The future of Electrolyte

A strategy to achieve high purity and high efficiency

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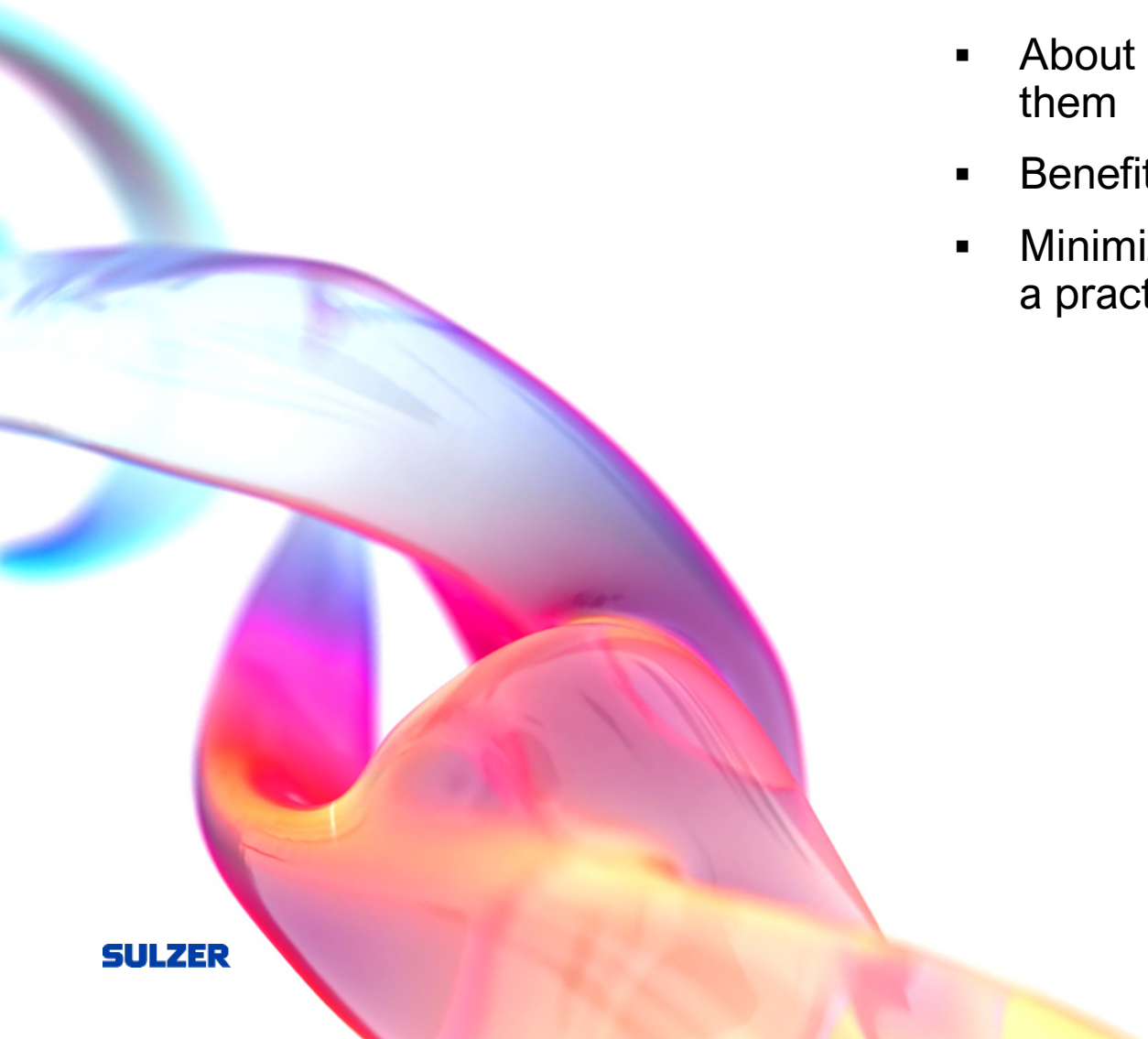
Agenda



- Melt crystallization principle
- About electrolytes, purification challenges and how to overcome them
- Benefits of crystallization: high purity and high efficiency
- Minimize energy consumption in electrolyte production: a practical example

