MATERIALS CHALLENGES FOR LI-ION BATTERY

WORLD MATERIALS FORUM 2021

June 2021

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WORLD MATERIALS FORUM

ARKEMA
INNOVATIVE CHEMISTRY

SERVING SUSTAINABILITY THROUGH TECHNOLOGICAL INNOVATION

WHY ELECTRIFICATION ?

→ **COP21/Paris agreement : hold global temperature rise well below 2°C by 2100**

→ **Road transportation being 21% of total CO2 emissions, electrification is a key solution**

"Cradle-to-Grave" CO_2 emissions
Up to -75% for electric vehicle vs Thermal vehicle

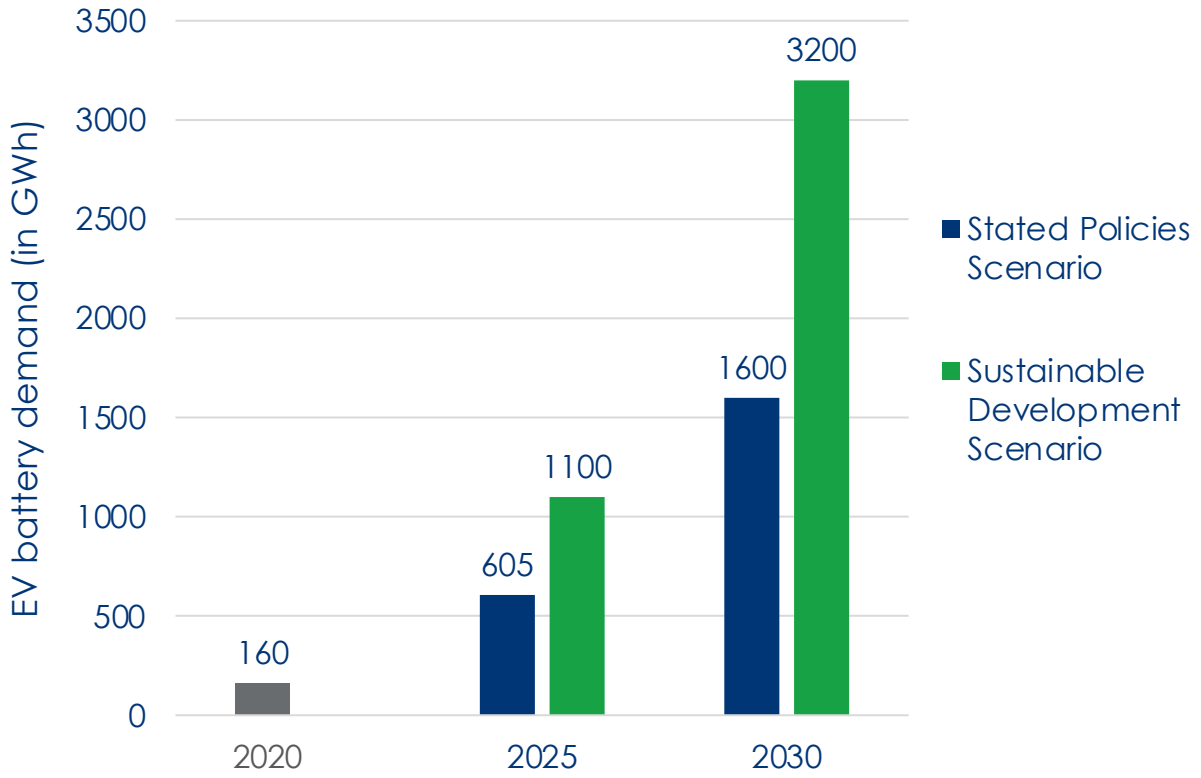
"Well-to-Wheel" CO_2 emissions
52Mt CO_2-eq avoided in 2020 thanks to EV

