

Enabling Energy's Future™



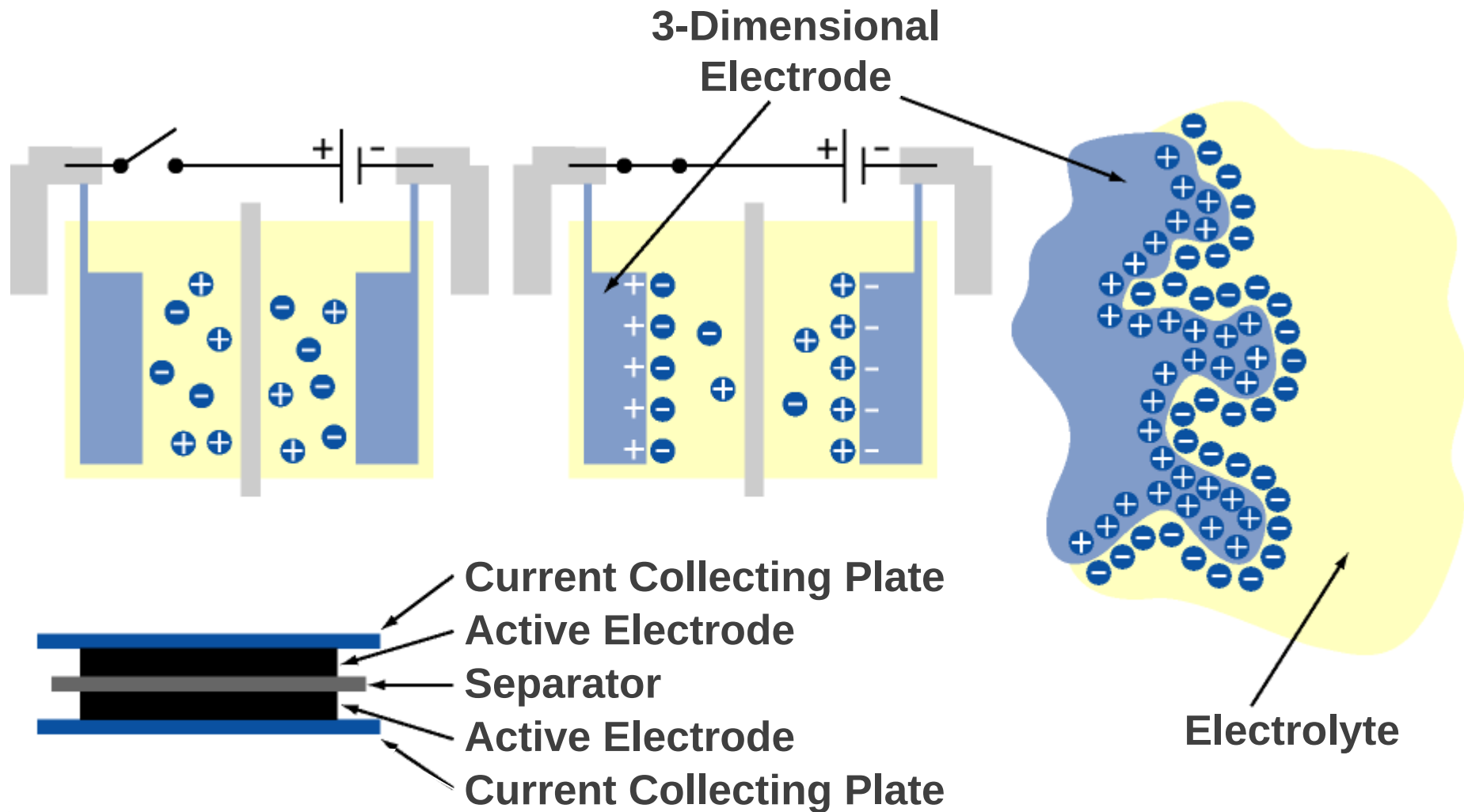
Maxwell Technologies

January 16th, 2013

