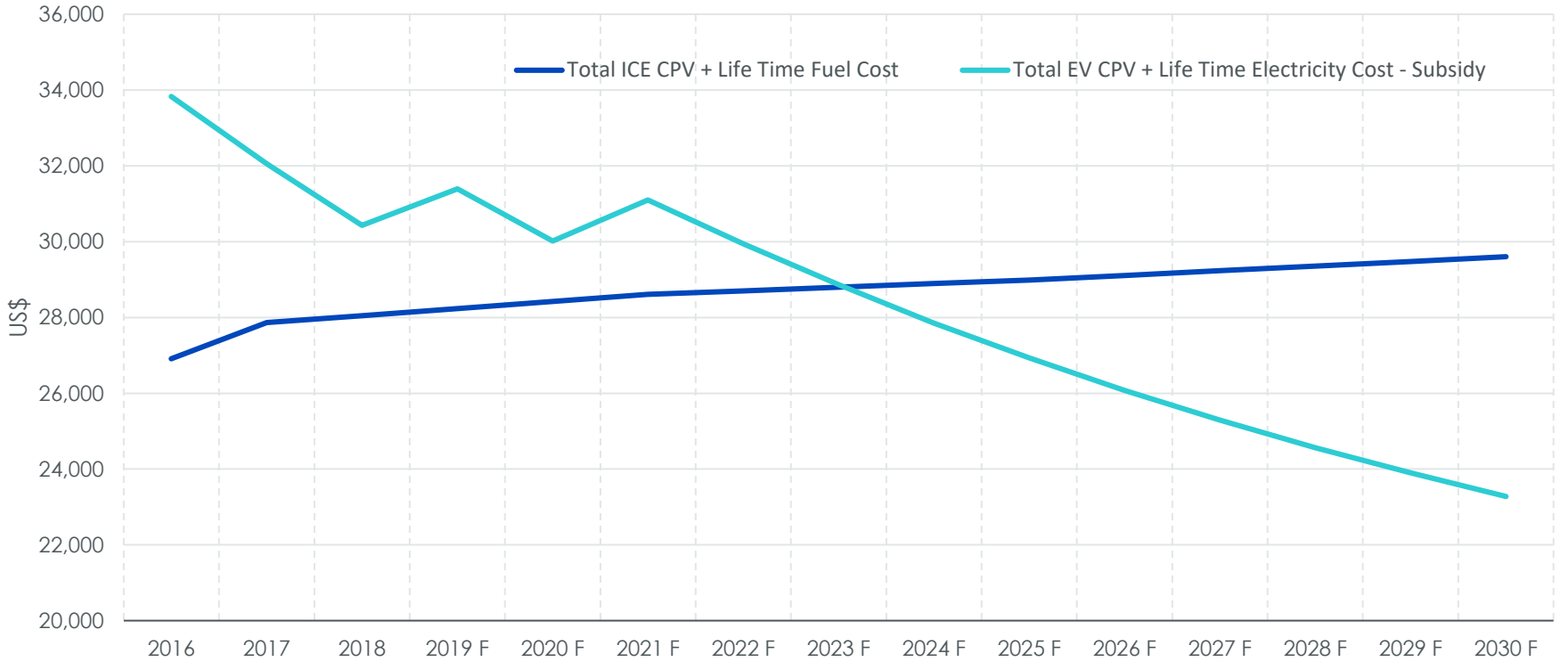


Source: WisdomTree, Wood Mackenzie, forecasts from 2018.
$100/kWh is considered an important tipping point for battery adoption.
Forecasts are not an indicator of future performance and any investments are subject to risks and uncertainties.

Electric vehicles are quickly becoming economically viable

By 2023 the total cost of owning an electric vehicle could rival an internal combustion vehicle

Total cost of ownership forecasts



ICE = Internal Combustion Vehicle, EV = Electric Vehicle, CPV = current purchase value.

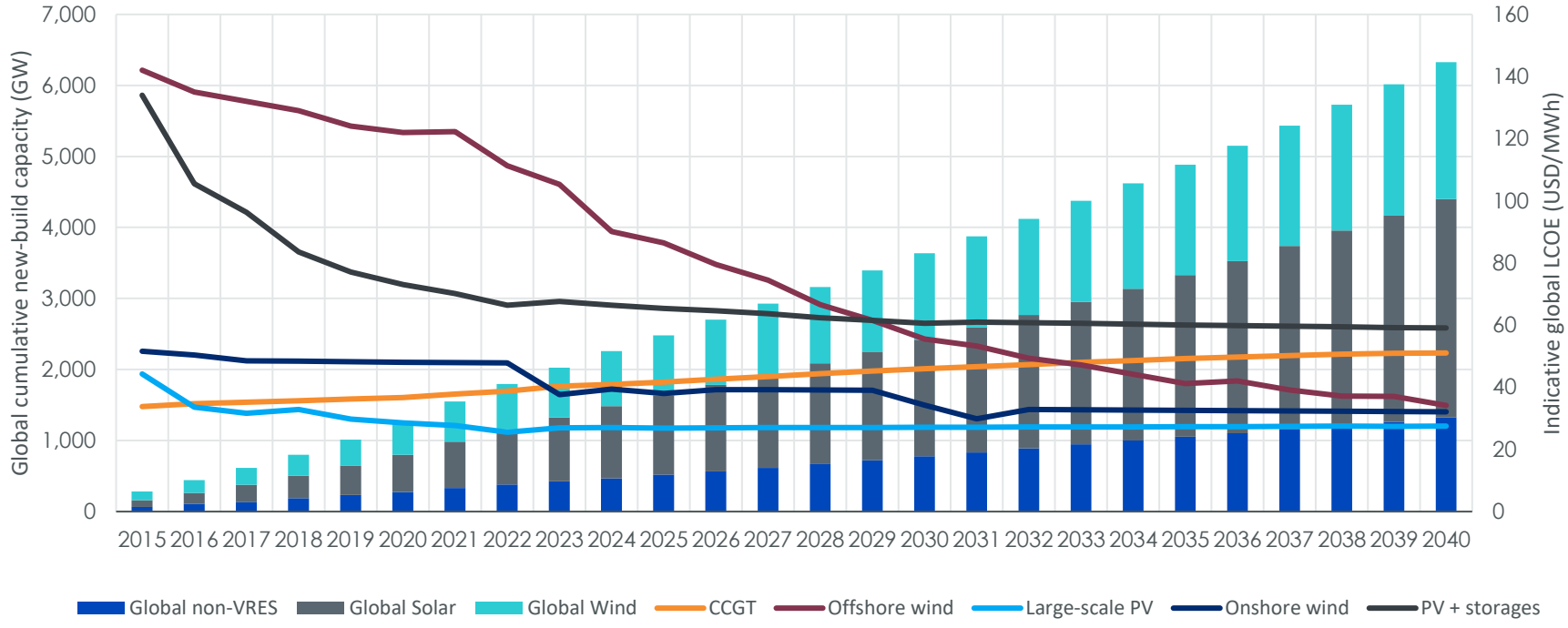
Source: WisdomTree, Wood Mackenzie, forecasts from 2018.