Source: International Energy Agency, 2021

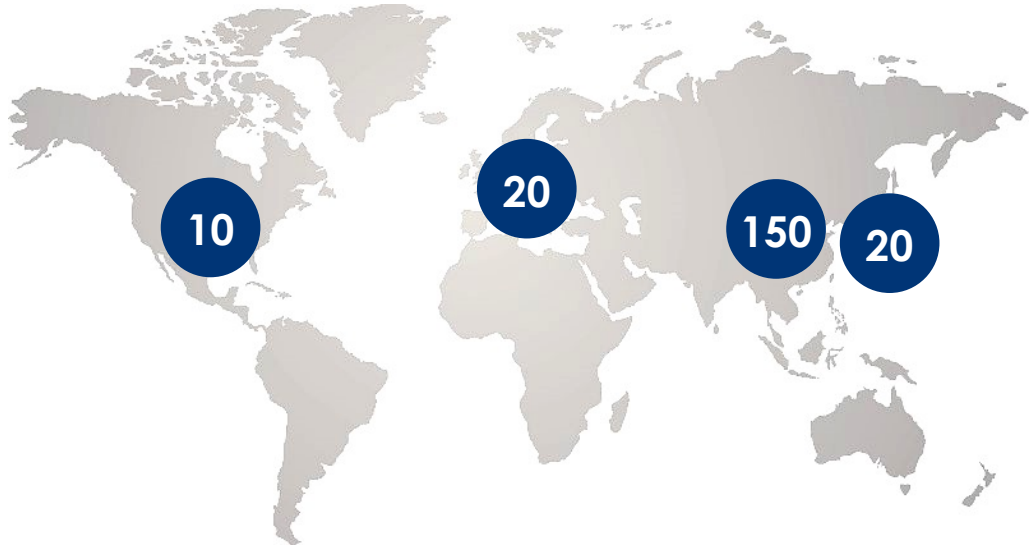
LI-ION BATTERY DEMAND DRIVEN BY EXPONENTIAL GROWTH OF EV

→ **In 2020 +40% EV sales worldwide in 2020 - 10 million EV on the roads**

EV battery demand, by scenario



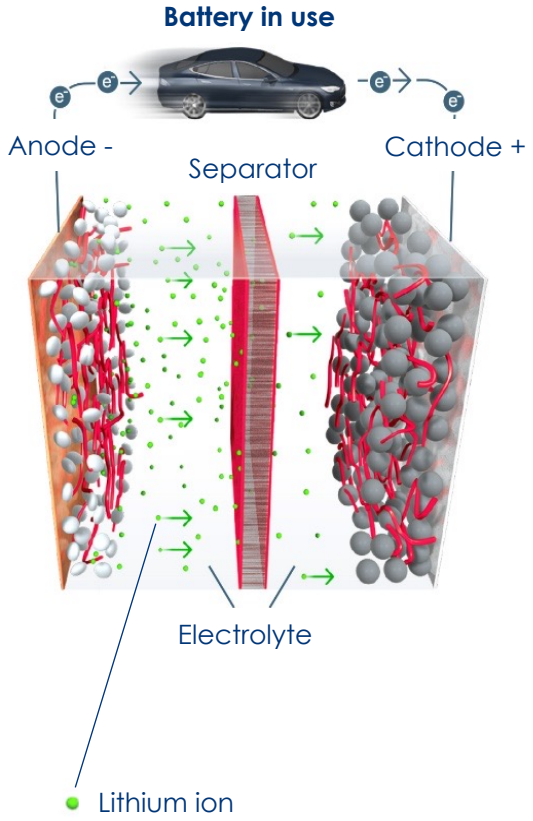
>200 Gigafactories planned



3,400 GWh production capacity announced for 2030

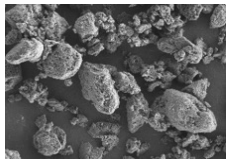
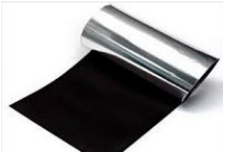
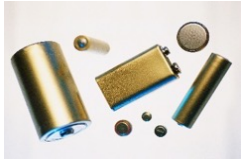
Source: International Energy Agency, 2021

WHAT IS A BATTERY AND WHO ARE THE PLAYERS (PARTICIPANTS WMF) ?



The battery value chain

Mining → Materials → Electrodes Separator Electrolyte → Cells → Modules Packs → Battery management system → Recycling and re-use