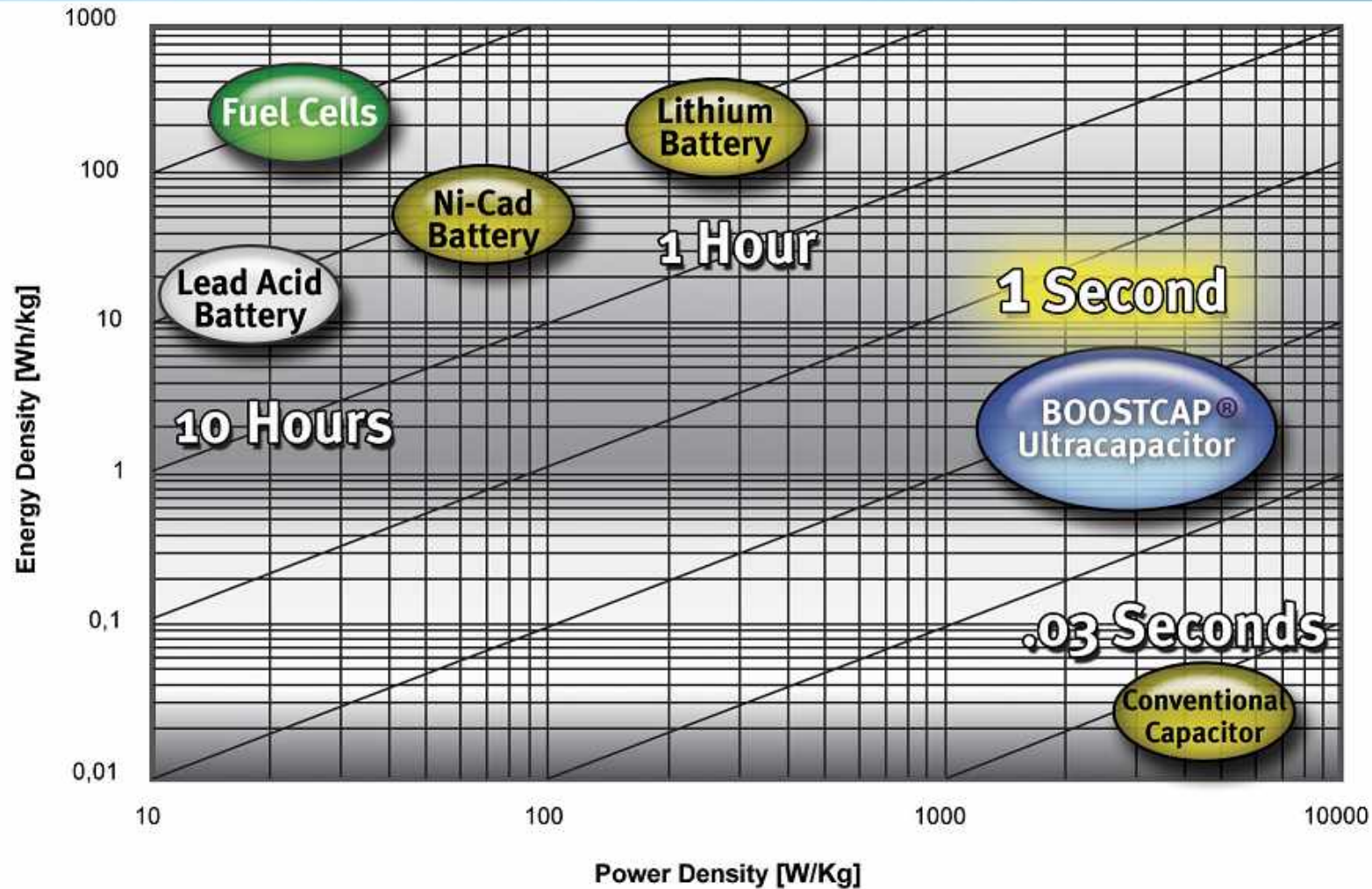


Maxwell
TECHNOLOGIES

How Does an Ultracapacitor Work?