Forecasts are not an indicator of future performance and any investments are subject to risks and uncertainties.

Global renewable energy has a strong growth forecast

Large-scale PV is already cost competitive with gas-fired power based on indicative global LCOEs

Global new-build capacity & indicative LCOE**: gas vs solar and wind



- **non-VRES** (variable renewable energy) encompasses all renewable power generation technologies that are nonwind or solar-based
- **PV –** Photo Voltaic **; CCGT** = combined cycle gas turbine ; **CAGR** - Compounded annual growth rate

** **LCOE** - Levelized Cost of Electricity

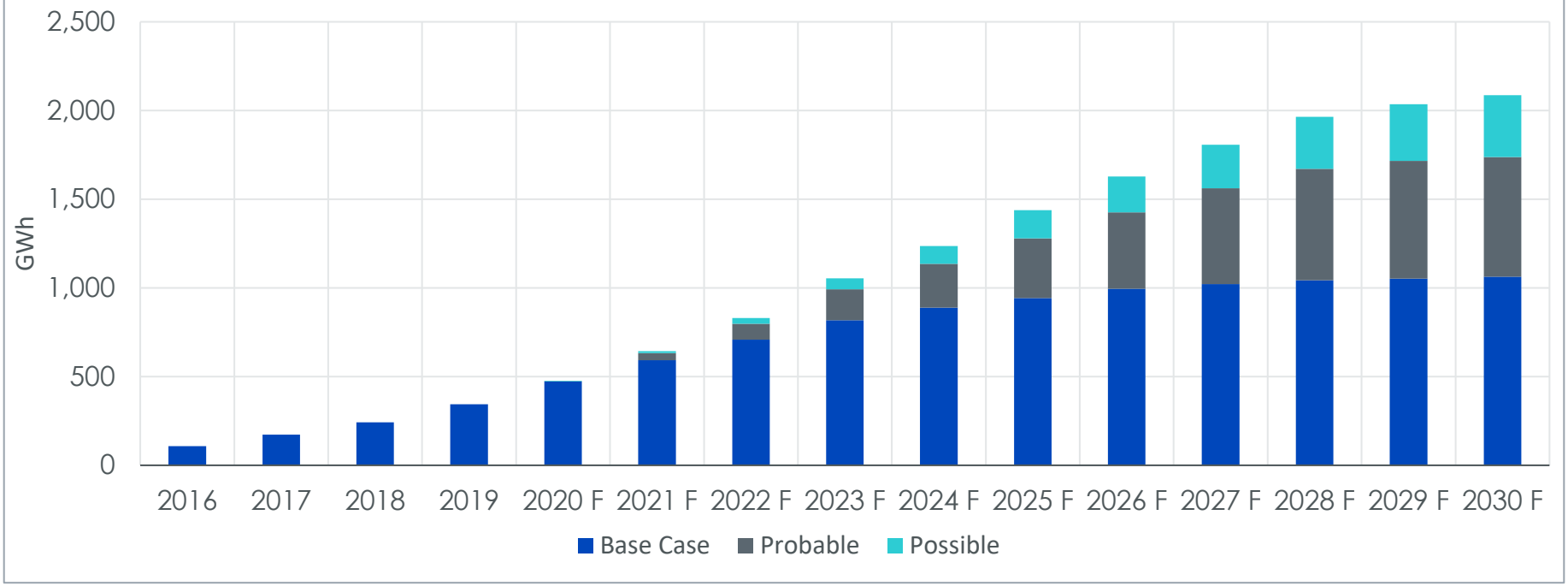
Forecasts are not an indicator of future performance and any investments are subject to risks and uncertainties.

Source: Wood Mackenzie

Battery capacity is building to meet its growing demand

Whole value chain needs to grow with rising scale of battery manufacturing capacity

Lithium-ion battery call manufacturing capacity



Probable: Projects that are high in priority within their owners' project portfolios, but have yet to secure permitting and / or financing. It is assumed that projects in this category will not experience significant challenges in obtaining permitting and financing. These projects are typically well-advanced in planning and scope.
Possible: Projects comprise two principal groups. Firstly, projects owned by the established producers that appear low in their project development portfolios. Secondly, projects owned by the aspirant companies that may be at scoping stage, or show marginal economics or simply experiencing difficulty with financing. In general, projects in this category have greater risks associated with their development that result in longer lead times.

