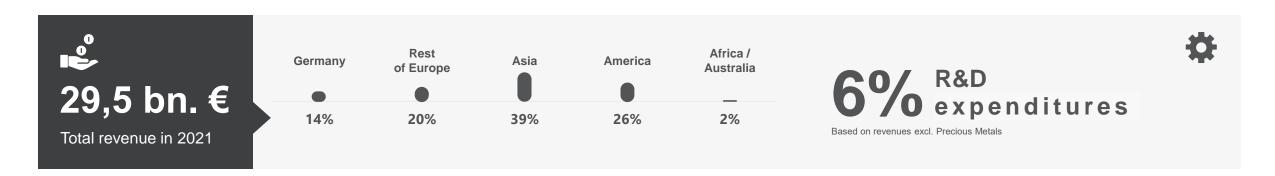


### HERAEUS – A GLOBALLY SUCCESSFUL PORTFOLIO COMPANY



market-oriented

GLOBAL BUSINESS
UNITS

TOP FAMILY-OWNED COMPANIES in Germany



Clobal 500

More than 100 Sites
—— in 40 Countries



Approx.

16,200

employees worldwide

including staff leasing



Germany Rest of Europe Asia

merica

Africa/Australia

1%

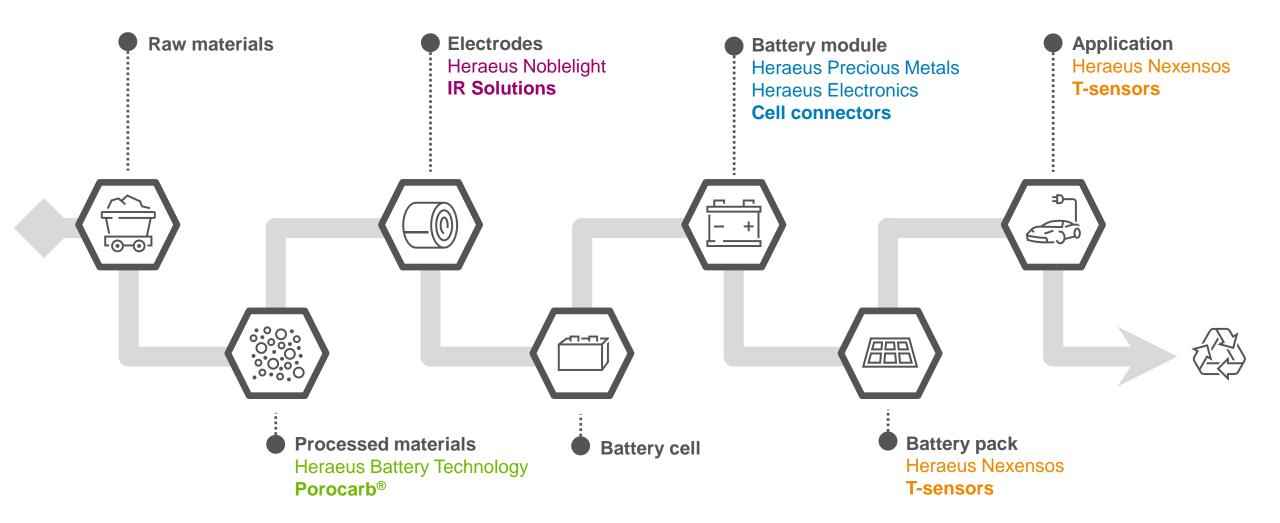
3

33%