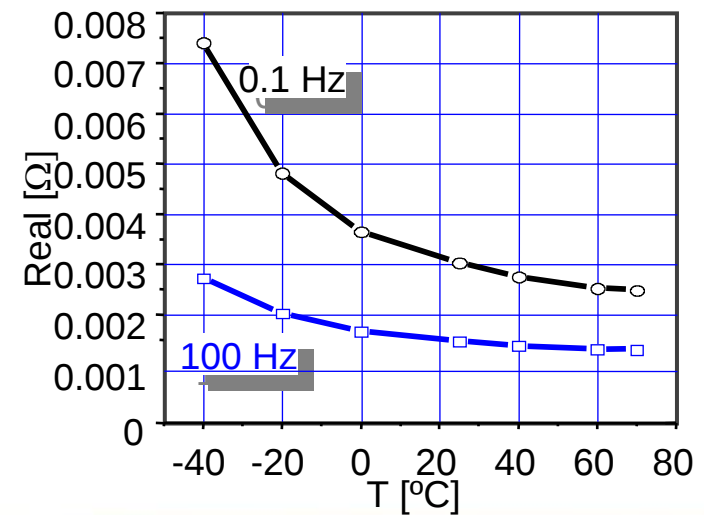
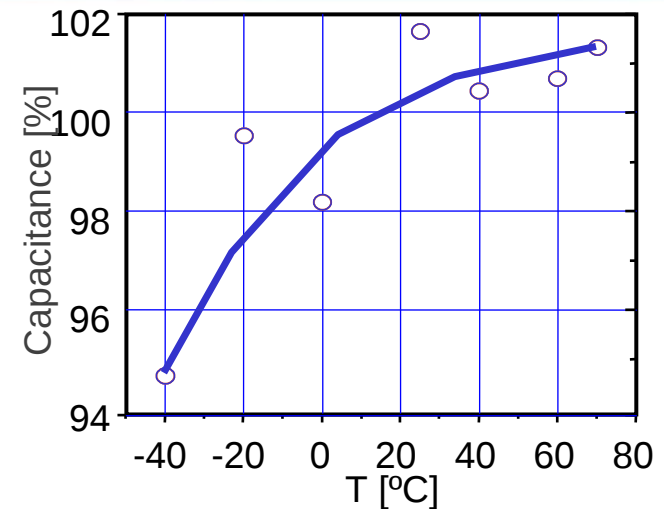