Sulzer: global and agile

We combine reach with responsiveness

3.2
Billion sales (CHF) 2022

13’800
Employees

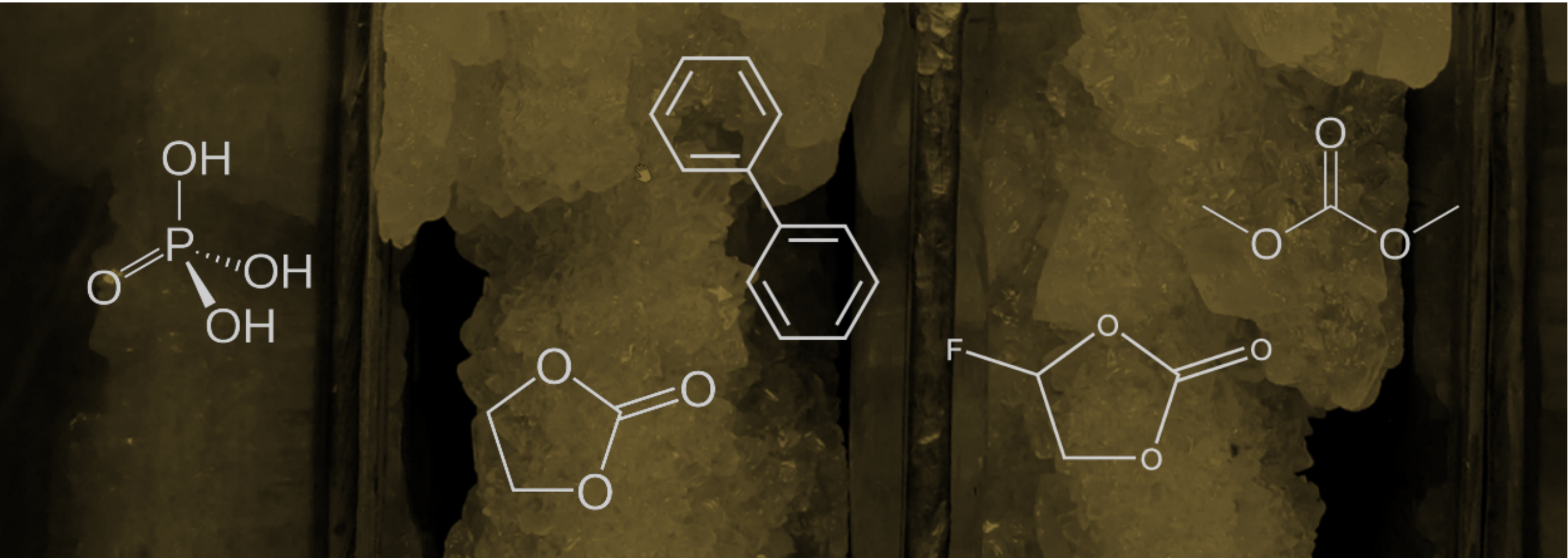
40
Production locations

140
Service centers

100
Countries with Sulzer presence

We supply mass transfer equipment and technologies to the industry

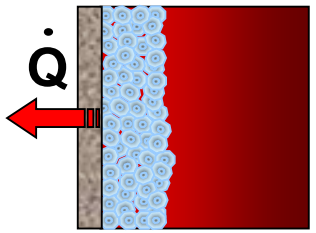
Electronic chemicals



Sulzer crystallization technologies

Fractional Solvent-free Melt Crystallization