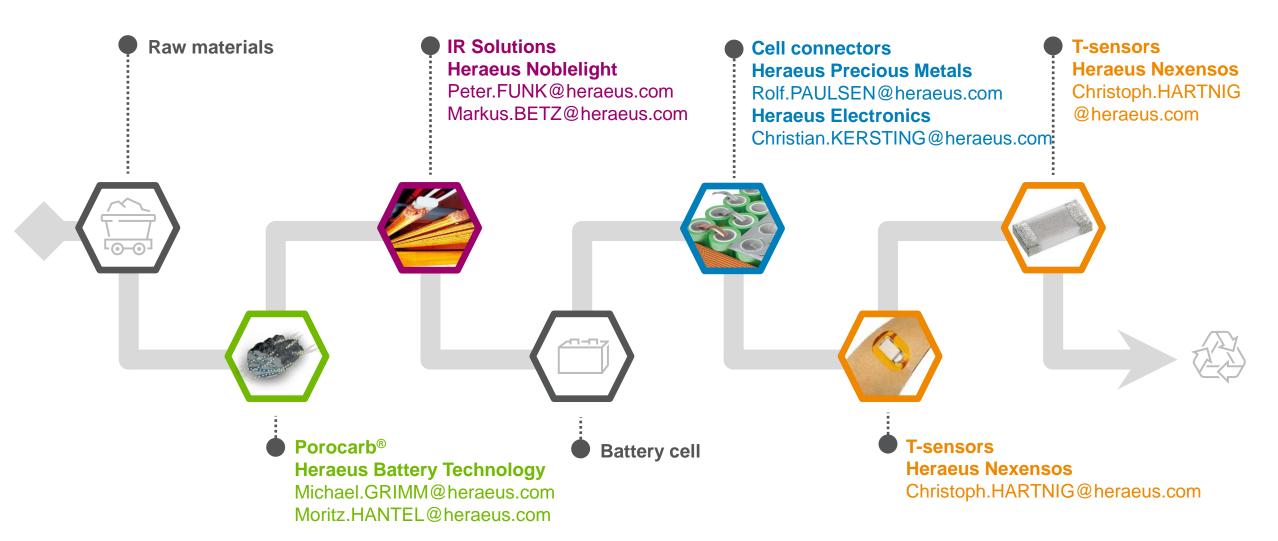
16%

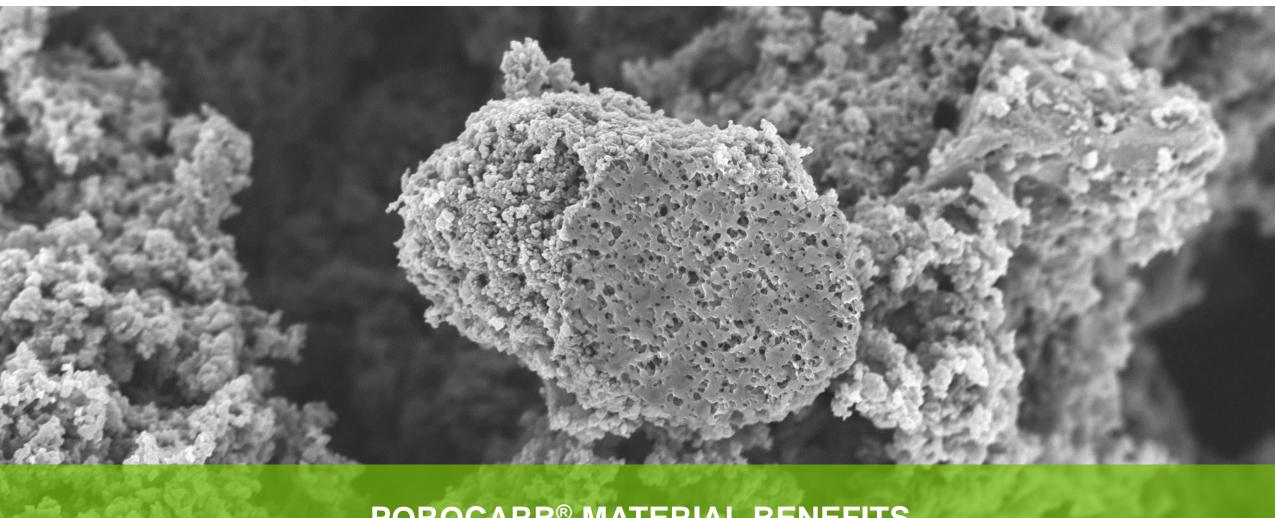
27%

### OUR VIEW ON THE BATTERY VALUE CHAIN



### OUR VIEW ON THE BATTERY VALUE CHAIN





POROCARB® MATERIAL BENEFITS

THE SYNTHETIC CARBON PERFORMANCE ADDITIVE

## CONDUCTIVE CARBON ADDITIVE LANDSCAPE













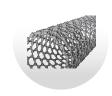
Performance Additive











**SWCNT** 

**Agglomerated** 





Graphite