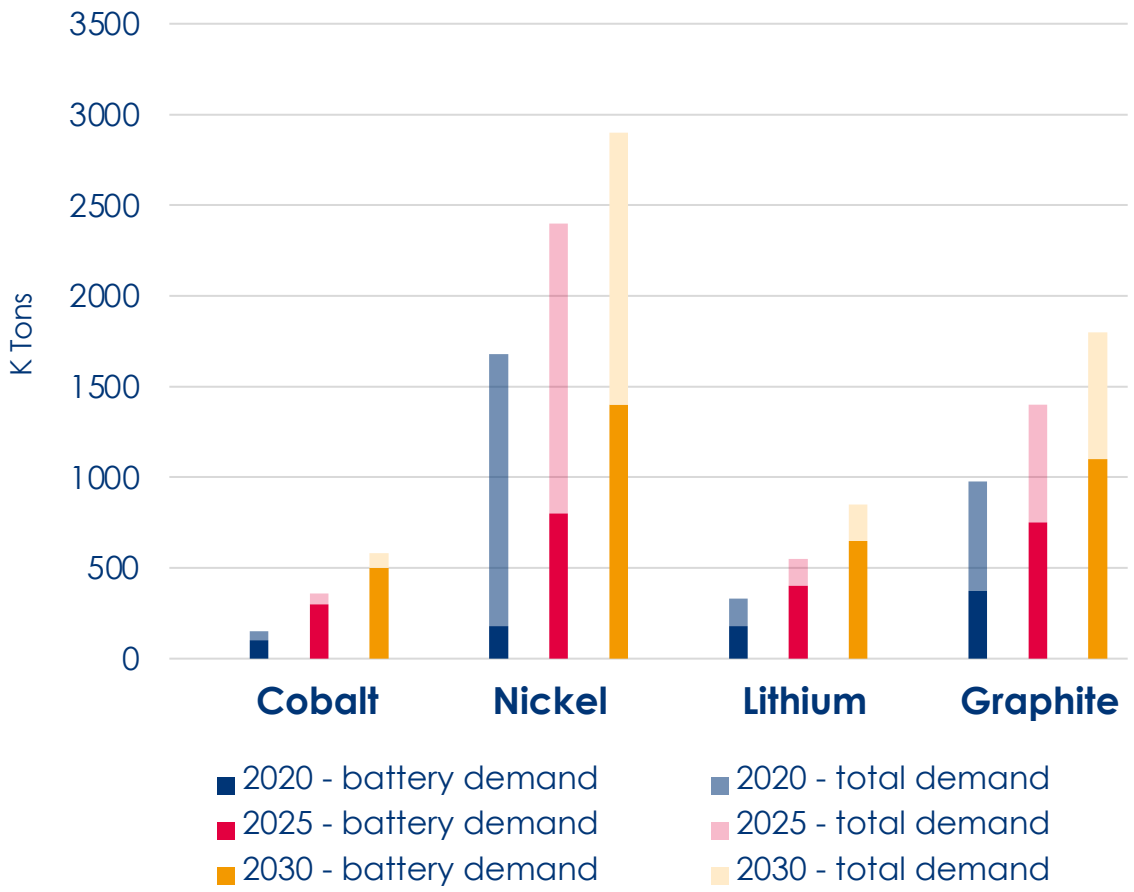
Mining companies	Chemical companies	Battery companies	OEM	All
MP MATERIALS	umicore	northvolt	RENAULT Passion for life	SUEZ
JX Nippon Mining & Metals	BASF The Chemical Company	CUBERG		VEOLIA
ANGLO AMERICAN	ARKEMA	saft a company of TOTAL	BMW	
IVANHOE MINES	SOLVAY	SEPIOL TECHNOLOGIES	STELLANTIS	MOMENTUM TECHNOLOGIES
		NAWA TECHNOLOGIES		
		Zeta ENERGY		

Universities and research institutes: Université de Lorraine, Stanford, Monash University, Berkeley University of California

Energy providers: Hydro Québec, EDF

RAW MATERIALS DEMAND, SCARCITY OF RESOURCES AND RECYCLING

Evolution of raw materials demand



Source: Benchmark Mineral Intelligence, Avicenne, IAE, 2020

Scarcity of raw materials, especially cobalt and nickel, drives :