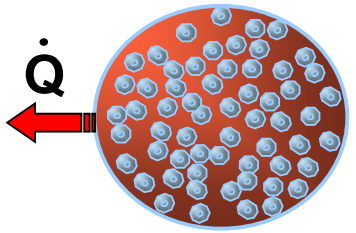
1 Layer Crystallization



Static

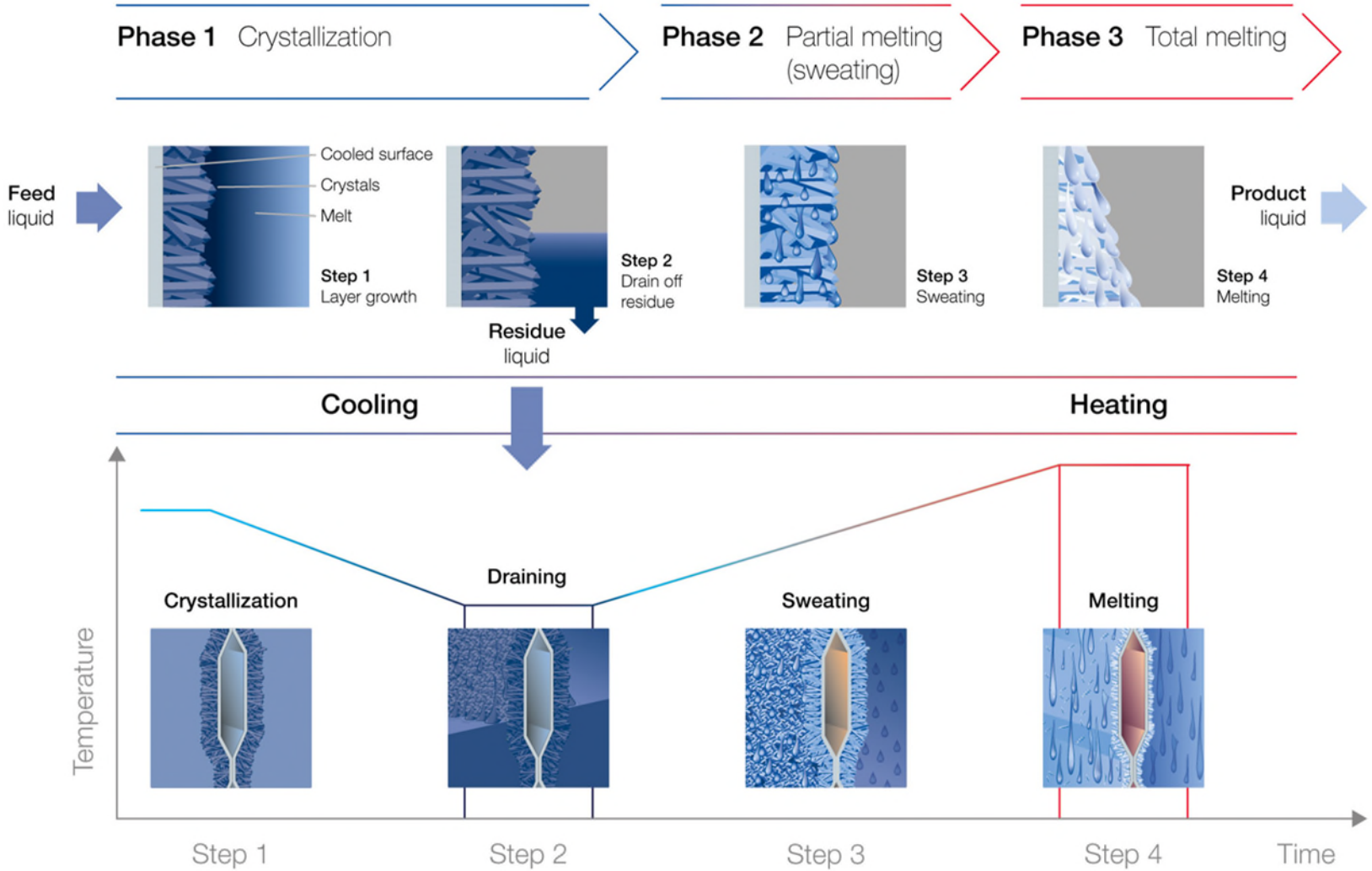
Falling Film

2 Suspension Crystallization



Suspension

Crystallization 101 – stage

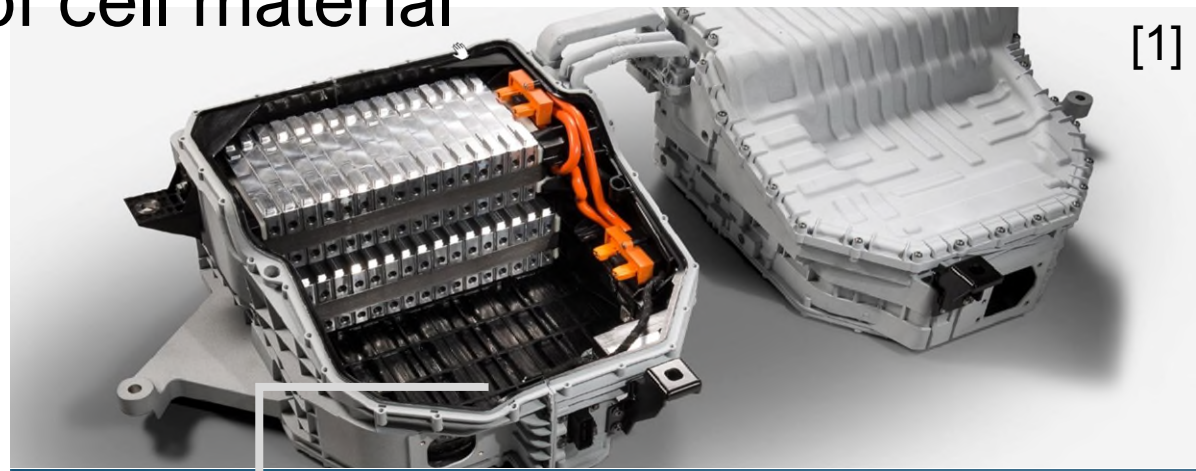


Lithium-Ion Battery: identification of cell material

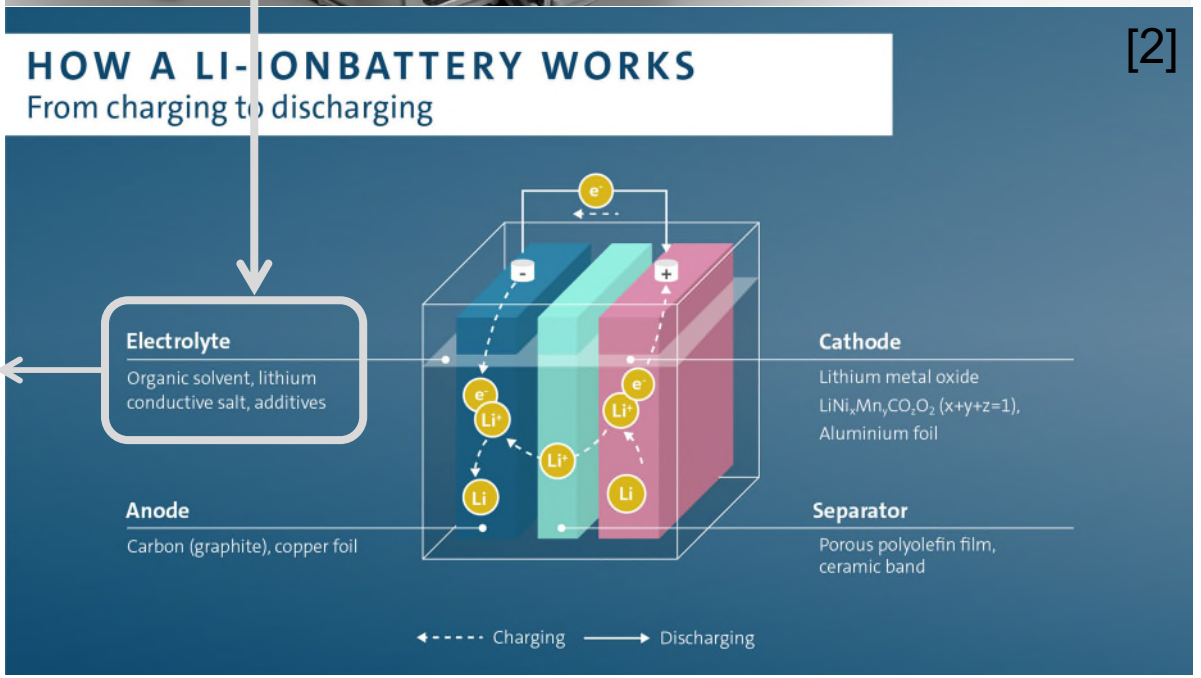
Breaking Down **Total Cost** of an EV Battery Cell

$101/kWh
Avg. Cell Cost in 2021

[3]



[1]