Carbon **Black** 

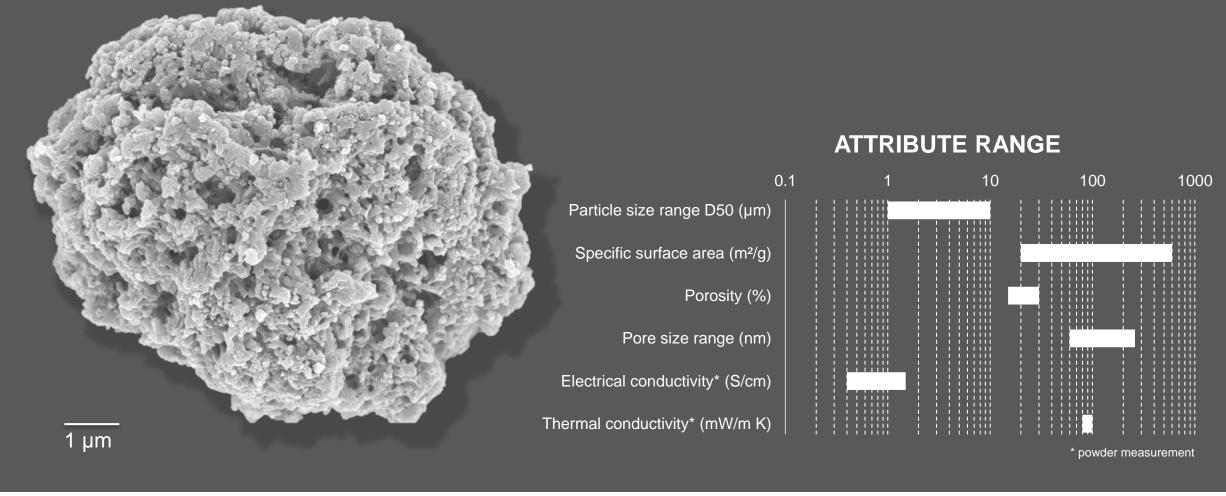
**Highly structured Carbon Black** 

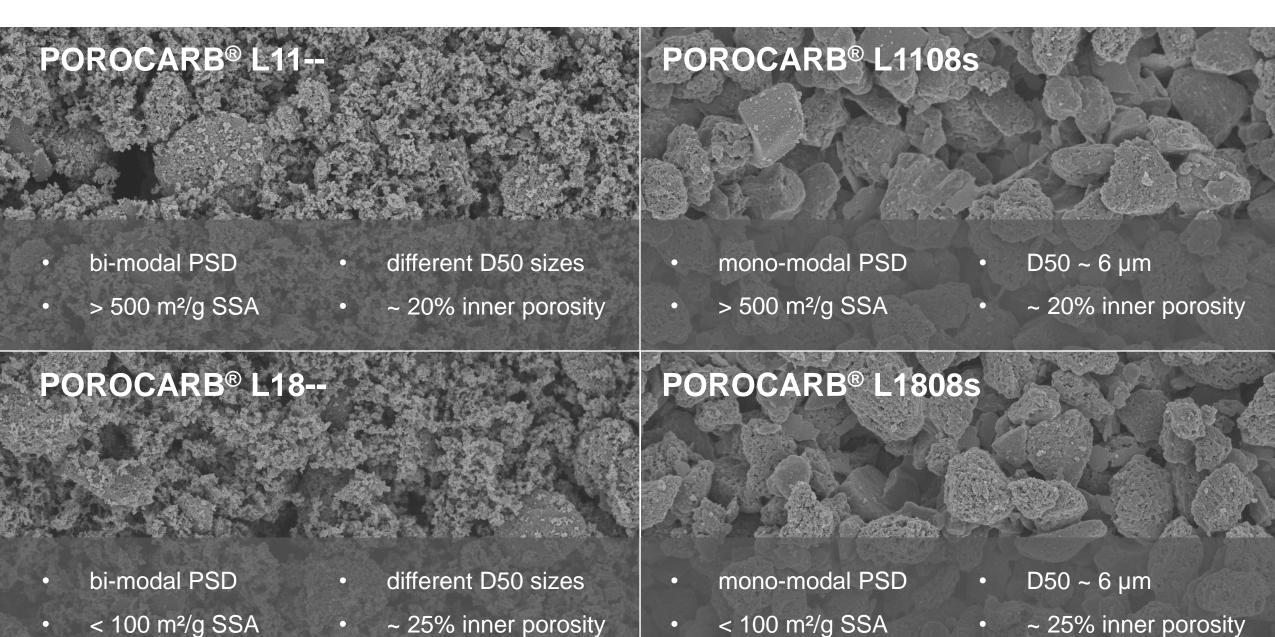
Acetylene **Black** 

**MWCNT** 

**VGCF** 

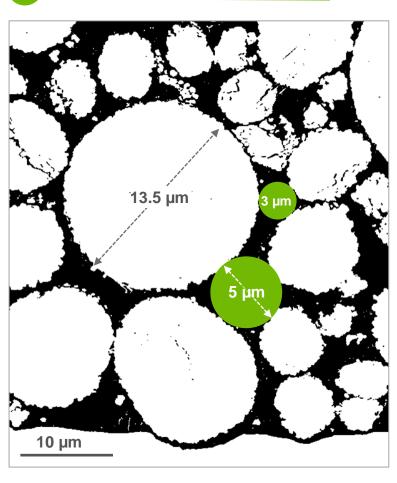
## POROCARB® - TAILORED POROUS CARBON ADDITIVE



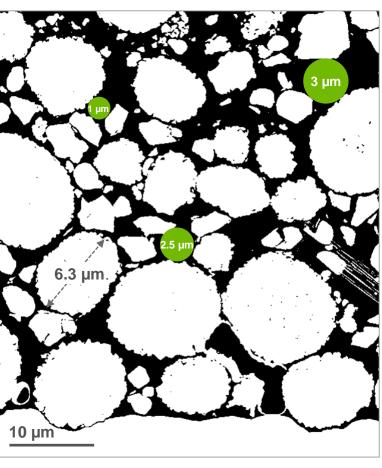


Large active material

### DIFFERENT POROCARB® SIZES AVAILABLE TO SUIT YOUR ACTIVE MATERIAL







#### **Different active materials**

- Large polycrystalline CAM