Ragone Plot of Different Storage Devices

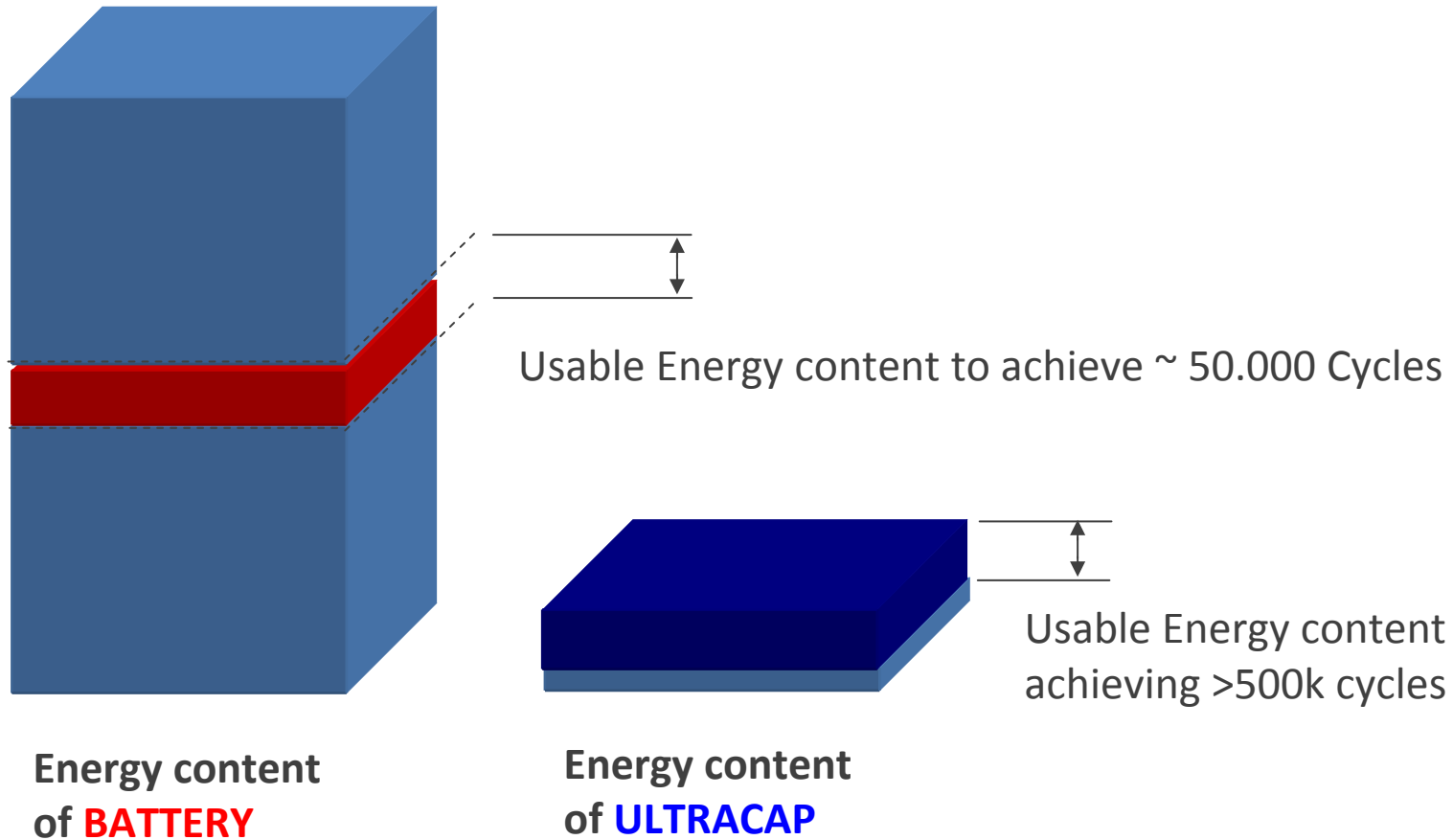


Ultracapacitors Key Features

- Excellent power density
- High durability and long lifetime
 - 1 Million cycles
 - 10 years lifetime
- Standard form factors
- Highly efficient energy transfer
- Cost effective in terms of Wh-cycles
- Stable performance over large temperature range
- Safety certifications
 - UL certified
 - EU norms
 - Automotive standards



