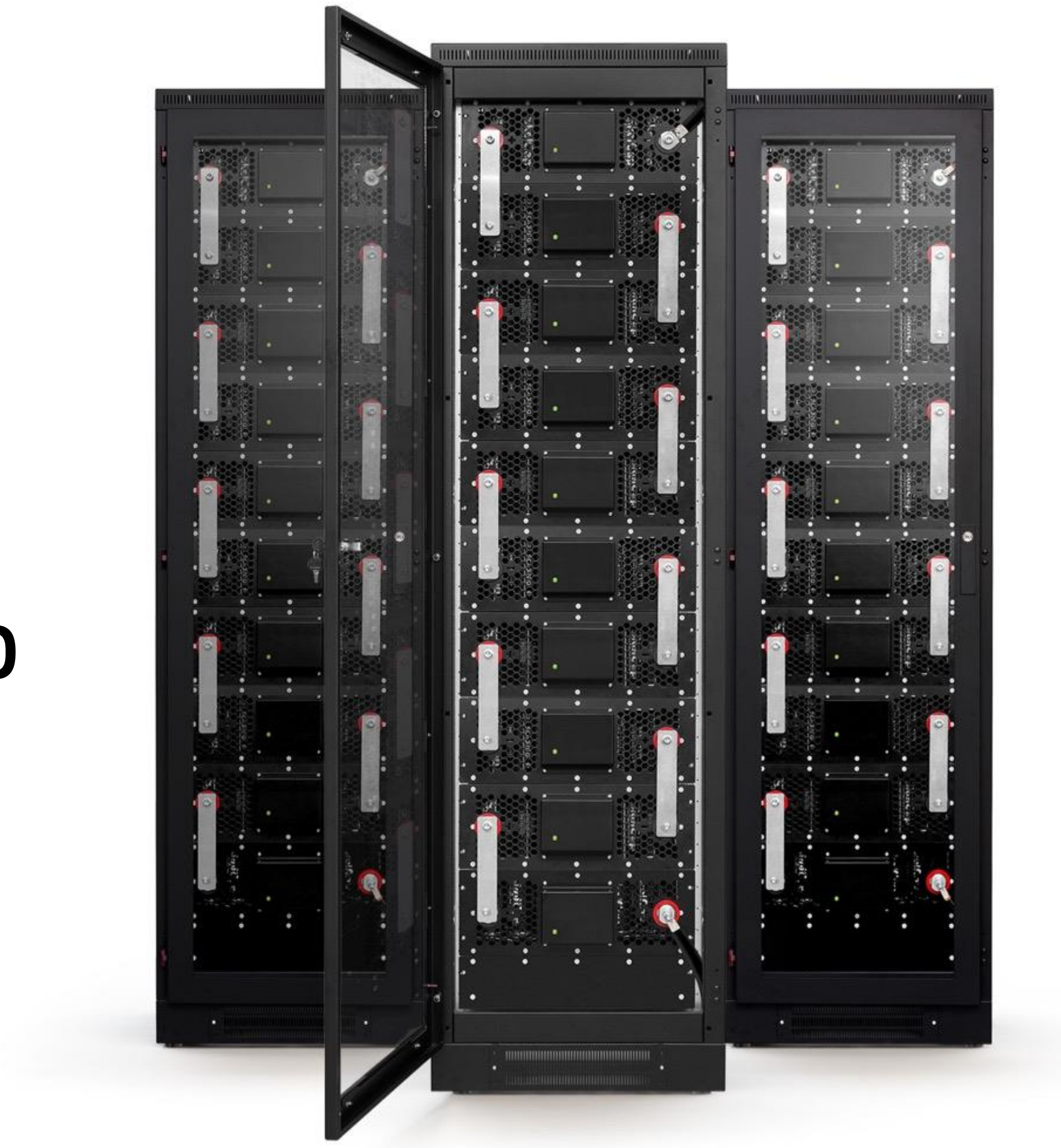
SKELETON TECHNOLOGIES

A NEW APPROACH FOR ULTRACAPACITOR-BATTERY HYBRID ENERGY STORAGE SOLUTIONS



Egert Valmra

Programme Director

PROUDLY EUROPEAN
Skeleton Technologies Group

Skeleton Technologies GMBH
Großröhrsdorf, Germany

- Industrial scale manufacturing facility
- Ultracapacitor development research center
- Electrode centre of excellence
- Management
- Application Engineering