- Small single crystalline CAM
- Graphite and SiOx / SiC

#### **Bi-modal Porocarb®**

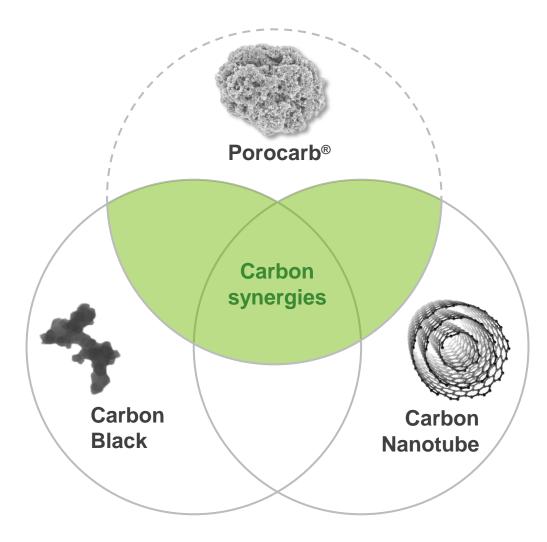
- · Different PSD available
- Larger particles to fill voids
- · Small particles percolation aid

### **Mono-modal Porocarb®**

- Large particles filling the voids
- · Minimized Porocarb amount
- Relies on existing percolation