Comparison of energy storage devices



Quelle: WIMA

Storage Technologies

Lead Acid Battery

Low cost,
low lifetime

NiMH-Battery

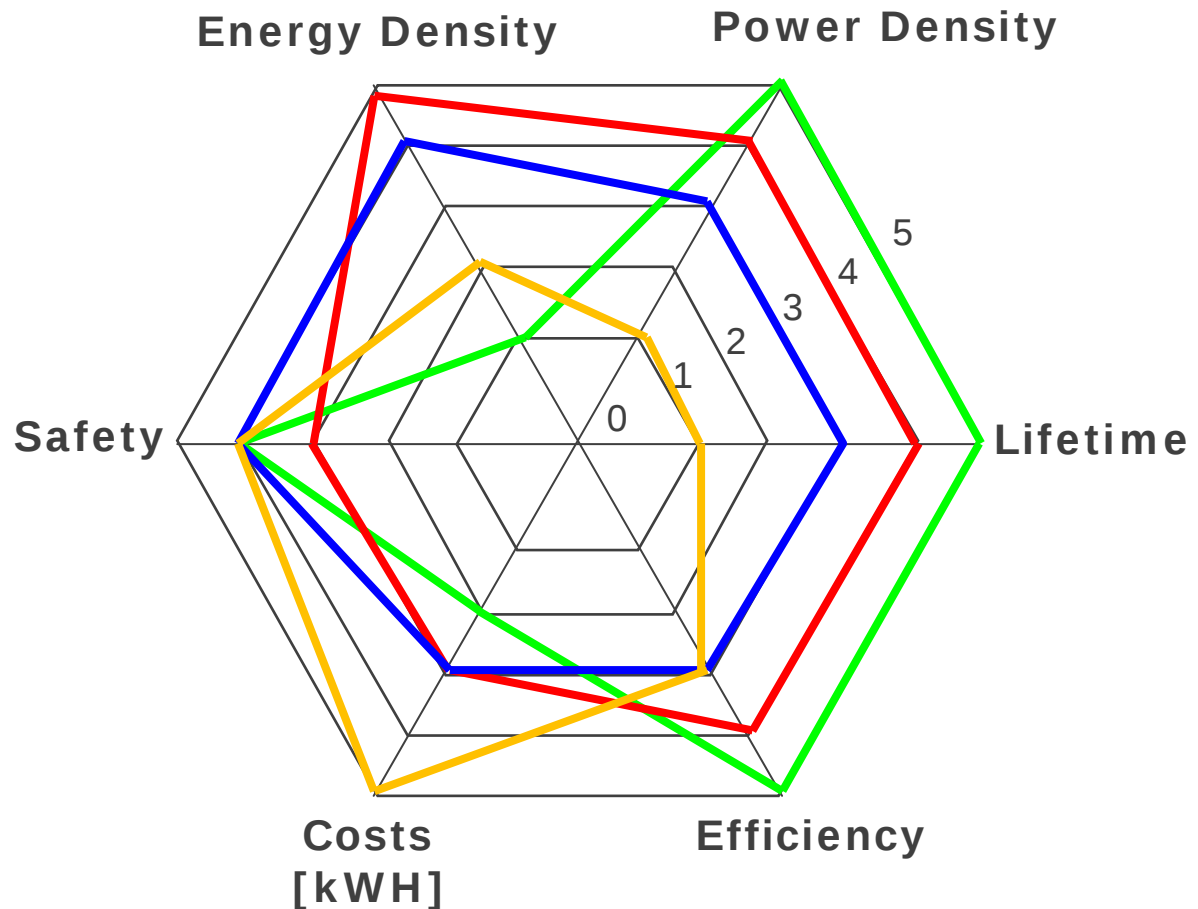
Overall good
performance

Li-Ion-Battery

High performance