Skeleton Technologies OÜ
Tallinn, Estonia

- Electronics Engineering
- Module & System Development
- IT
- Finance

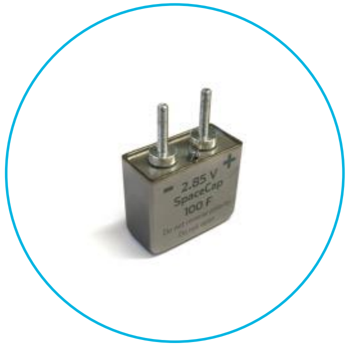
ONLY ULTRACAP MANUFACTURER WITH A COMPLETE VALUE CHAIN

MATERIALS

Curved Graphene
OUR PATENTED RAW MATERIAL

SINGLE CELLS

SkelCap SCA series
INDUSTRIAL ULTRACAPACITORS



SpaceCap
CUSTOM ULTRACAPACITORS

SOLUTIONS

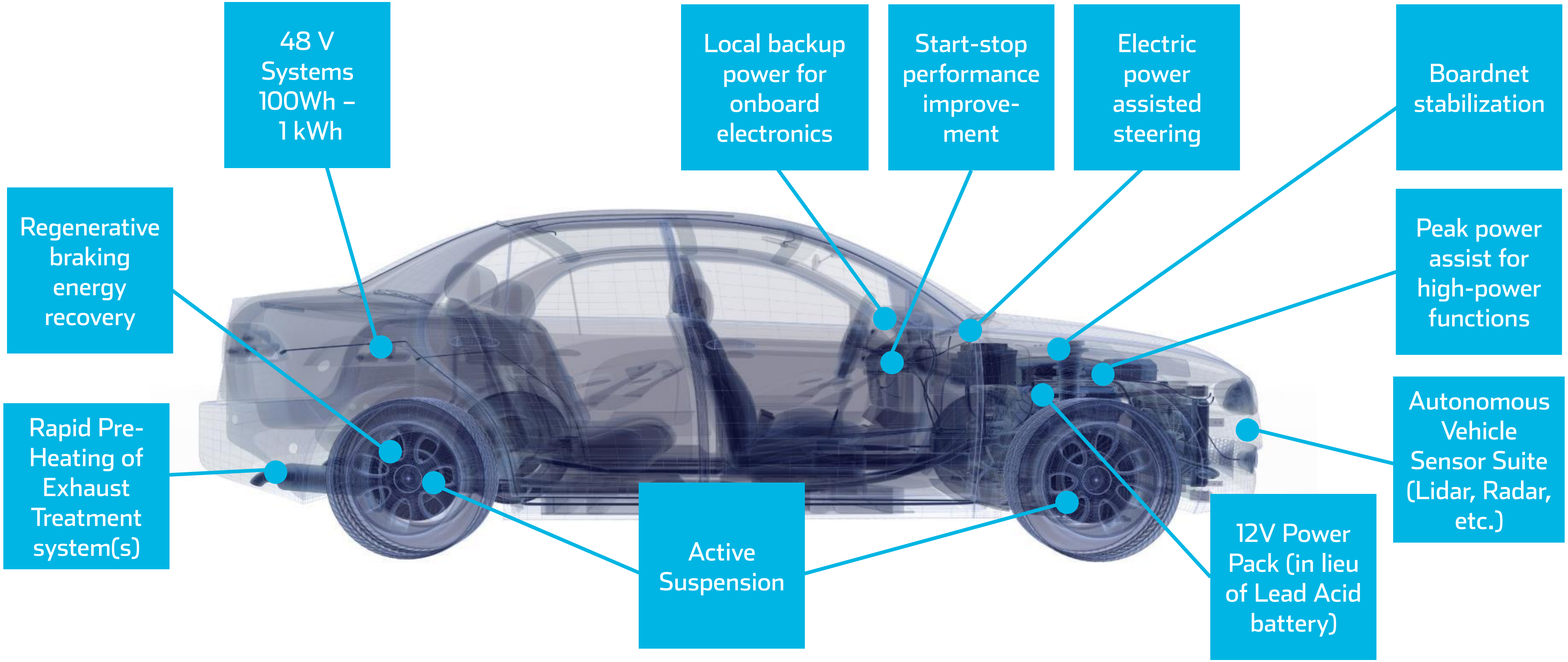
SkelMod 51V
ULTRACAPACITOR MODULE

SkelMod 170V
ULTRACAPACITOR MODULE

SkelStart Engine Start Module
ULTRACAPACITOR MODULE

SkelGrid
ULTRACAPACITOR-BASED ENERGY STORAGE SYSTEM

Automotive applications
Ultracapacitors in vehicles



Automotive applications
48 V: Hungry for Power?

SKELETON TECHNOLOGIES

PTC Heating – 5 kW
A/C compressor – 5 kW
Compressor – 7 kW
Window Heating – 2 kW
Start-stop – 10kW

in addition to…

E-Steering– 2 kW
Acceleration– >20 kW
Active Suspension – 4 kW

Power limit of 48 V battery packs will be reached soon

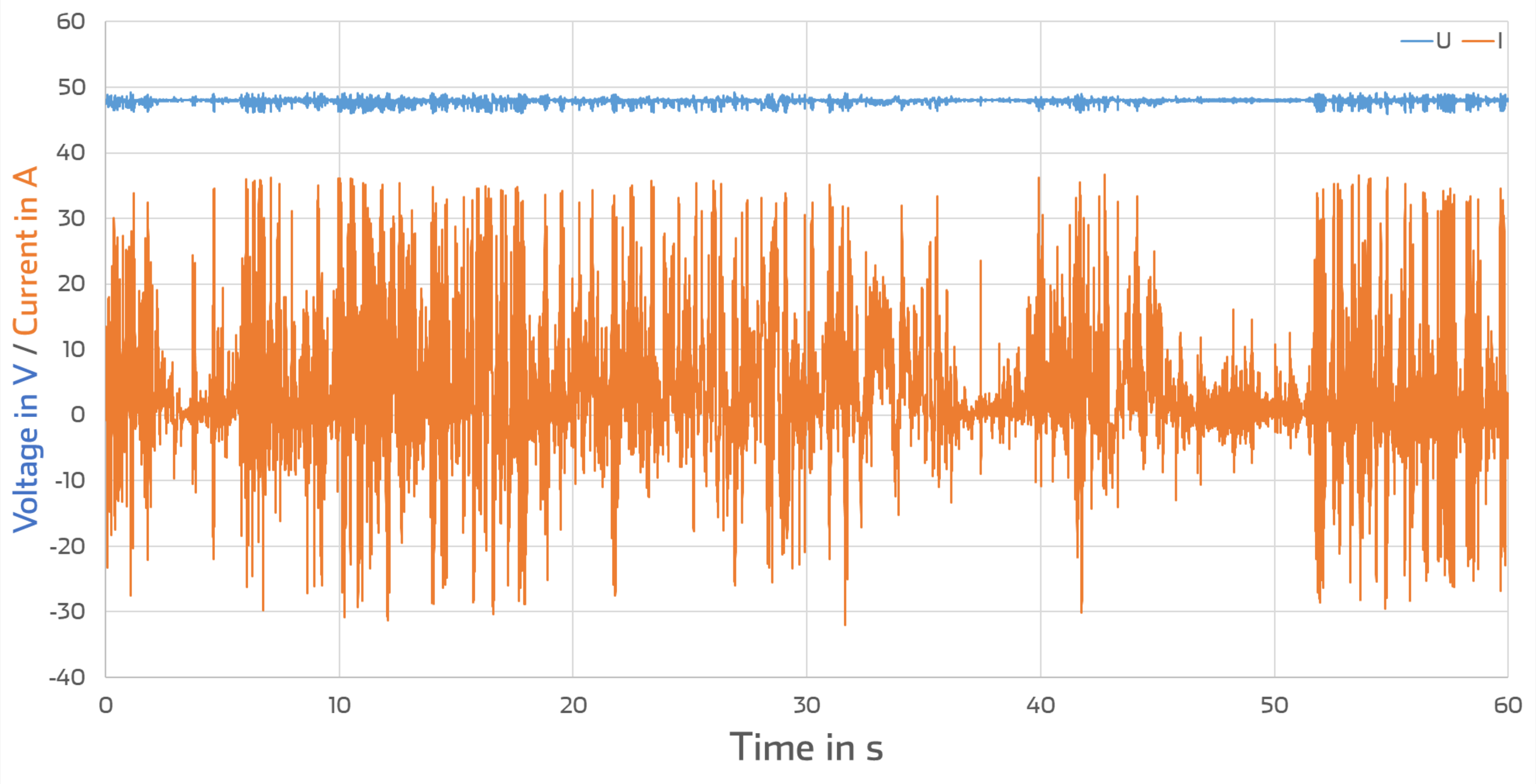
6 kW (Continental)