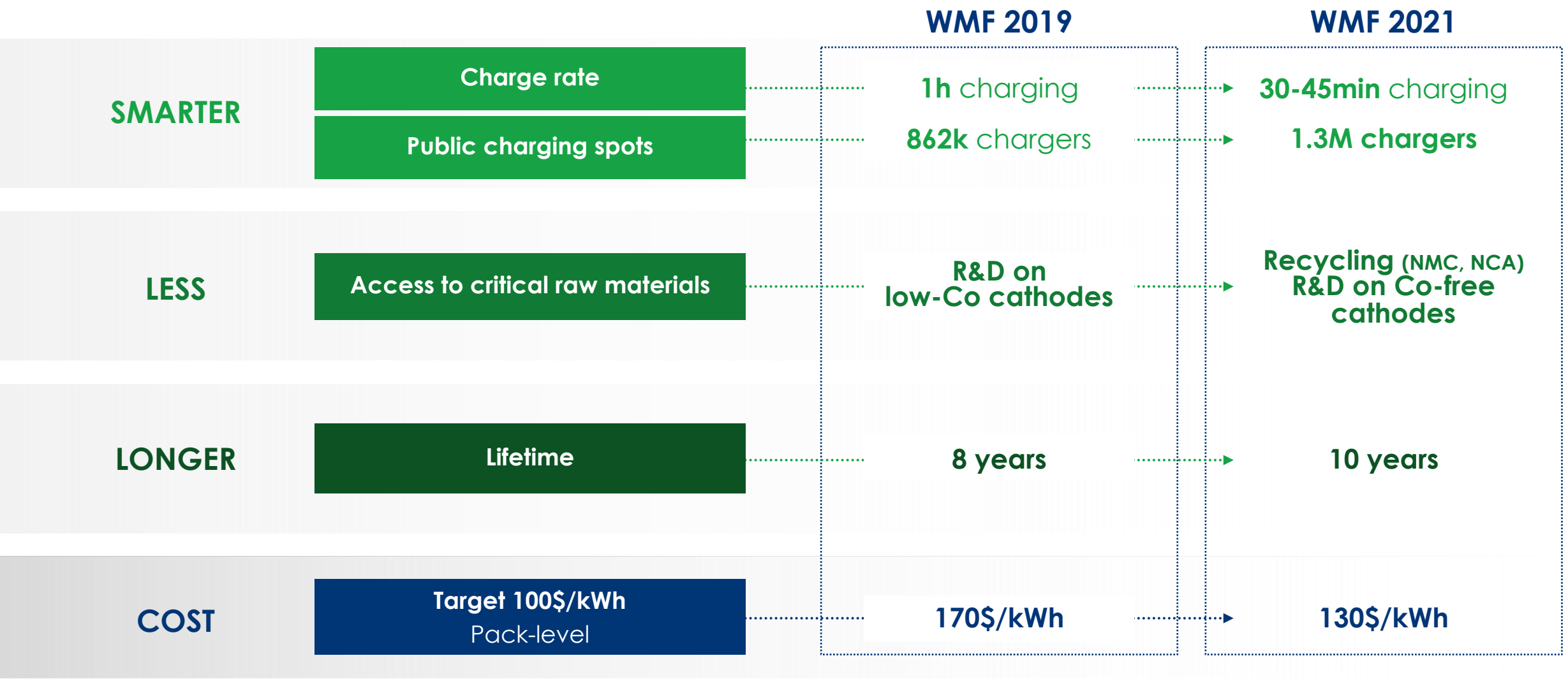
→ **RECYCLING**

- To secure raw materials supply availability
- To address environmental impact
- To improve economics