Source: WisdomTree, Wood Mackenzie, forecasts from 2020.
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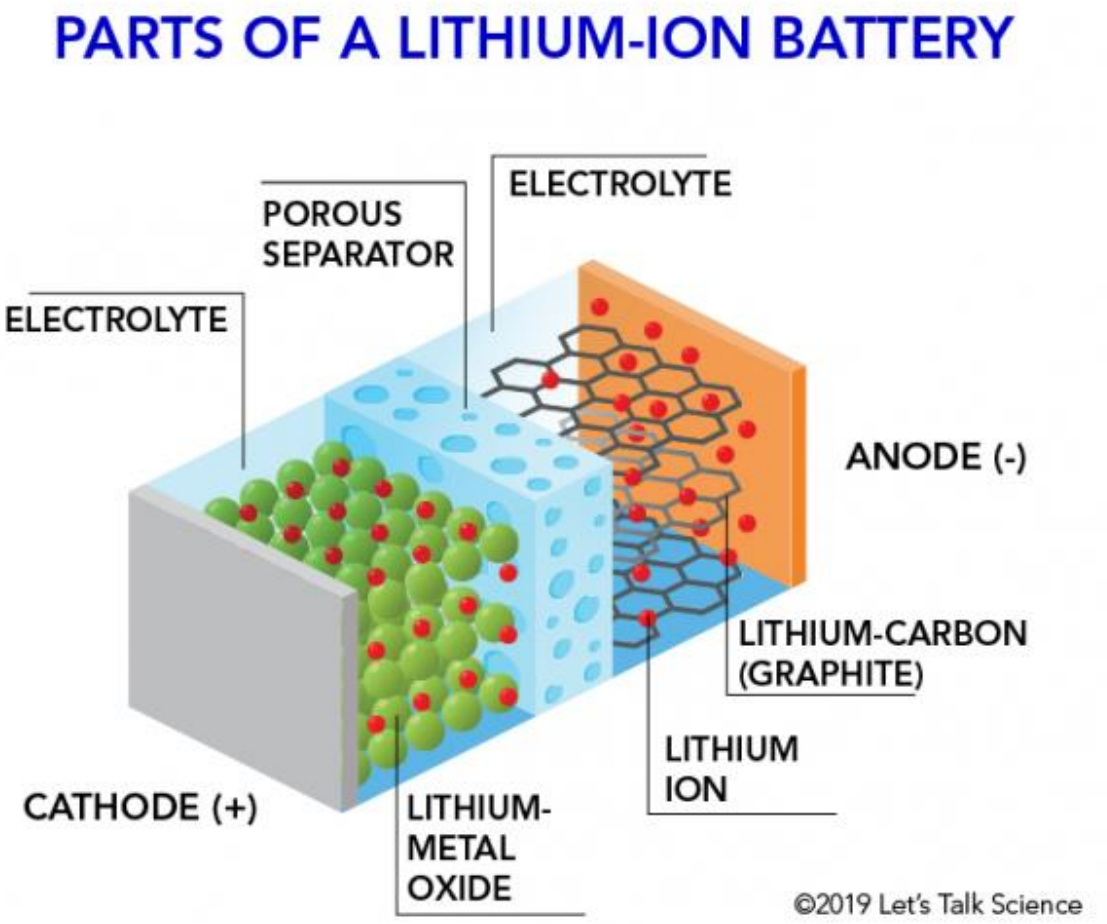
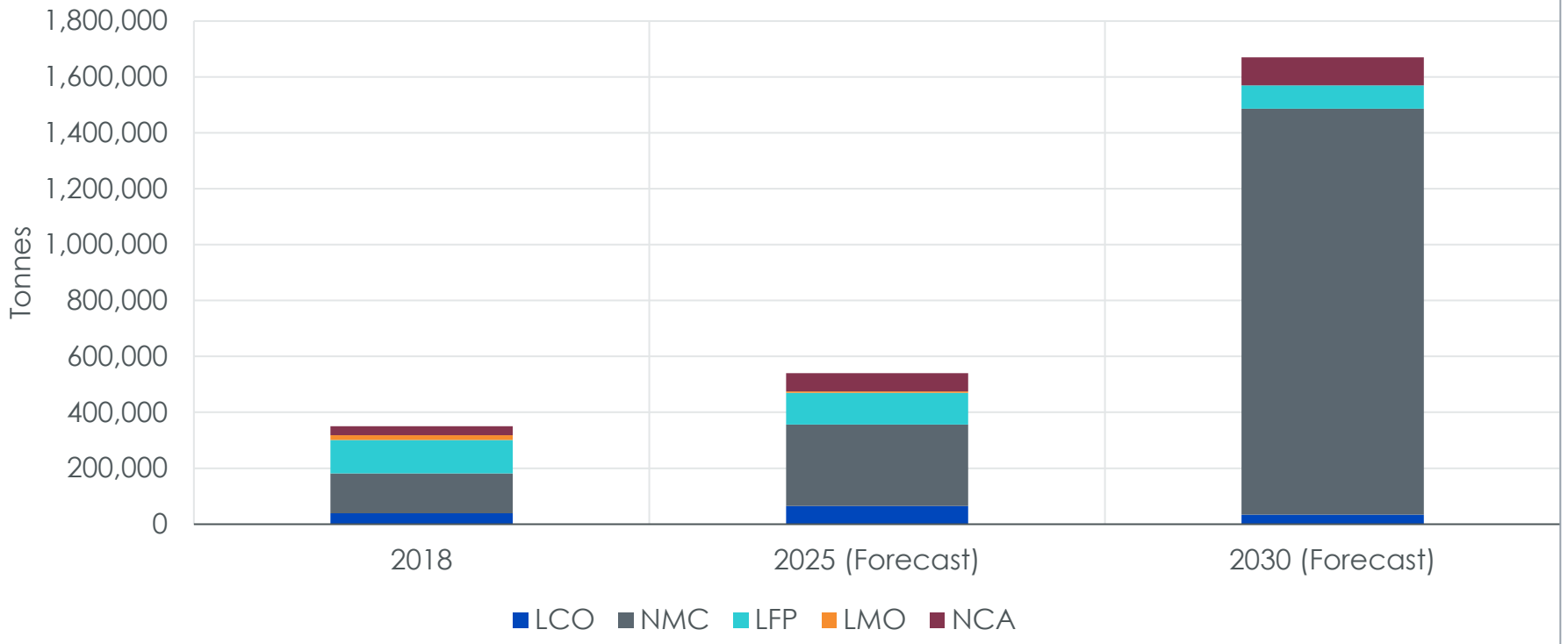
Cathode and anode active materials, electrolytes, and separators