10 kW (Bosch)

15 kW (Valeo)

30-40 kW (OEM requirements)

Automotive applications
Active suspension



- Ultracapacitor 48 V pack able to cover whole operational range
- Up to 4 kW pulses with low average power
- LiB system simulation showed EoL after 2 years
- Ultracapacitor pack showed more than sufficient lifetime (whole vehicle life)

Transport applications

Example: Mild Hybrid ESS

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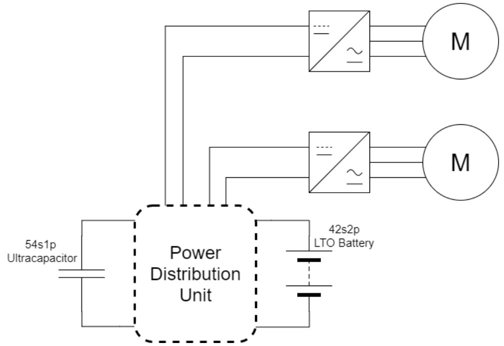
Products and Services Rendered

- Extensive drive cycle simulations
- Engineering support
- Module design



Key Benefit

- Optimal match to drive cycle
- **Energy storage pack lifetime increase from 2 to 10 years**
- One point of contact for complete module

-36% GHG @ 99 Pax with Ucap

-30% GHG @ 85 Pax. with Lithium Battery

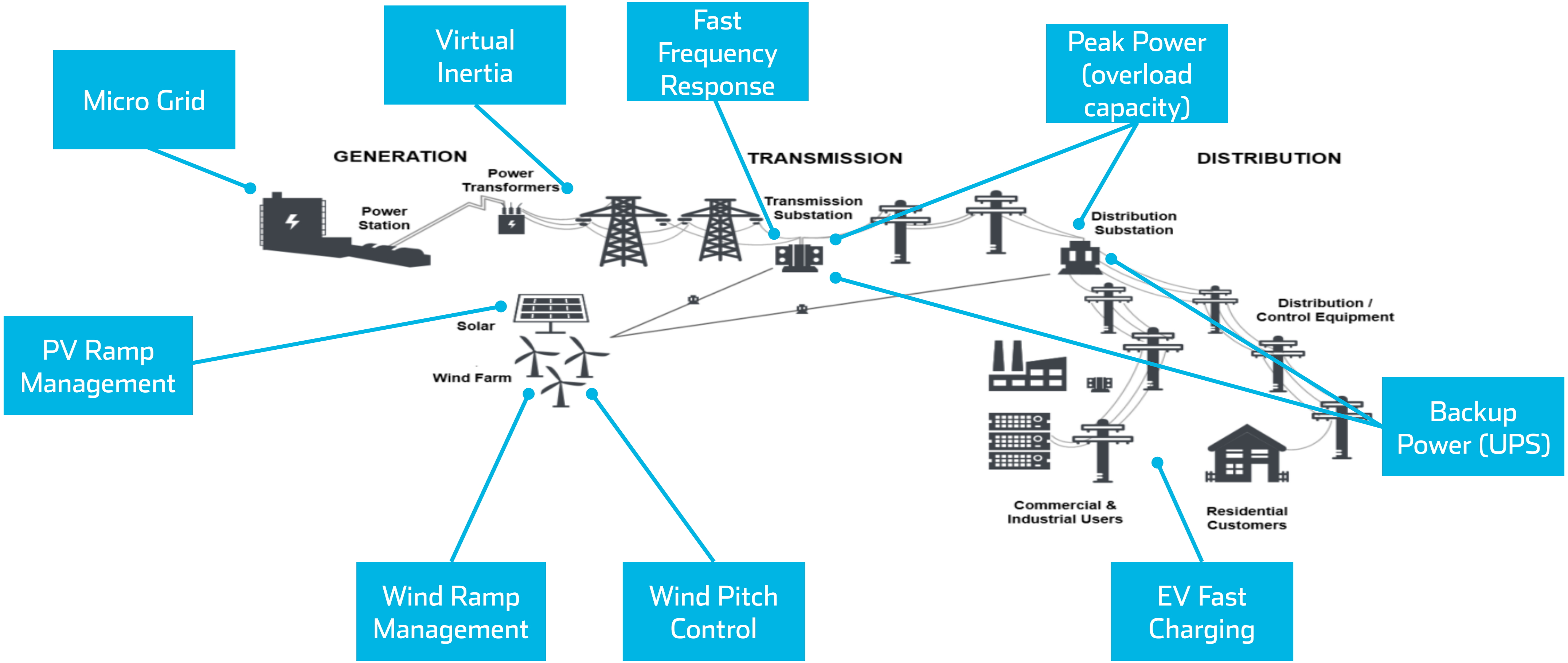
500%

Longer energy storage lifetime

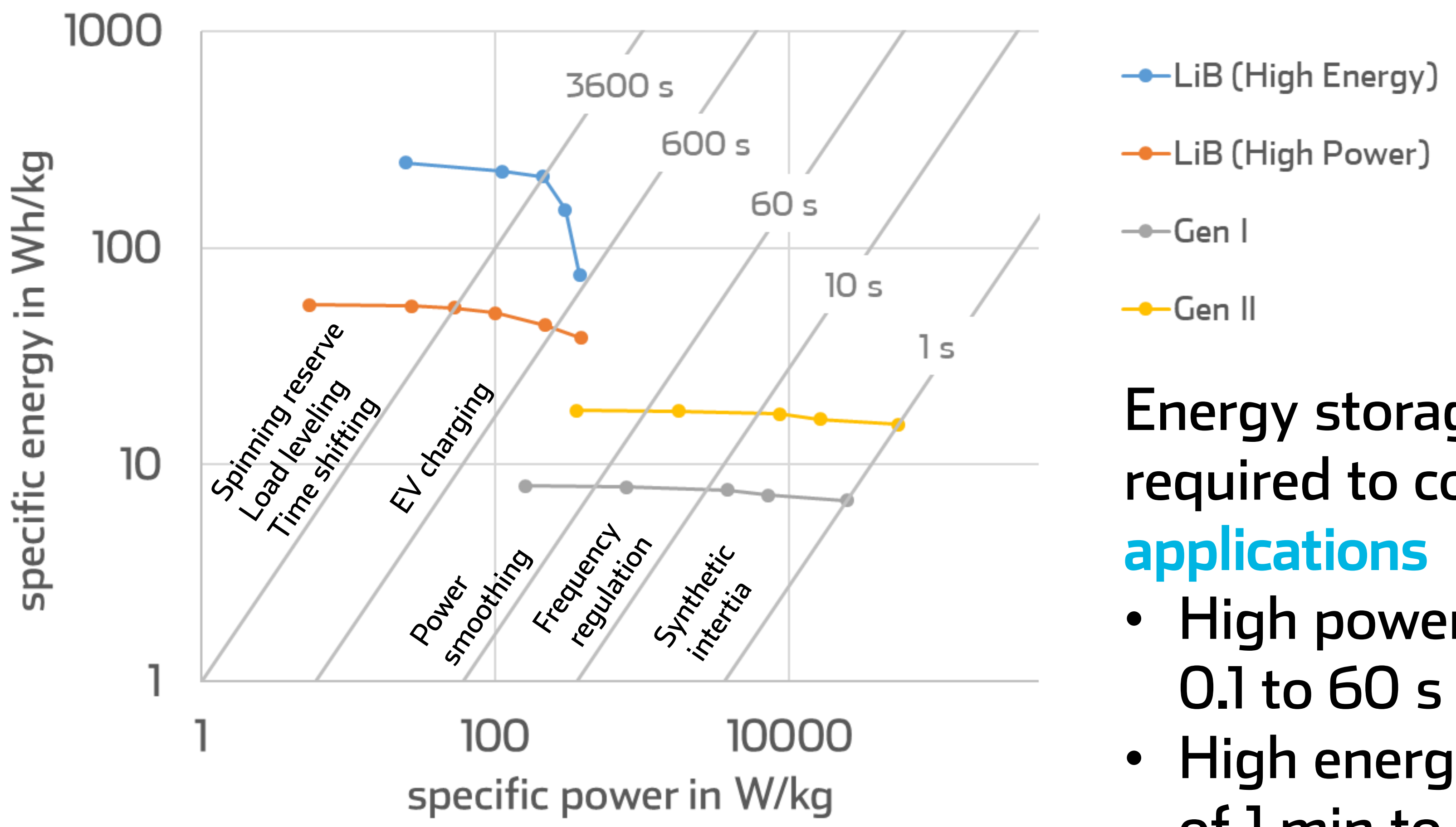