→ **COBALT-FREE CATHODE CHEMISTRIES**

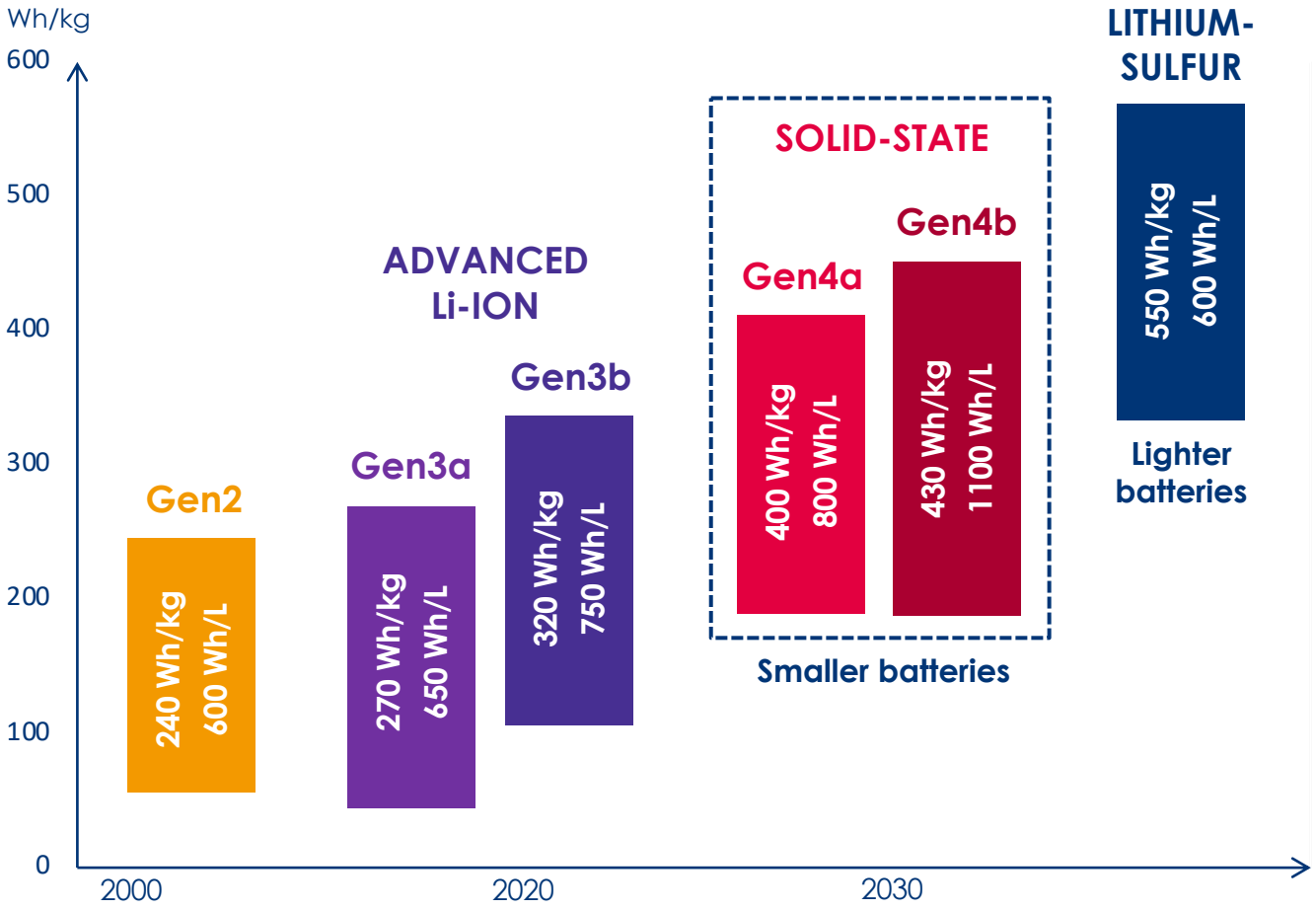
- LFP, LMFP, LNMO, NMx, …

OVERCOMING MATERIAL EFFICIENCY CHALLENGES FOR LITHIUM-ION BATTERIES



LI-ION BATTERY TECHNO ROADMAP

→ **Key performance driver : energy density increase**



Other drivers

→ **Sustainability**

→ **Safety**

→ **Cost**

LITHIUM VS HYDROGEN : WHO IS THE CHAMPION FOR E-MOBILITY ?

Li-ion Battery Electric Vehicle		H_2 Fuel Cell Electric Vehicle
≈ **300km** driving range		**> 500km** driving range
> 30 - 45 min charging		**A few min** charging
1.3M public charging stations WW		**600 charging stations** WW

Already cost-competitive
Vs thermal for
urban cars

Sweet spot for trucks : **H_2 will match thermal cost in 2025**

→ **Both techno will significantly evolve. Complementary rather than competing**

ARKEMA JOURNEY TO SUSTAINABLE AND EFFICIENT BATTERIES

European Commission

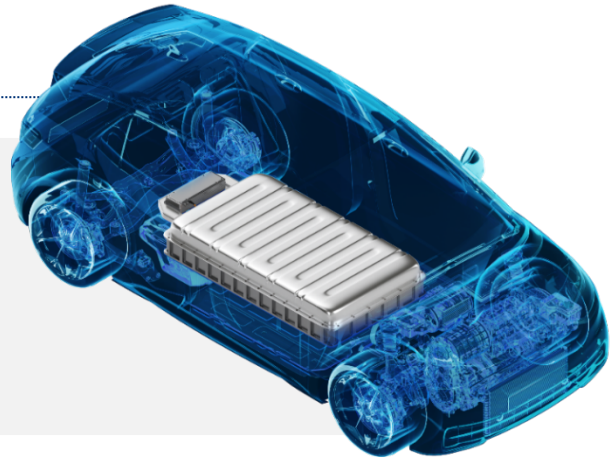
" The Commission puts forward a new future-proof regulatory framework on batteries to ***ensure that only the greenest, best performing and safest batteries make it onto the EU market*** *"*