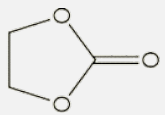
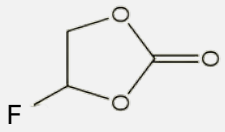
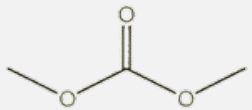
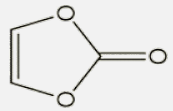
[2]

80% solvent
5% additives
15% salts

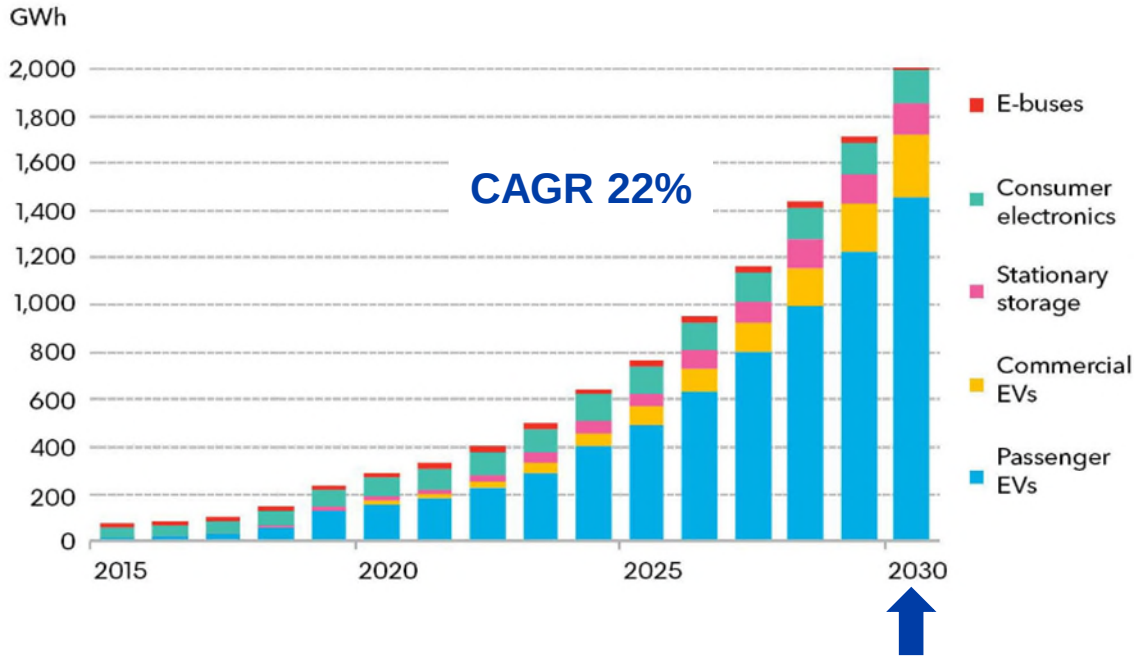
[1] from "BASF Battery Offering"
[2] from Battery cell assembly: pilot line started | Volkswagen Newsroom (volkswagen-newsroom.com)
[3] from Breaking Down the Cost of an EV Battery Cell (visualcapitalist.com)