Grid applications

SKELETON OFFERS SOLUTIONS TO 9 DIFFERENT GRID APPLICATIONS

SKELETON TECHNOLOGIES



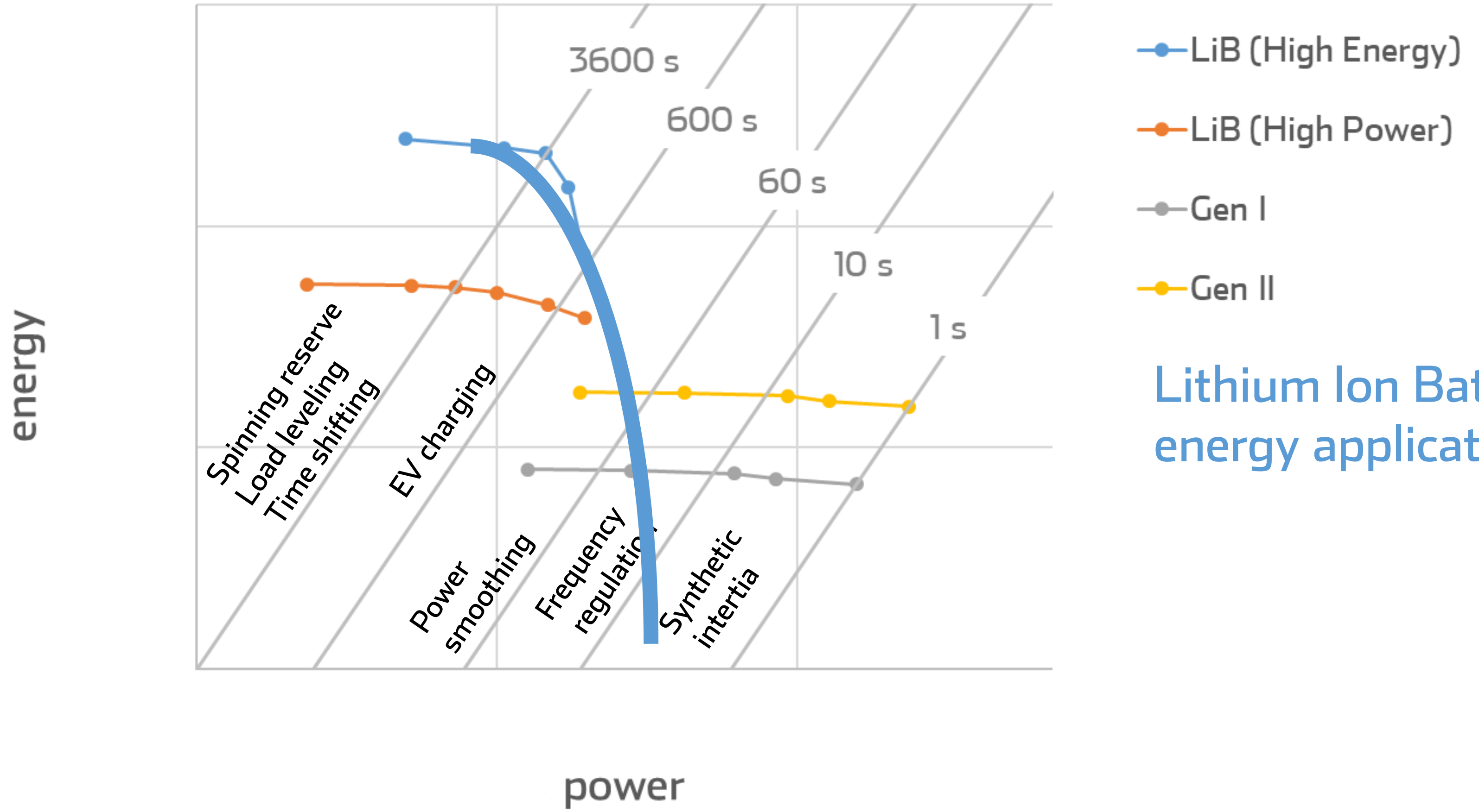
Hybridization opportunities



Energy storage systems are often required to cover a **wider range of applications**

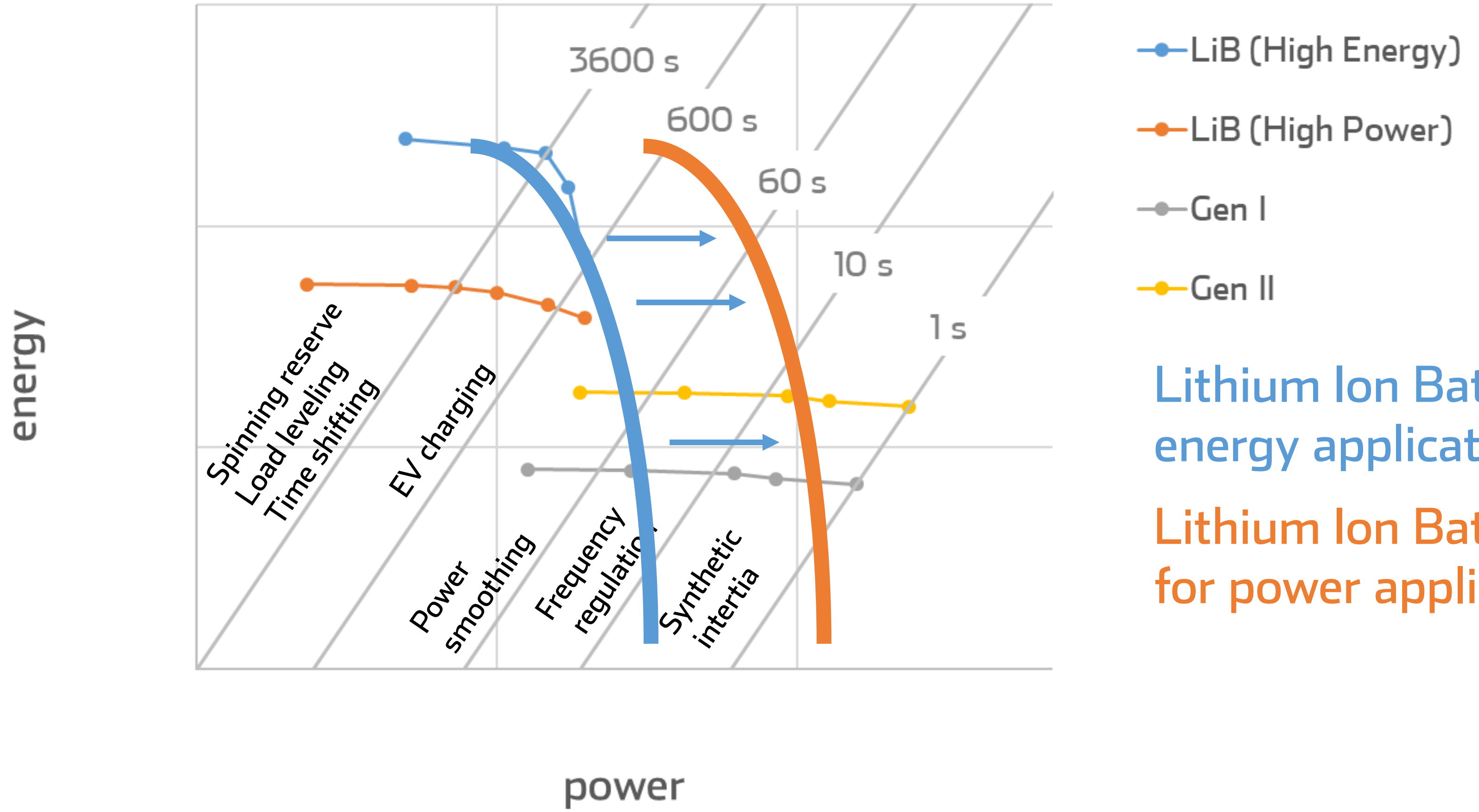
- High power applications in the range of 0.1 to 60 s pulses
- High energy applications in the range of 1 min to 10 h charge-discharges