Source: Let's Talk Science

Nickel-based cathodes expected grow

Cathode active materials in lithium-ion batteries



Lithium Cobalt Oxide (LCO), Lithium Nickel Manganese Cobalt Oxide (NMC), Lithium Nickel Cobalt Aluminium Oxide (NCA), Lithium Manganese Oxide (LMO) and Lithium Iron Phosphate (LFP)
Source: Avicenne Energy 2019

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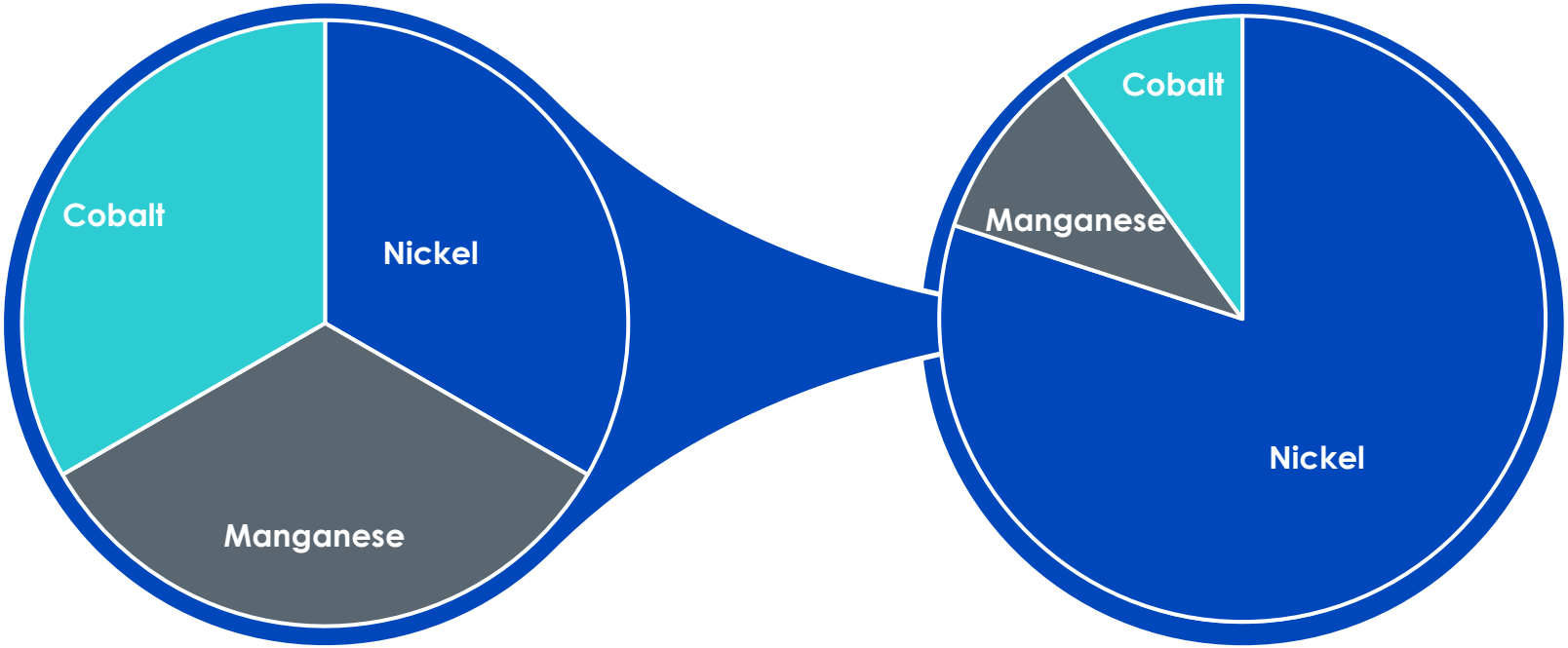
Nickel content of NMC cathodes in transition