CO_2-based organic carbonates for Li-ion batteries

Green electrolytes to foster energy decarbonization

Ethylene carbonate (EC)	Fluoroethylene carbonate (FEC)	Dimethyl carbonate (DMC)	Vinylene Carbonate (VC)
			

Annual lithium-ion batteries (LiBs) demand



2000 GWh / 3.7 V = 541 GAh
3.2 g of electrolytes per Ah → **1.73 Mt electrolytes**

Source : seekingalpha.com

Electrolyte solvents

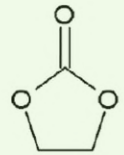
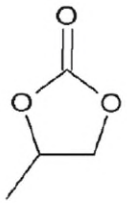
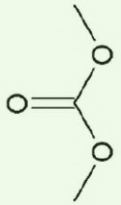
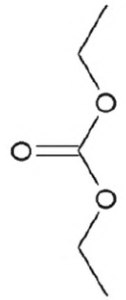
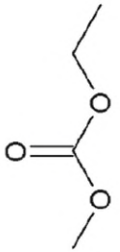
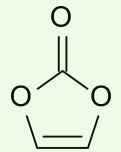
Desired characteristics for electrolyte solvents are:

- ✓ High dielectric constant
- ✓ Low viscosity
- ✓ Inert
- ✓ Non-toxic
- ✓ Liquid at ambient

None of the solvents can meet all the requirements

In most cases, ternary and quaternary systems, such as EC-DEC-DMC, are used.

TABLE 1. Comparison of basic organic, esteric solvents in LIBs; based on melting point (T_m), boiling point (T_b), flash point (T_f), viscosity (η) and dielectric constant (ε) [1].

Solvent	Ethylene carbonate (EC)	Propylene carbonate (PC)	Dimethyl carbonate (DMC)	Diethyl carbonate (DEC)	Ethylmethyl carbonate (EMC)	Vinylene Carbonate (VC)
						
T_m / °C	36.4	-48.8	4.6	-74,3	-53	22
T_b / °C	248	242	91	126	110	178
T_f / °C	160	132	18	31		
η / cP	1.9 (40°C)	2.53	0.59 (20°C)	0.75	0.65	
ε	89.78	64.92	3.107	2.805	2.958	

[1] From "Electrolytes – Technology Review" in Review on Electrochemical Storage Materials and Technology, AIP Conf. Proc. 1597, 185-195 (2014); doi: 10.1063/1.4878487

Advantages of Crystallization: Enhancing Purity and Efficiency

Ultra High **Purity**

The **highest purities** is achieved

No solvent recovery
and product is not contaminated with a solvent

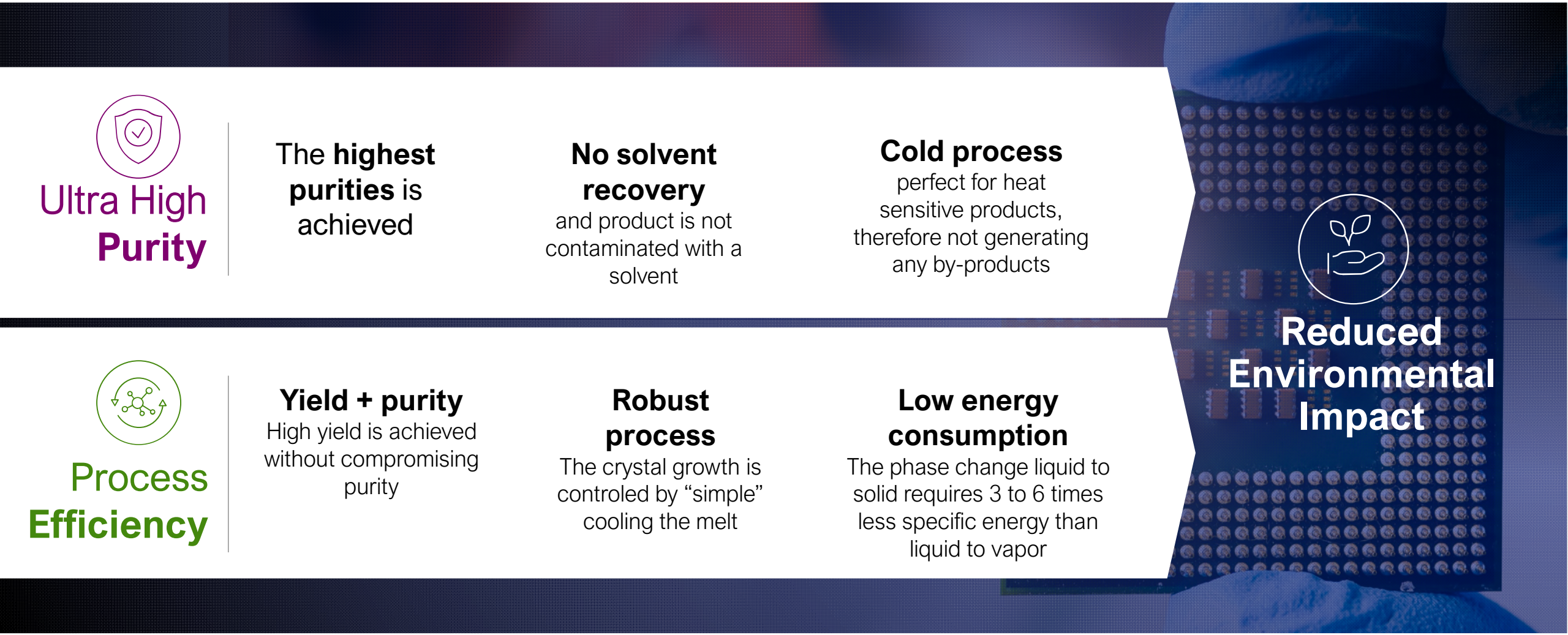
Cold process
perfect for heat sensitive products, therefore not generating any by-products