Maroš Šefčovič / Commission Vice-President for inter-institutional relations

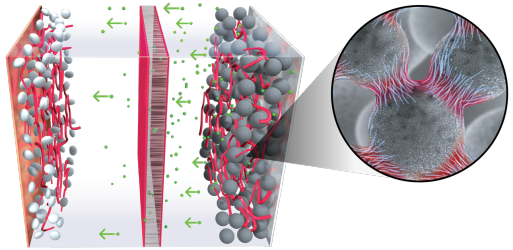
BATTERY SOLUTIONS FOR ELECTRIC VEHICLES BY ARKEMA

BATTERY SOLUTIONS BY ARKEMA

Unique value offer of high-performance materials for inside and outside of the battery cell



CELL



FORANEXT®
Ultra Pure LiFi Salt and LTDI additive for electrolyte salts

KYNAR®
PVDF Binder for electrode and separator coating

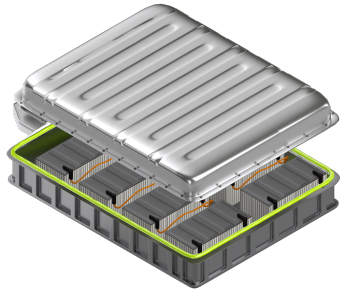
GRAPHISTRENGTH®
Carbon nanotubes conductive additive

MODULE

PIEZOTECH®
Piezolectric polymers for monitoring sensors

BOSTIK®
Smart adhesives for cell-to-cell and cell-to-module bonding

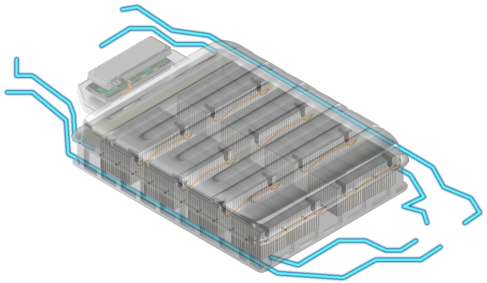
PACK



KEPSTAN® PEKK
Thermoformable for high resistant parts

ELIUM®
Thermoplastic composites pack casing

THERMAL MANAGEMENT



RILSAN® & RILSAMID®
PA11 & PA12 for battery cooling circuit

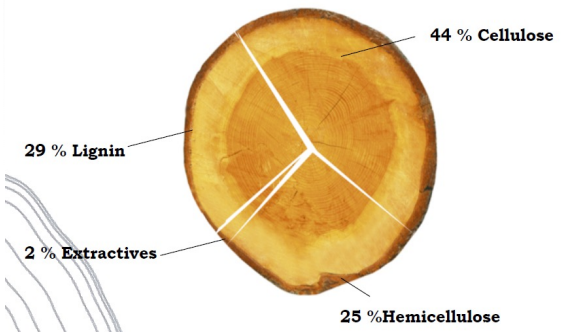
FORANE®
Immersion cooling solutions for battery thermal management

FROM CRUDE TALL OIL TO KYNAR® PVDF BINDER (patent pending)

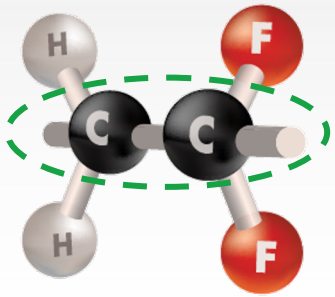
CRUDE TALL OIL

from pine trees in Scandinavia

Co-product of paper pulp industry



BIO-BASED ETHYLENE



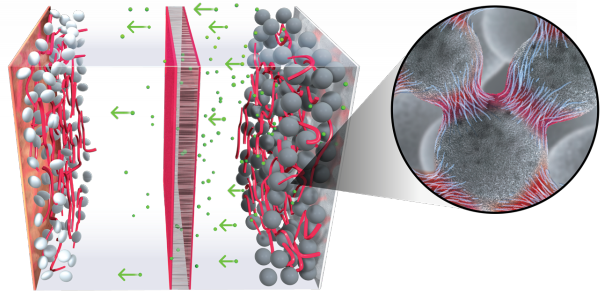
VF2 monomer

Polymerization Reactor

ARKEMA UNIQUE PROPRIETARY EMULSION PROCESS

Kynar® PVDF

- 100 % renewable attributed carbon certified
- Mass balance approach
- ISCC+ CERTIFIED