Hybridization opportunities



Lithium Ion Battery sized for energy applications

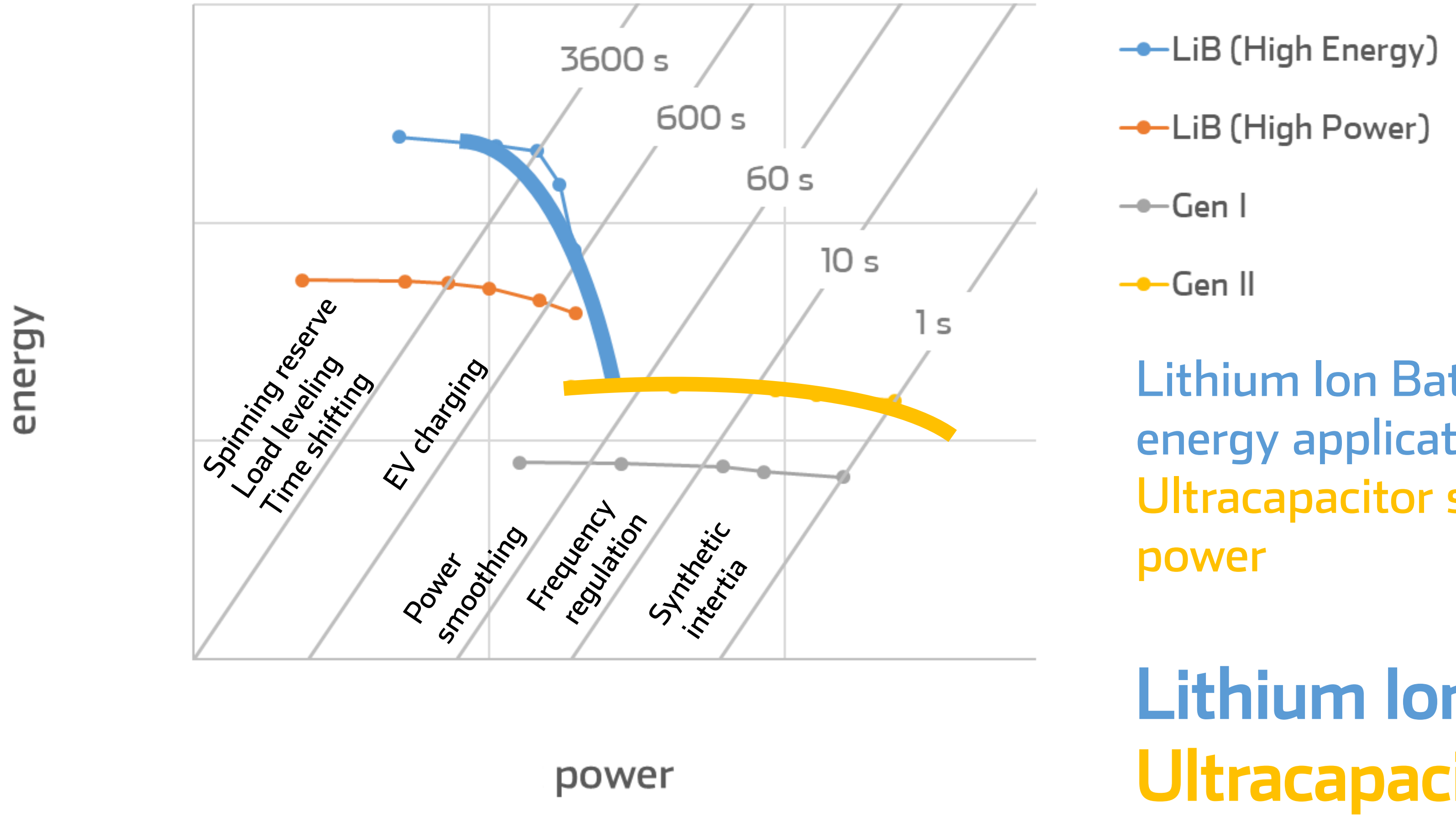
Hybridization opportunities



Lithium Ion Battery sized for energy applications

Lithium Ion Battery oversized for power applications

Hybridization opportunities

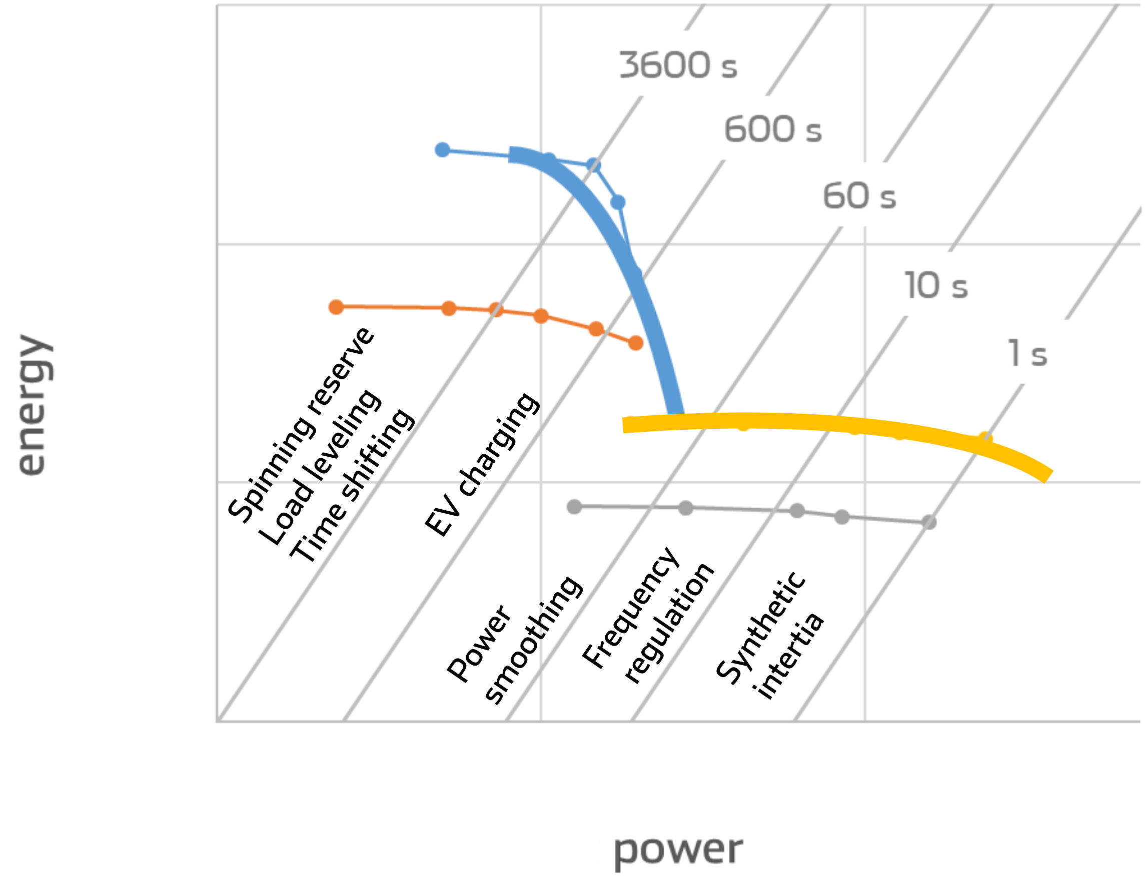


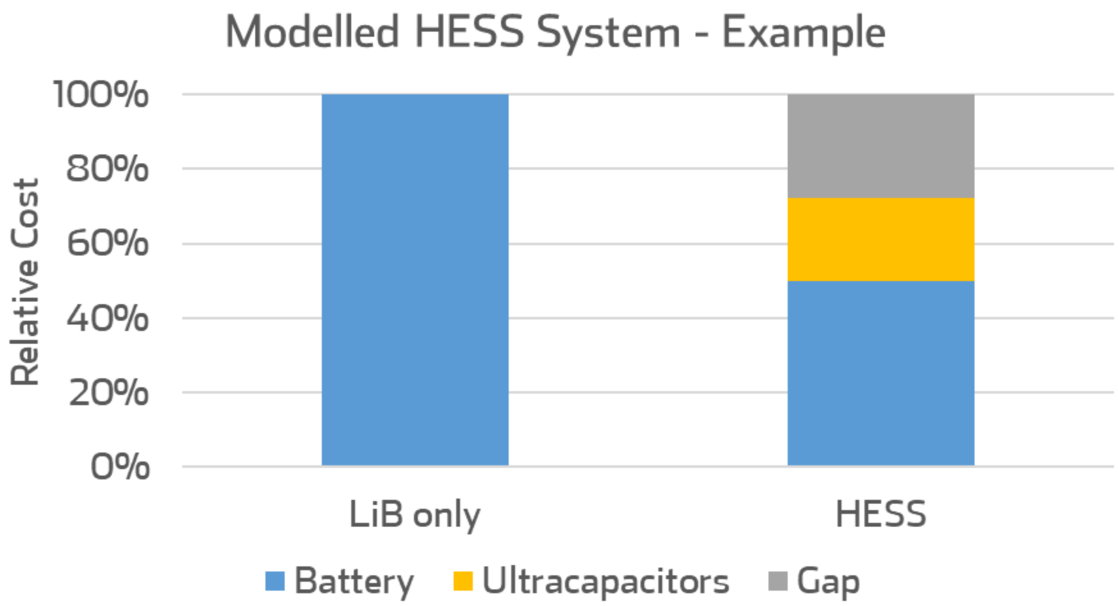
Lithium Ion Battery sized for energy applications