Pre-2017 NMC cathodes were equal weight

Technological solutions allow for a 8:1:1 ratio



NMC = Nickel, Manganese, Cobalt

Source: WisdomTree

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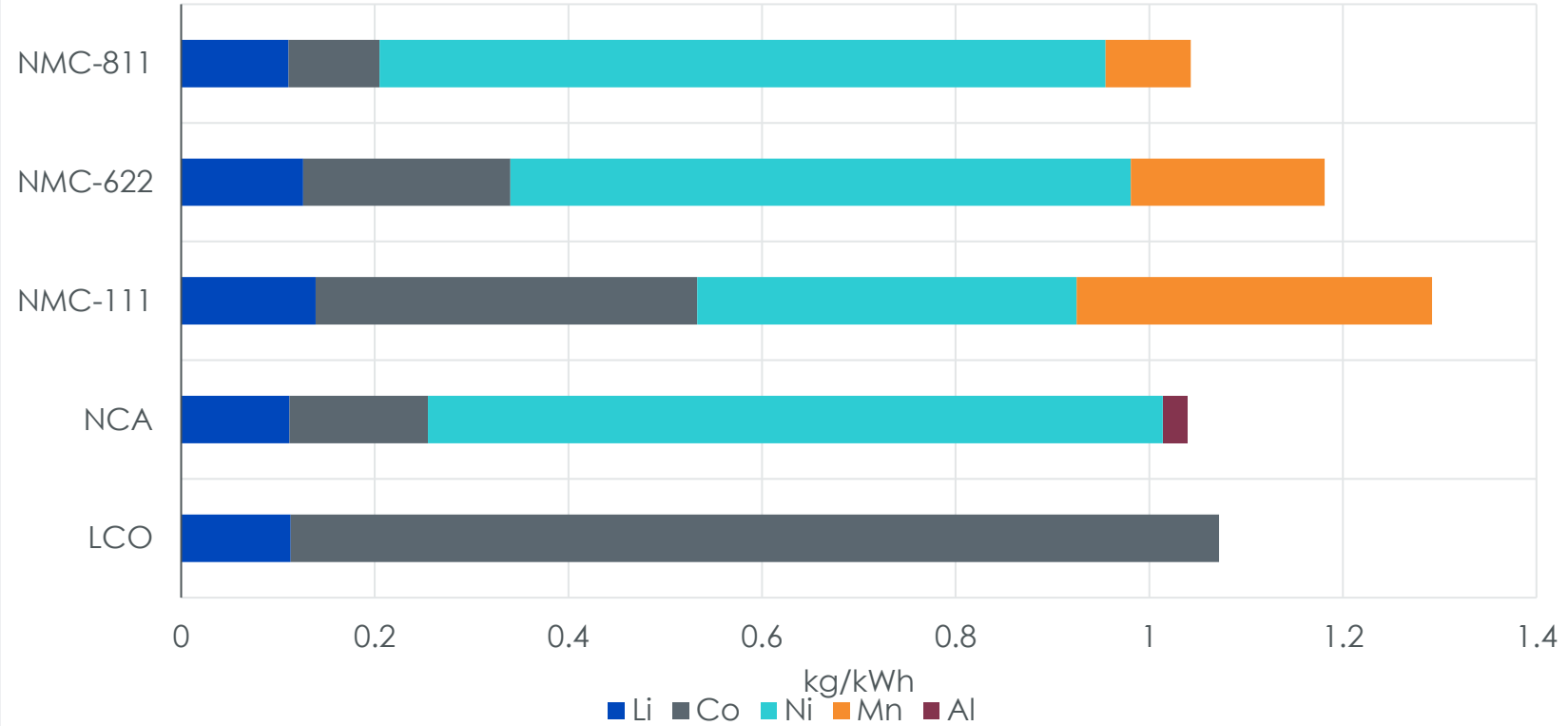
Nickel-dominant chemistries provide higher energy density

Element requirements in kg/kWh



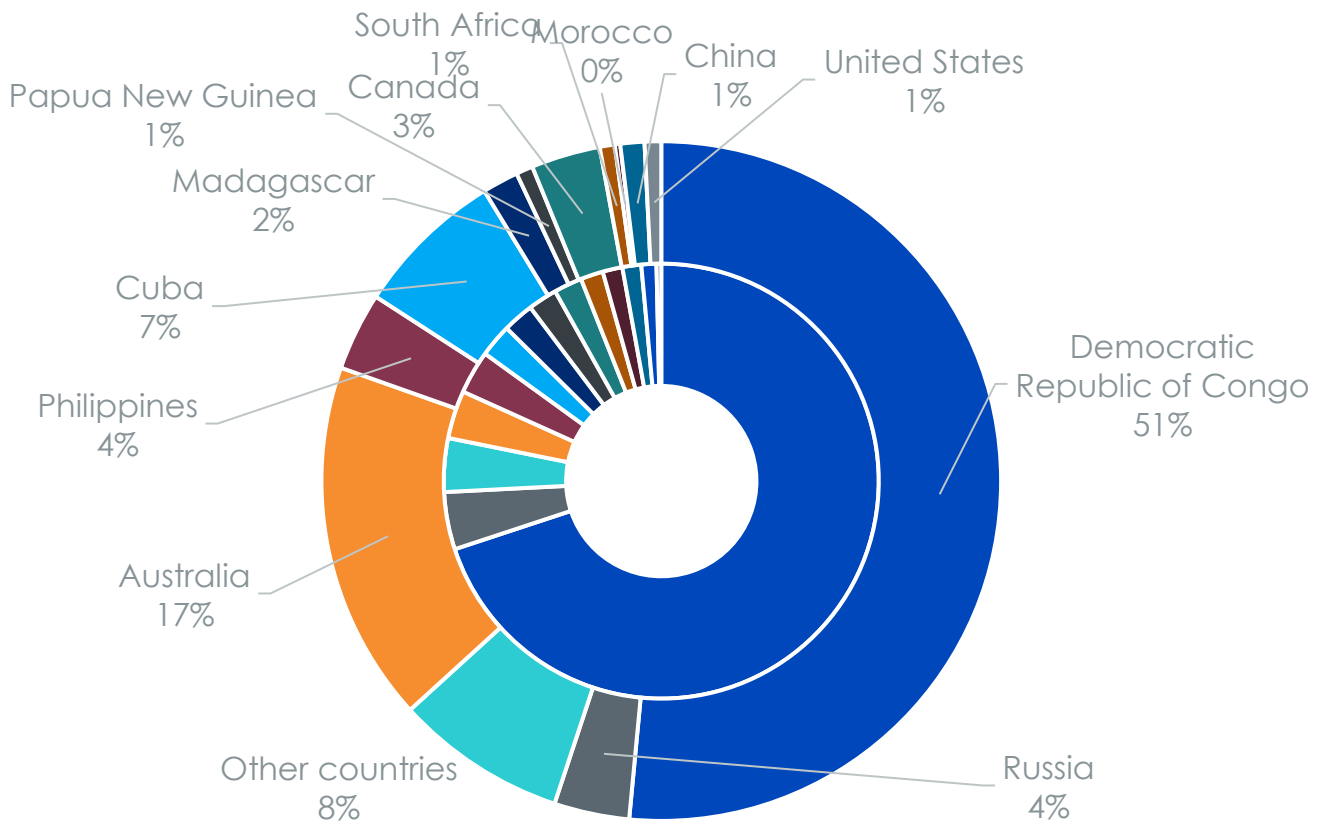
Source: Research Interfaces who have plotted data from "Lithium-Ion Battery Supply Chain Considerations: Analysis of Potential Bottlenecks in Critical Metals" by Fu et al.