10

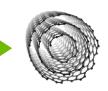
### ADDING A NEW DEGREE OF FREEDOM FOR CARBON PERCOLATION





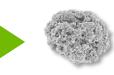
#### **Carbon Black**

- Electrical conductivity
- Small particles
- Percolation network



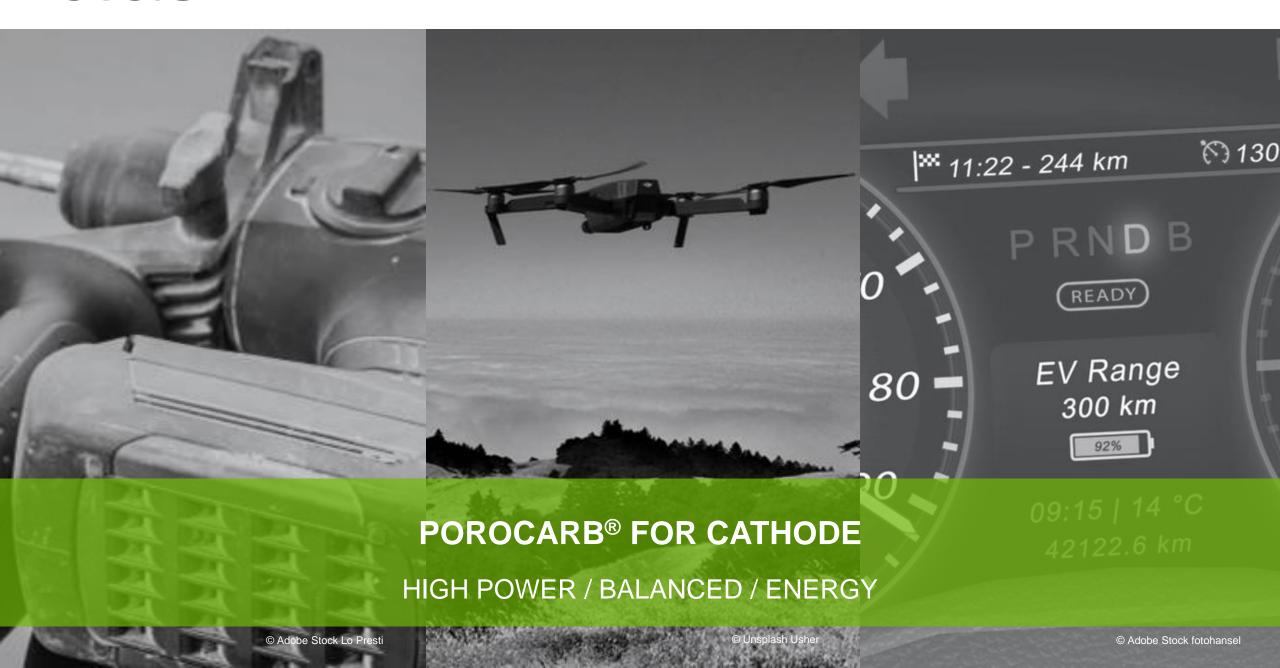
#### **Carbon Nanotube**

- Electrical conductivity
- Long fibrous
- Flexible structure



#### Porocarb<sup>®</sup>

- Electrolyte transport
- Thermal conductivity
- Large porous particles



### BATTERY MARKET SEGMENTATION BY DESIGN



### High power design

### **Electrode boundaries**

- Active material size
- Carbon content
- Thickness
- Porosity









#### Porocarb® USP

...longer duration and increased max power due to lower cell self-heating at high power

...and improved cycle life



### **Balanced design**

#### **Electrode boundaries**

- · Active material size
- Carbon content
- Thickness
- Porosity

### Typical applications







#### Porocarb® USP

...improved performance due to increased pulse power capability

...improved C-rate discharge performance and therefore boost of application run time