Ultracapacitor sized for peak power

Lithium Ion Battery – Ultracapacitor Hybrid

Hybridization opportunities





Hybridization opens avenues for more efficient energy storage systems at a lower cost per kWh storage capacity!

So why are Ultracapacitors not used in more applications already?

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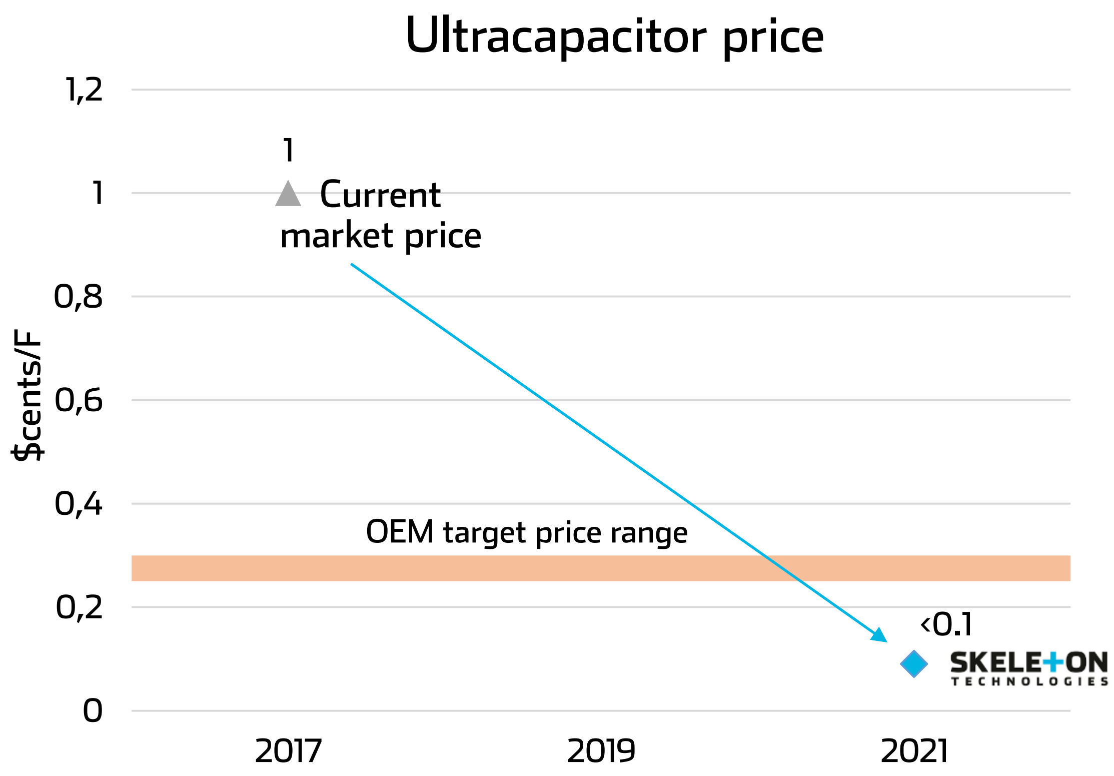
Two simple answers (1): Cost