Process **Efficiency**

Yield + purity
High yield is achieved without compromising purity

Robust process
The crystal growth is controled by “simple” cooling the melt

Low energy consumption
The phase change liquid to solid requires 3 to 6 times less specific energy than liquid to vapor



Reduced Environmental Impact

Challenges for electronic grade electrolyte solvents and additives

Traditional distillation

High temperature process with decomposition and generation of impurities as by-product

Can achieve 99.99 wt-%

Because impurities are affecting the performance of the lithium-ion batteries, there is a trend for higher purities.

Crystallization

Extreme high purity separation

Can achieve much above >99.999 wt-%

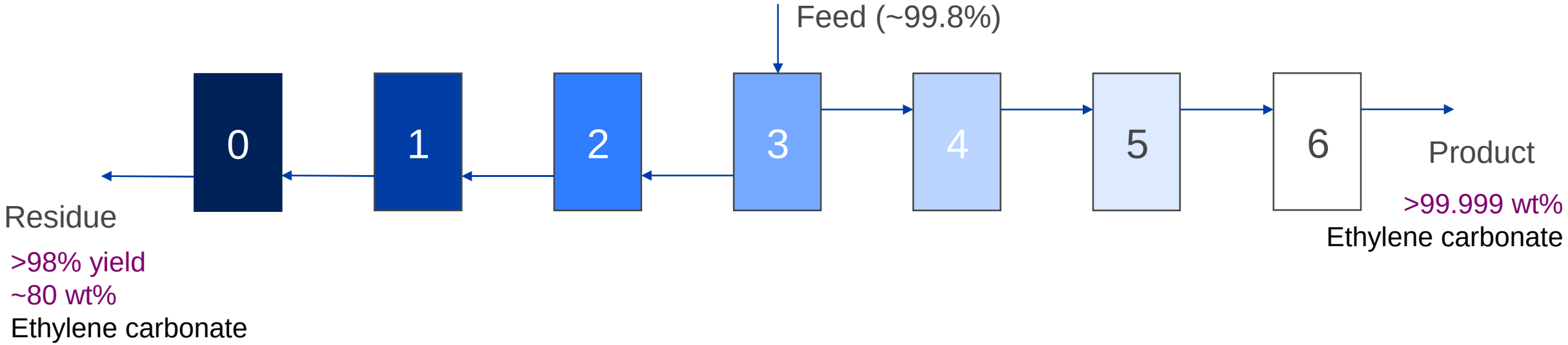
EC with less than 10ppm water / glycols

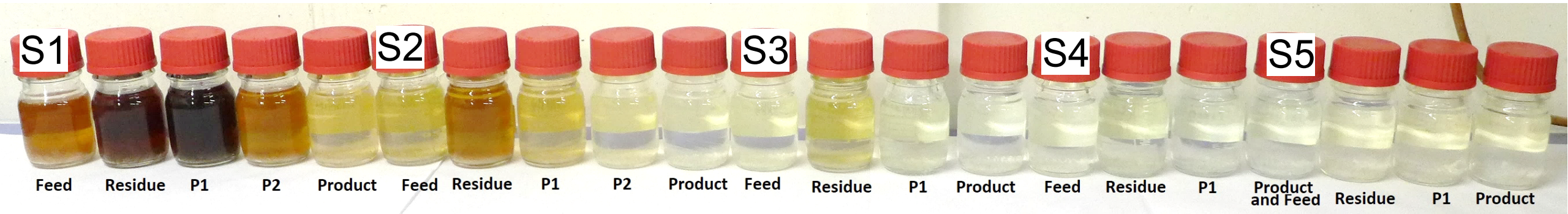
High purity not compromising yield

Low energy consumption

Pilot testing of EC crystallization

Over performance with 7 stages





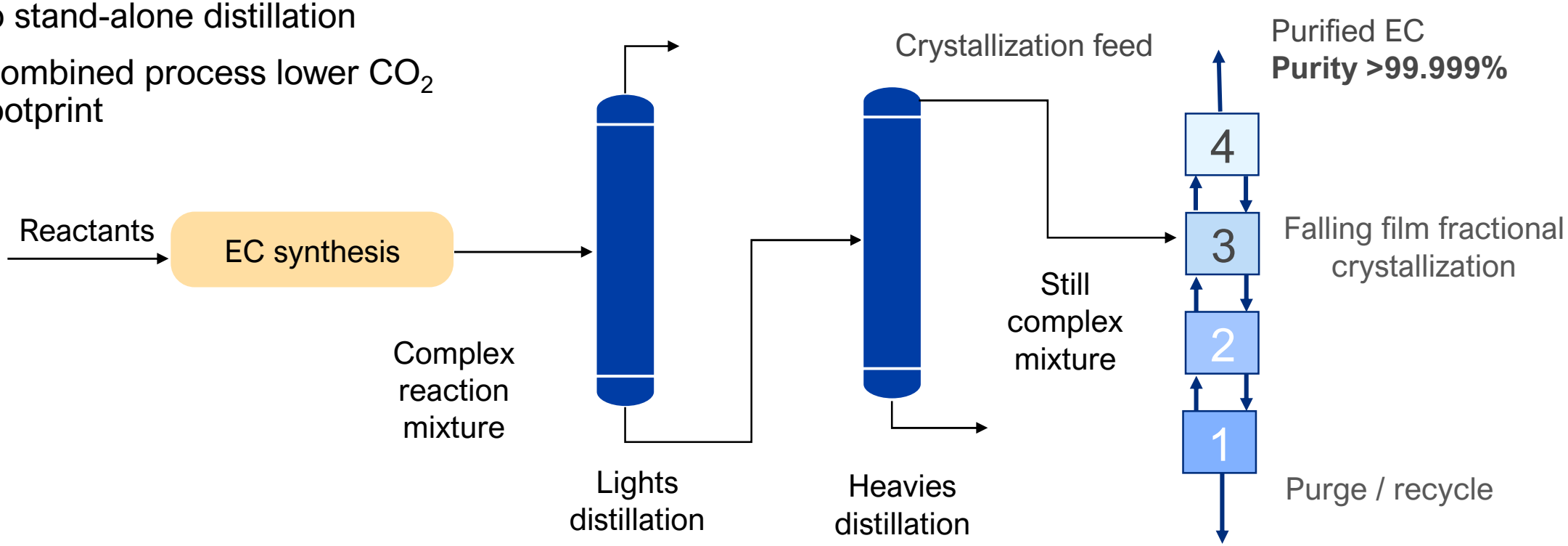
The perfect fit: The ideal solution for your unique operation

Achieve balance across key factors

EC purification through hybrid distillation-crystallization method

Finalizing the initial process concept

- Hybrid approach demonstrated
- Final purity higher compared to stand-alone distillation
- Combined process lower CO_2 footprint