### High energy design

#### **Electrode boundaries**

Active material size



Carbon content



Thickness



Porosity

### **Typical applications**







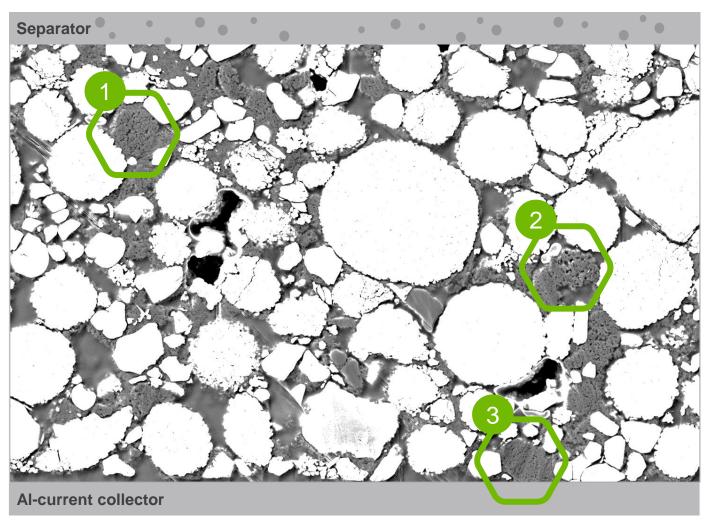
13

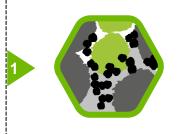
#### Porocarb® USP

...improved charging performance at low temperature

...improved C-rate discharge performance and therefore boost of driving range

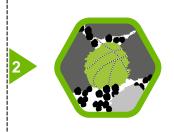
## POROCARB® - ADDING CONTROLLED POROSITY TO THE CATHODE





### **Single Particle**

- Increased slurry solid content
- Better additive dispersion
- Homogeneous carbon network



### Intrinsic open porosity

- Improved mass transport
- Easy electrolyte wetting
- Enhanced heat distribution



### **Anchor point for binder**

- Binder reduction possible
- Improved resistance
- Maximizing active material



POROCARB® PROCESSING

EASY INTEGRATION WITH ADDITIONAL BENEFITS

### POROCARB® SYNERGIES WITH HS CB – SC NMC622 RHEOLOGY



#### **Test method**

Finalized slurry

Degassing for 10 min at < 10 mbar

Rheology measurement



### **Key results**

- Easy slurry process
- Porocarb<sup>®</sup> reduces shear viscosity
- Porocarb<sup>®</sup> allows for higher solid content

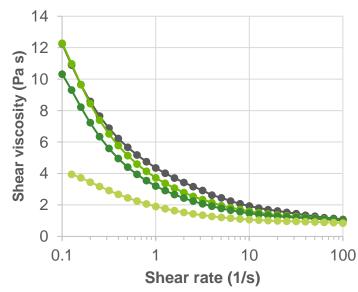


### **Different carbon ratios**

### Slurry with Σ 1.5 wt.% carbon

	0% PC	33% PC	50% PC	67% PC
PC NMC (wt.%)	97	97	97	97
HS CB (wt.%)	1.5	1.0	0.75	0.5
Porocarb® (wt.%)	-	0.5	0.75	1.0
PVDF (wt.%)	1.5	1.5	1.5	1.5
Solid content (%)	72	73	73	73

### Slurry rheology





### POROCARB® SYNERGIES WITH HS CB - SC NMC622 PEEL STRENGTH



#### **Test method**

1 cm wide densified electrodes 90° peel test

Average force over 5 cm peel length



### **Key results**

- · Reference with normal peel strength
- Adding Porocarb® increases peel strength
- 43% improvement with 33% Porocarb<sup>®</sup>



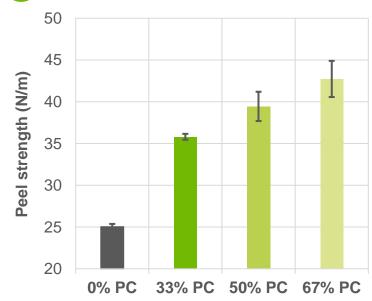
### Different carbon ratio

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PC NMC (wt.%)	97	97	97	97
HS CB (wt.%)	1.5	1.0	0.75	0.5
Porocarb® (wt.%)	-	0.5	0.75	1.0
PVDF (wt.%)	1.5	1.5	1.5	1.5
Loading AM (g/m <sup>2</sup> )	250	250	251	248
Density (g/cm <sup>3</sup> )	3.61	3.62	3.61	3.58