→ **Battery Binder with CO_2 footprint reduced by 20%**

LIFSI, A HIGH PERFORMANCE ECO-DESIGNED ELECTROLYTE SALT

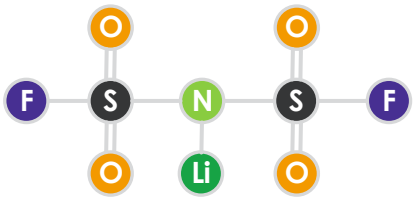
FORANEXT BY ARKEMA

→ Arkema is upscaling **high purity LiFSI** for battery electrolytes (liquid & solid)
High performance electrolyte salt for **fast charge, power performances and lifetime**

Eco-design advantages of LiFSI vs. classic electrolyte salt LiPF6

Less critical materials use

- → No Phosphorus
- → 3x less Fluorine vs LiPF6



Compatible with Co-free materials

- → Electrochemically stable up to 5V
- → Can be used with high-voltage LNMO cathode

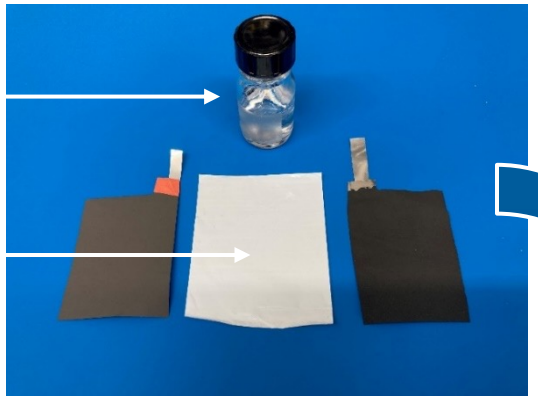
Recovery & Re-use

- → Recycling patented technology
- → Enables to recover Lithium

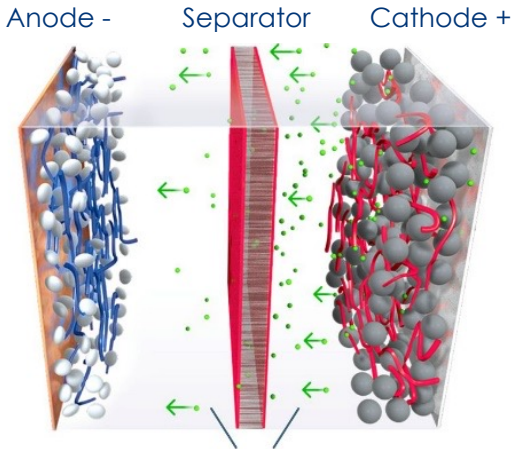
ARKEMA INNOVATION TOWARDS SOLID-STATE BATTERIES

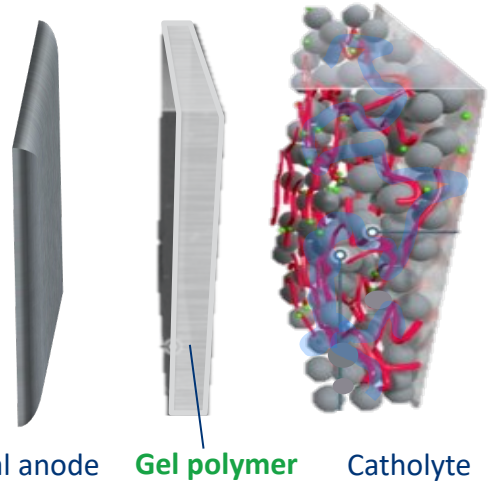
Liquid electrolyte injected in the cell

Conventional separator



Arkema gel polymer





→ **No electrolyte leakage + reduced flammability = SAFETY**

→ **Compatible with Li-Metal anode = ENERGY DENSITY**

TOGETHER FOR E-MOBILITY

WHY ?

Reducing CO_2 emissions

HOW ?

INNOVATION
Materials / Processes / Technologies
Solid-state batteries, Li-sulfur, Hydrogen, …

SUSTAINABILITY as the framework

WHO ?

Strong COLLABORATIONS needed along the value chain