Hybrid Distillation-Crystallization Calculation

Finalizing the initial process concept

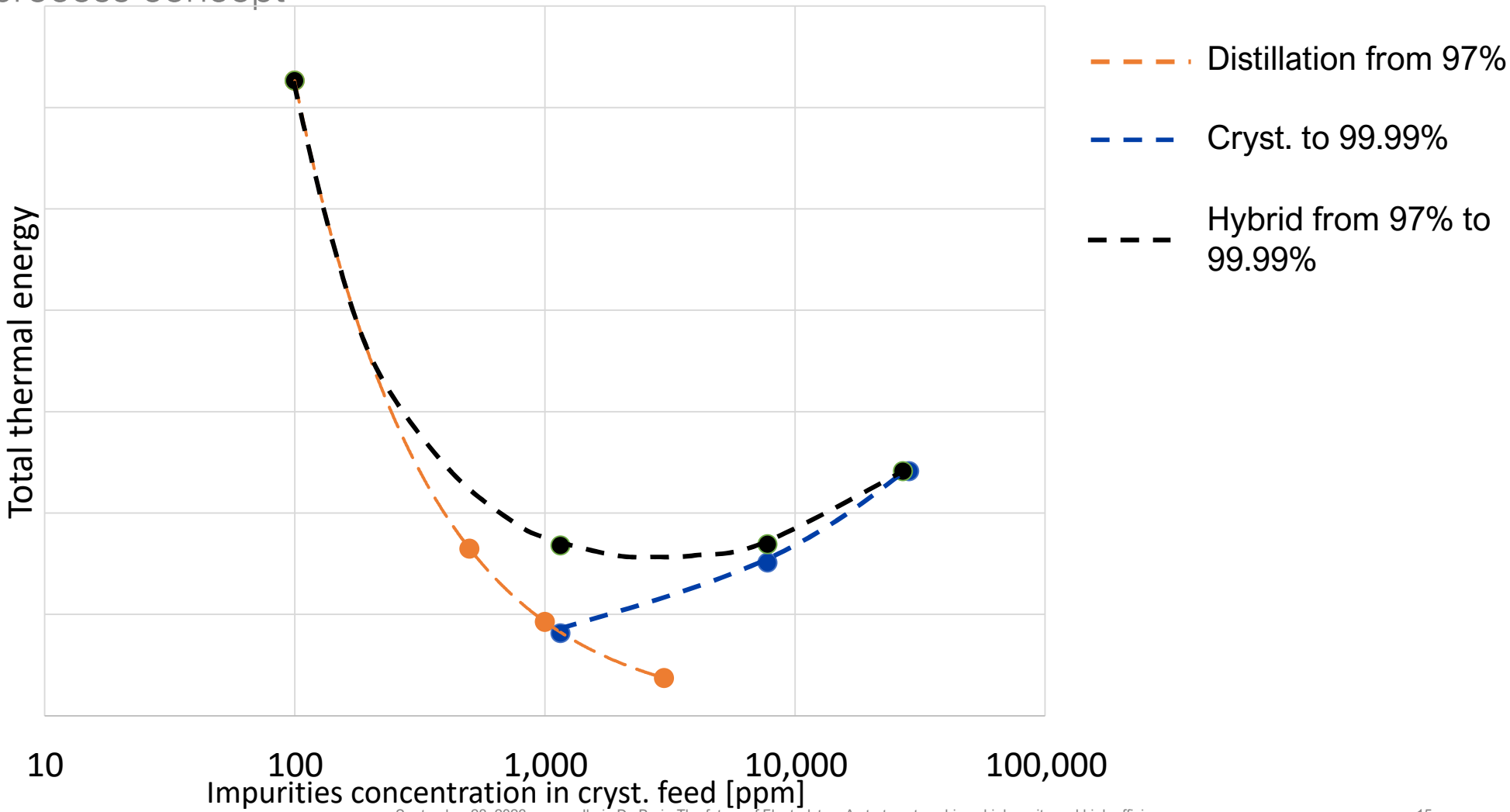
Complex reaction mixture
Purity ~97%

Dist.

Cryst. feed
Intermediate Purity

Cryst.

Purified EC
Purity 99.99%



SULZER

The power of testing

Minimizing the risks and shortening the time to market

Idea screening

Bench-scale test

Proof of concept
Investment sizing

Pilot test

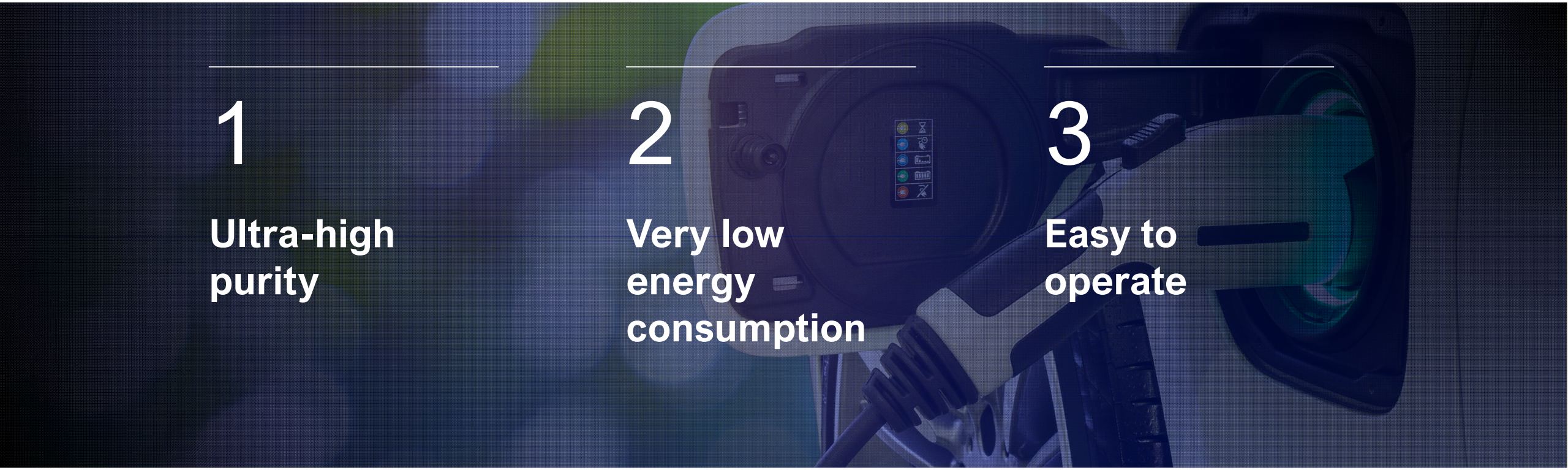
Tolling production
Market teasing

FF and SC mobile units

Less than 6 months from the idea to market

Ready for testing **at your site**

Empowering Battery Innovation: The Advantages of Sulzer Crystallization



1

Ultra-high purity

2

Very low energy consumption

3

Easy to operate

Thank you for your attention!

Your dedicated contacts at Sulzer for Fractional Crystallization:

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