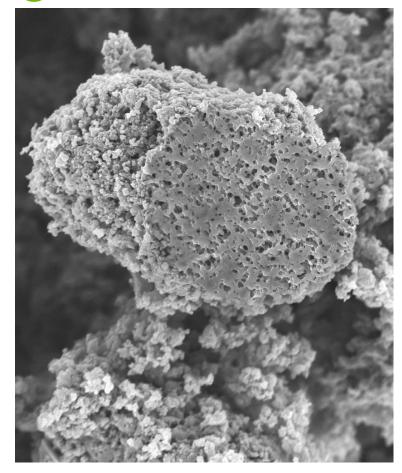
### Electrode peel strength

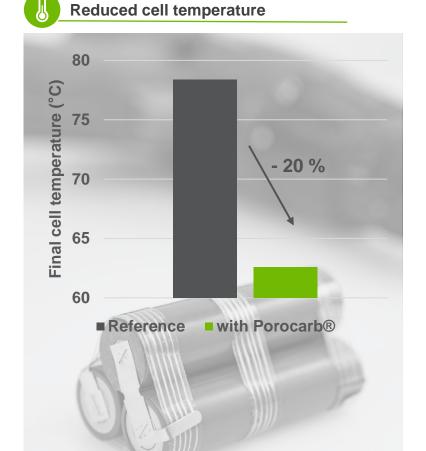




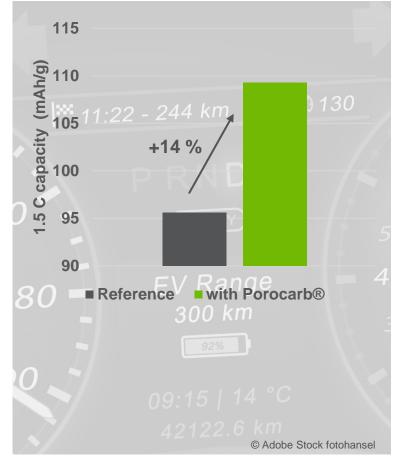
### POROCARB® – THE POROUS CARBON TO BOOST BATTERY PERFORMANCE





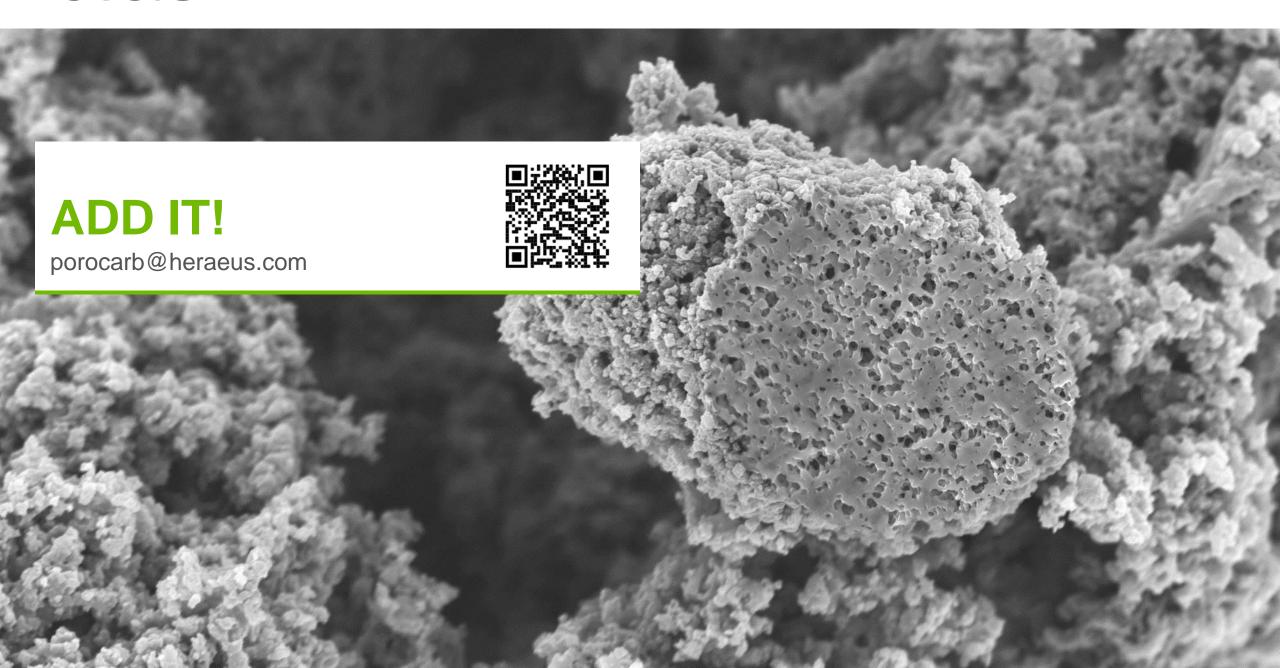






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OUR CONTACT DETAILS ARE: POROCARB@HERAEUS.COM

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