Li- lithium, Ni – nickel, Co- cobalt, Mn – Manganese, Al – Aluminium

Historical performance is not an indication of future performance and any investments may go down in value

Cobalt production highly concentrated

World cobalt mine production and reserves (2019)

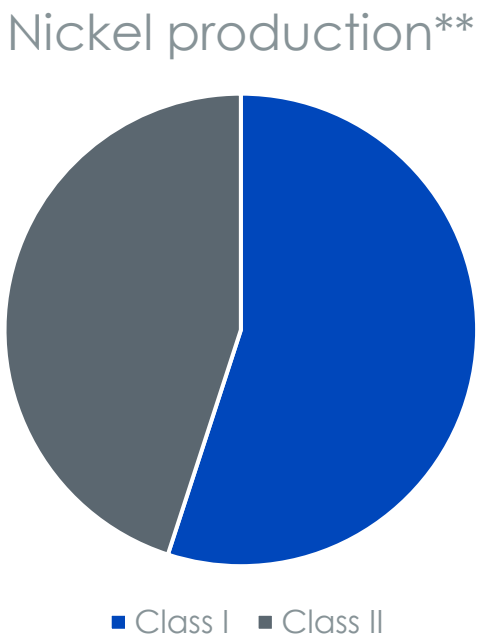


Source: US Geological study, WisdomTree, data available as of September 2020; Outer circle: reserves. Inner circle: 2019 production

Historical performance is not an indication of future performance and any investments may go down in value.

More than 2 million tonnes of nickel ore mined each year*, but is all suitable for batteries?

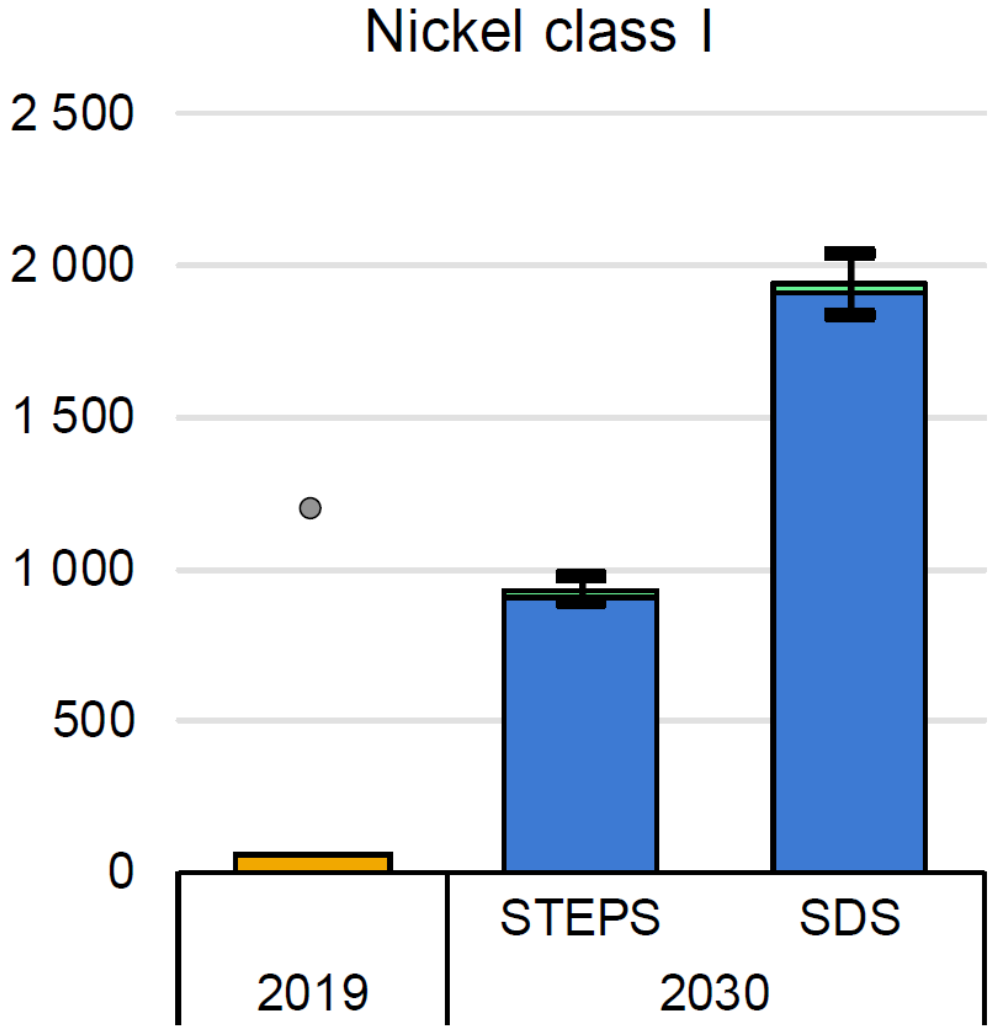
+ Nickel Class I describes a group of nickel products comprising electrolytic nickel, powders and briquettes, as well as carbonyl nickel.
+ Nickel Class II comprises nickel pig iron and ferronickel. These nickel products commonly have a lower nickel content and are used especially in stainless steel production, where stainless steel producers take advantage of the iron content.