High cost

Ultracapacitor

Cycle life,
high efficiency



Reference: Prof.Dr. Haag, Hochschule Esslingen, Germany

Storage Technologies

Lead Acid Battery

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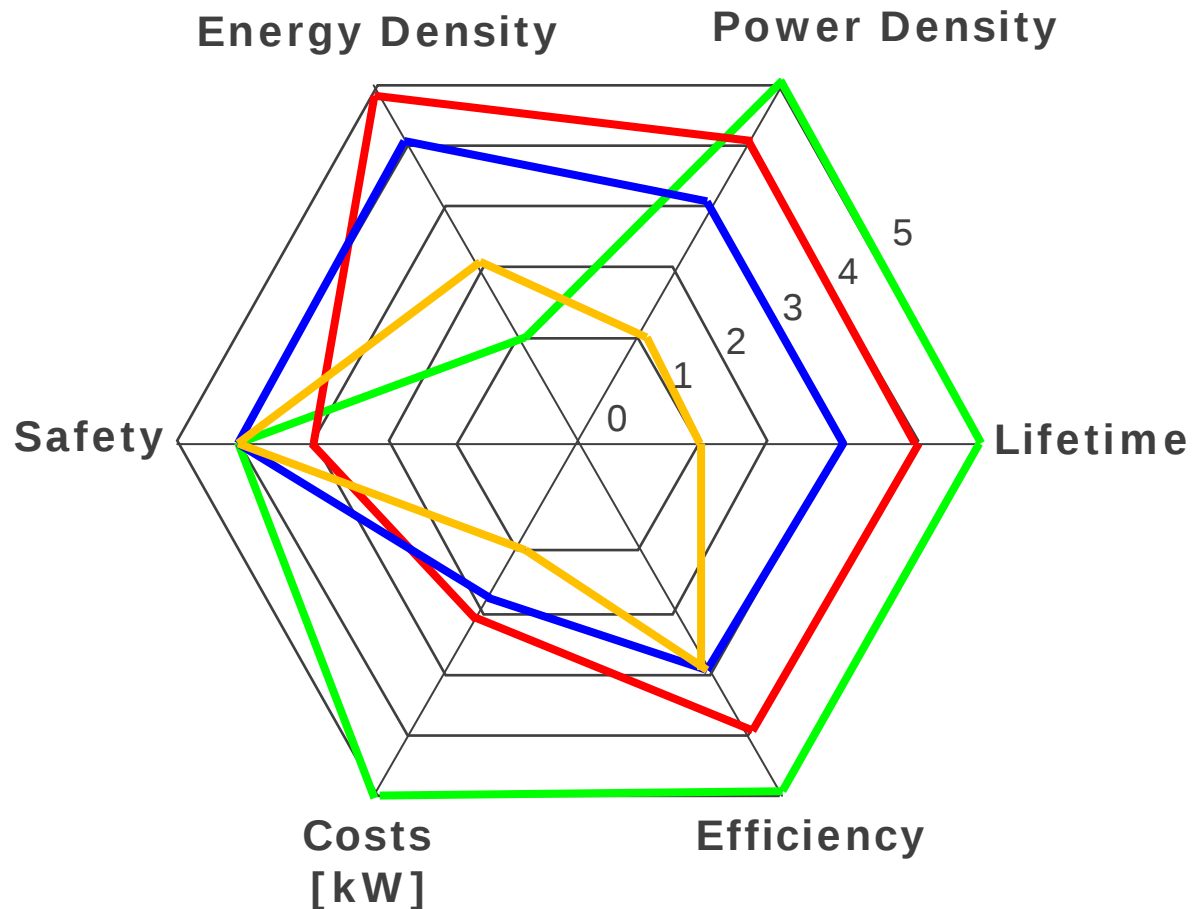