- Currently ultracapacitors can be found in 4 million passenger vehicles
- Price and performance are the main market drivers and key to the take-off of the ultracapacitor market
- Major OEMs have set a price target of 0.25-0.3 $cents/F - current market prices are ca 0.7 to 1 $cents/F, showing a 5% decline YoY



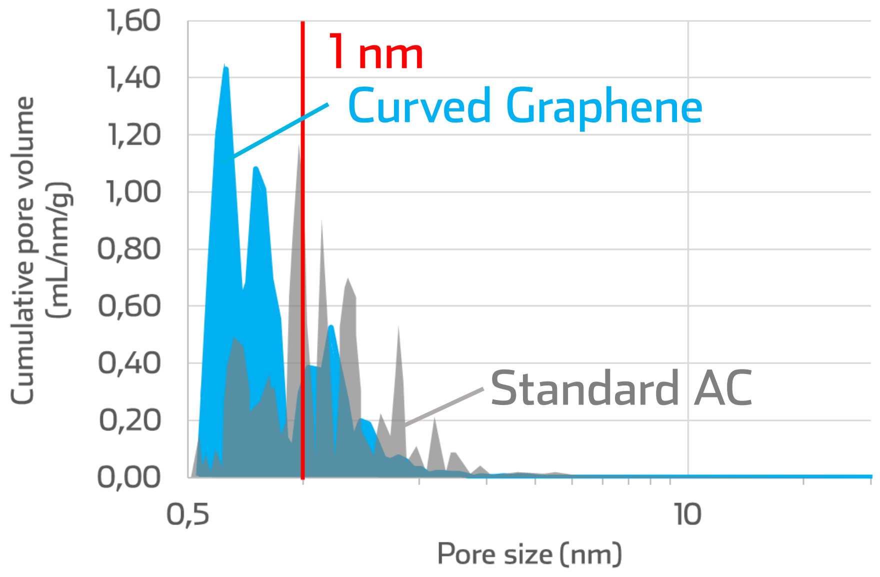
So why are Ultracapacitors not used in more applications already?

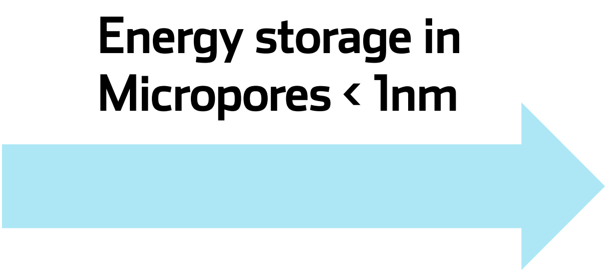
SKELETON TECHNOLOGIES

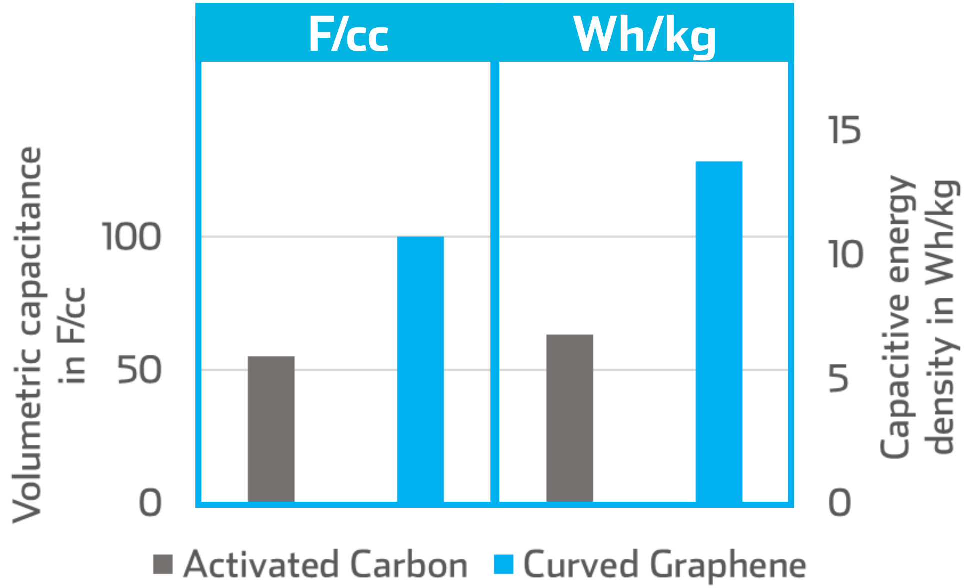
Two simple answers (2): Energy Density

+ Market demand for UC energy density shows a clear gap
+ Current generations of Ultracapacitors can only fulfil partial energy demands
+ Ultracapacitors with higher energy density can help to downsize batteries in many applications

Skeleton's clear path to more energy density: Curved Graphene







+ Skeleton's patented technology to reach <0.1 $cents/F price at the required performance level

+ Skeleton's patented technology will more than double the energy density of Ultracapacitors

Ultracapacitor Applications
Conclusions

- Energy storage applications are getting more power hungry
- Batteries need to be oversized in order to serve high power applications
- Ultracapacitors are optimal for high power applications
- Hybridization of Ultracapacitors and LiBs can yield more efficient and cheaper energy storage for multiple applications
- Current Ultracapacitor technology lacks energy density
- Skeleton Technologies is on track to **double the energy density** of Ultracapacitors until 2021

WE ARE SKELETON TECHNOLOGIES

WE HELP TO SAVE ENERGY

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