*Source: International Nickel Study Group, **Source: Nickel Institute

Historical performance is not an indication of future performance and any investments may go down in value

Annual demand from EV deployment 2019-2030 in Thousand Tonnes



STEPS = Stated Policies Scenario (which incorporates existing government policies)
SDS = Sustainable Development Scenario (fully compatible with the climate goals of the Paris Agreement)
For the low cobalt case: 10% NCA, 10% NMC 622 and 80% NMC 811
For the high cobalt case: 11% NCA and 76% NMC 622, 13% NMC 811. The central value is an average of these two cases.

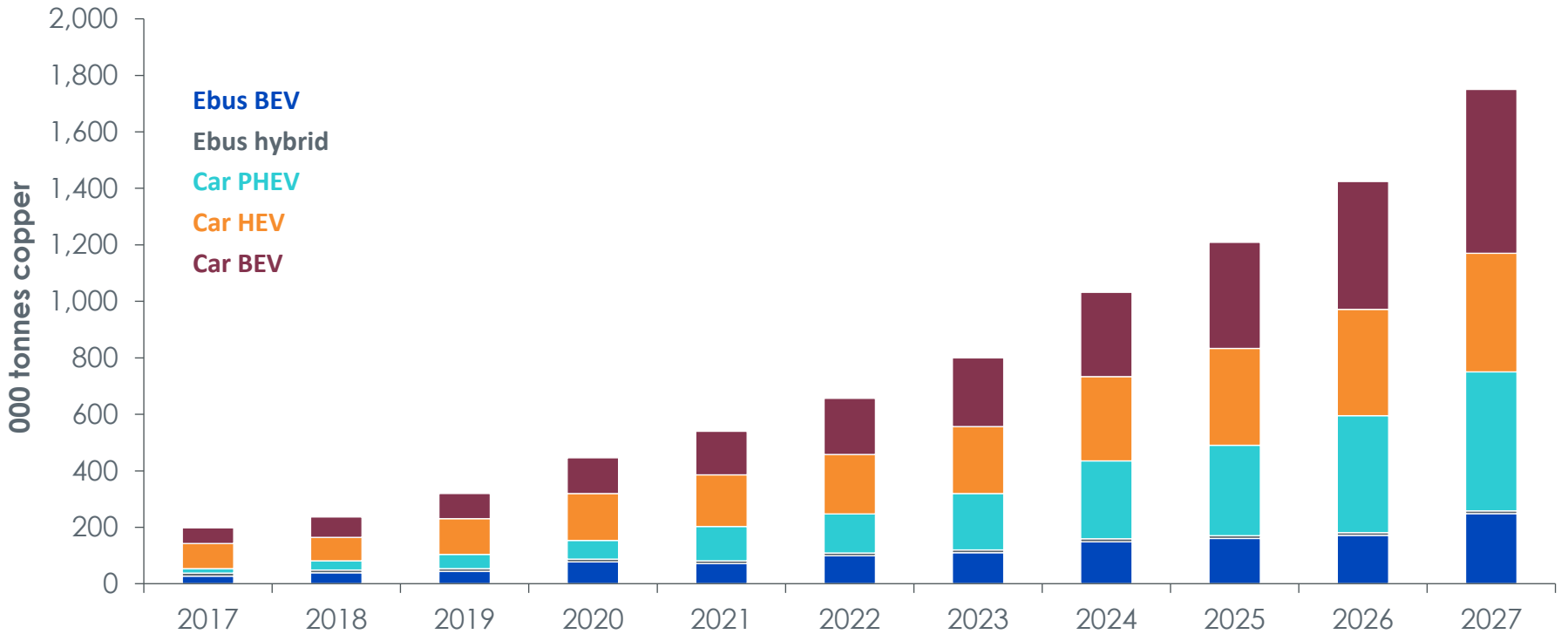
- Heavy duty
- Light duty
- Historical
- Variability for chemistry
- Current supply

Source: International Energy Agency

Historical performance is not an indication of future performance and any investments may go down in value

EVs may also boost copper demand

Electric vehicle copper demand forecasts



Source: International Copper Association, WisdomTree, data available in February 2020. Definitions on next slide.

Forecasts are not an indicator of future performance and any investments are subject to risks and uncertainties.

Key and assumptions

Internal combustion engine	23 kg of copper
Hybrid electric vehicle (HEV)	40 kg of copper
Plug-in hybrid electric vehicle (PHEV)	60 kg of copper
Battery electric vehicle (BEV)	83 kg of copper
Hybrid electric bus (Ebus HEV)	89 kg of copper
Battery-powered electric bus (Ebus BEV)	224–369 kg of copper (depending on the size of the battery)

Source: International Copper Association, data available in February 2020

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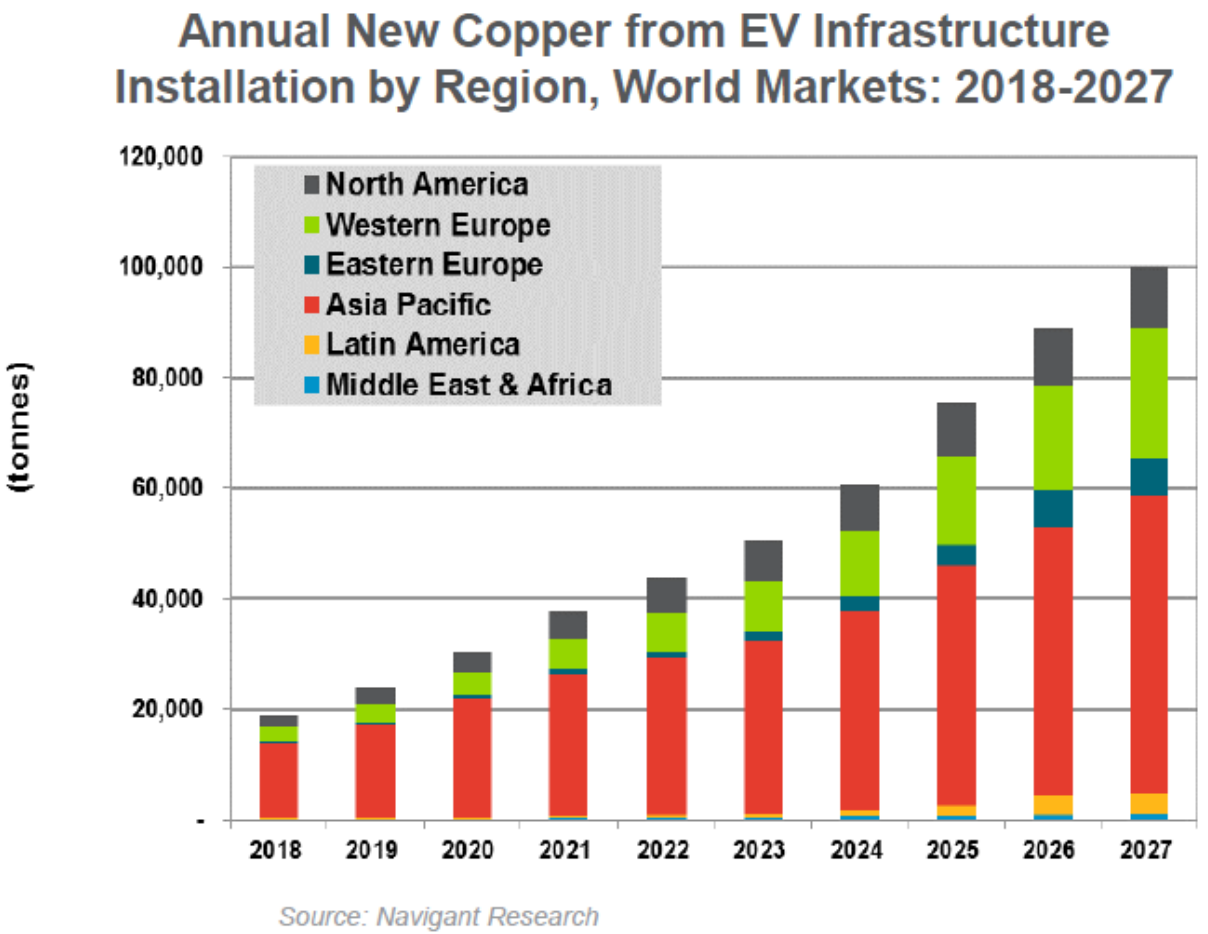
Copper wiring demand to rise with growing electric vehicle (EV) infrastructure demand



Source: Navigant Research, 2018

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Intelligent Exposure to a theme with exciting growth prospects

Breaking Down the Battery Value Chain

Raw Materials

Mining | **Chemicals**

Companies that focus on raw materials mining or extract chemicals specifically used for BESS*

Manufacturing

Processed Materials | **Cell and Pack**

Companies that process materials and build components such as Anode, Cathode for BESS*

Application

Production | **End-use**

The link in the value chain that drives demand

Emerging Technology

New Storage Technology | **New Application**

Companies that develop new storage technologies or apply BESS* in new applications

Enablers

Recycling | **Inverters** | **Charging Infrastructure** | **Grid Edge**

Companies that develop the building block components for BESS* and the ecosystem that supports its usage

Source: Wood Mackenzie, WisdomTree.
***BESS** is Battery and Energy Storage Solutions.

Appendix – Definitions

Decarbonisation policies in the EU – It has set mandatory internal climate targets for 2020 and 2030, which commit its member states to significantly reduce their greenhouse gas emissions, increase the share of renewable energy sources and improve their overall energy efficiency. (European Commission 2013)

LiB – Lithium ion Battery. Is a type of a rechargeable battery. Lithium-ion batteries are commonly used for portable electronics and electric vehicles. They are also growing in popularity for military and aerospace applications. Its key advantages are high energy density and low maintenance, while its limitations are transportation restrictions.

ICE - Internal Combustion Vehicle

BEV - Battery Electric Vehicle

PHEV - Plug-in Hybrid Electric Vehicle

HEV - Hybrid Electric Vehicle

PC - Passenger Cars

PV – Photovoltaic System. Photovoltaic systems (PV systems) are a renewable energy technology which transforms the energy from the sun into electricity using photovoltaics. These photovoltaics, also known as solar panels, provide a reliable green energy solution.

non-VRES (variable renewable energy) – encompasses all renewable power generation technologies that are nonwind or solar-based

LCOE - Levelized Cost of Electricity. is a measure of a power source that allows comparison of different methods of electricity generation on a consistent basis.

CAGR - Compounded annual growth rate

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