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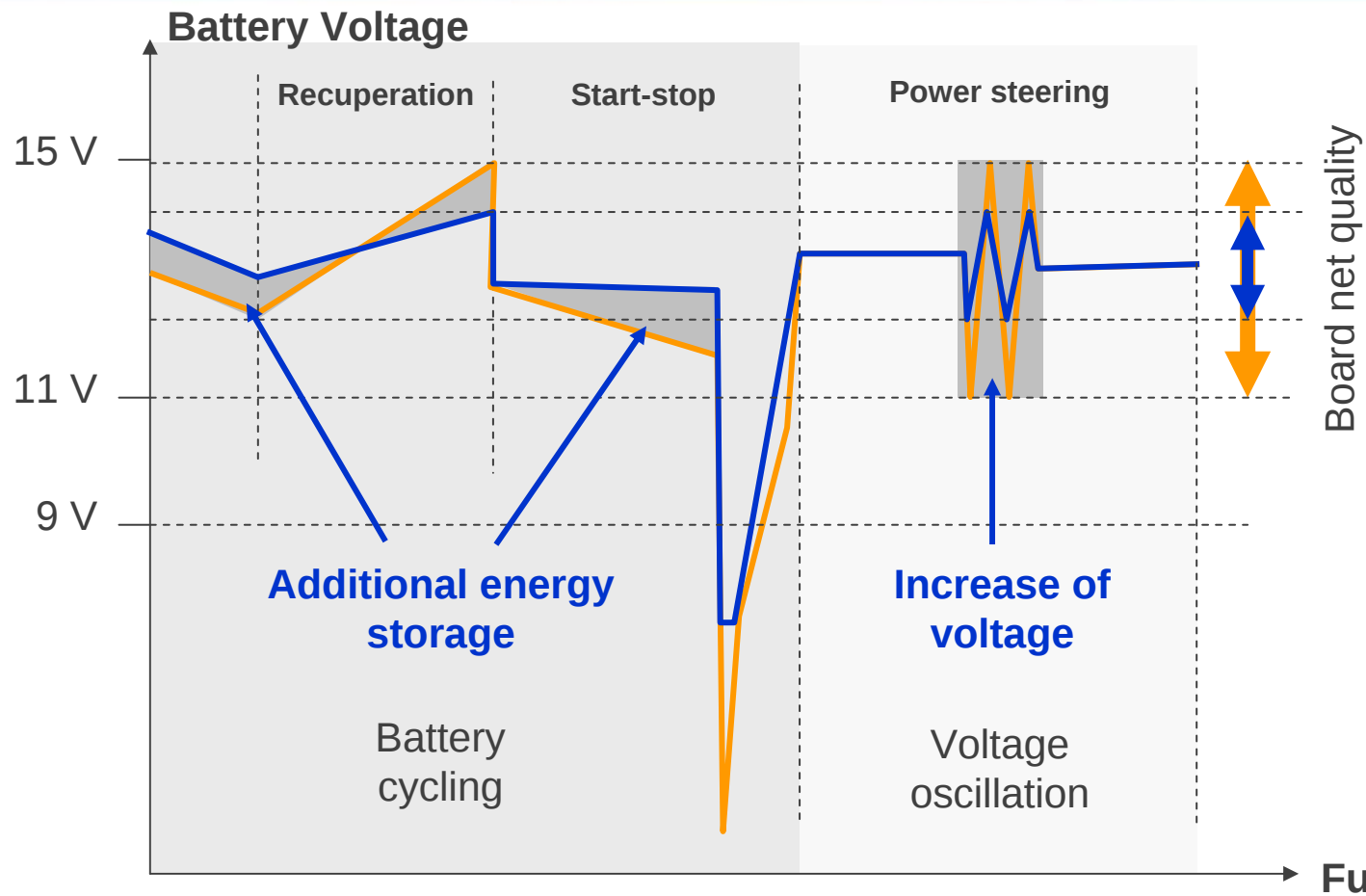
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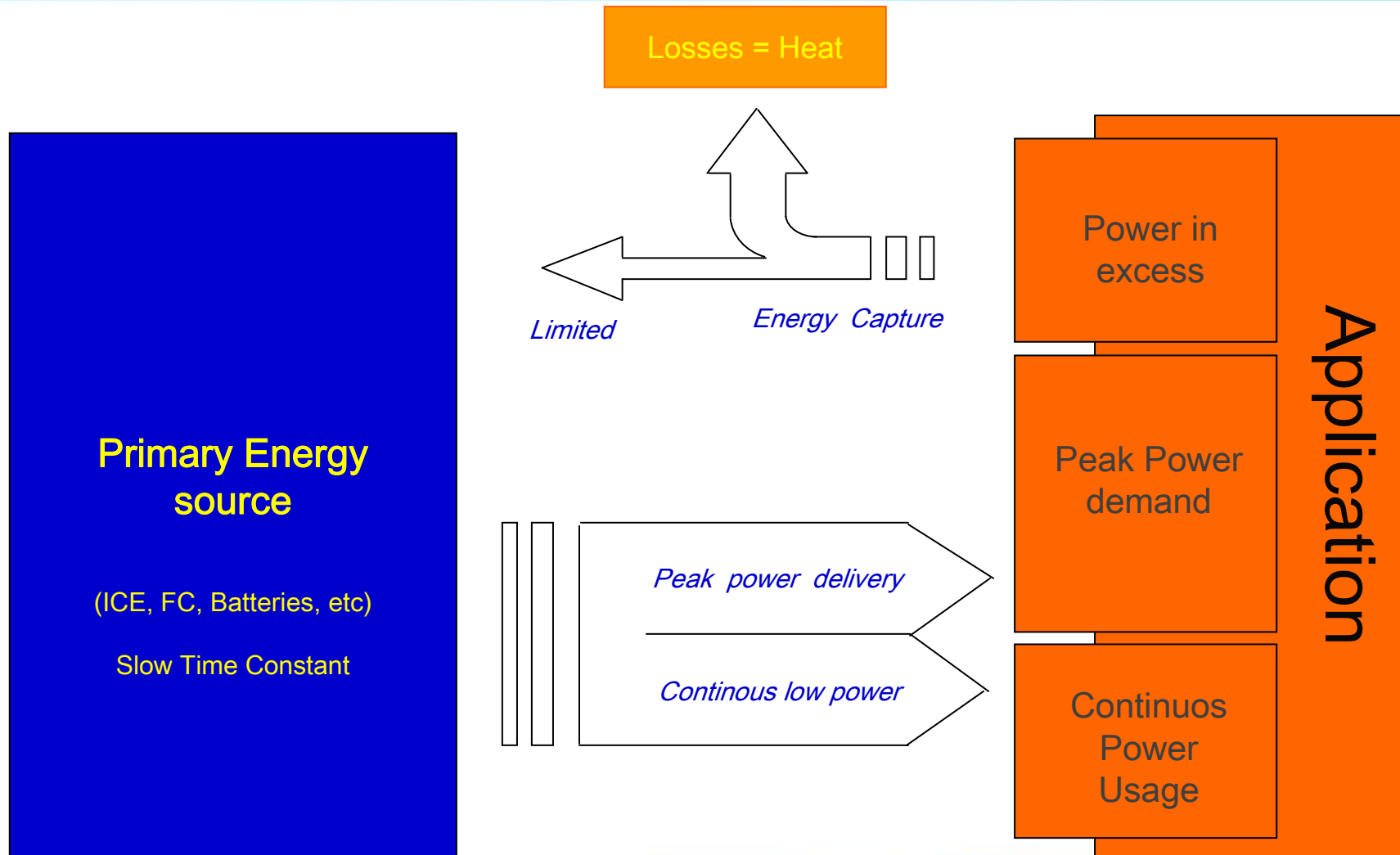
Board Net Stabilization



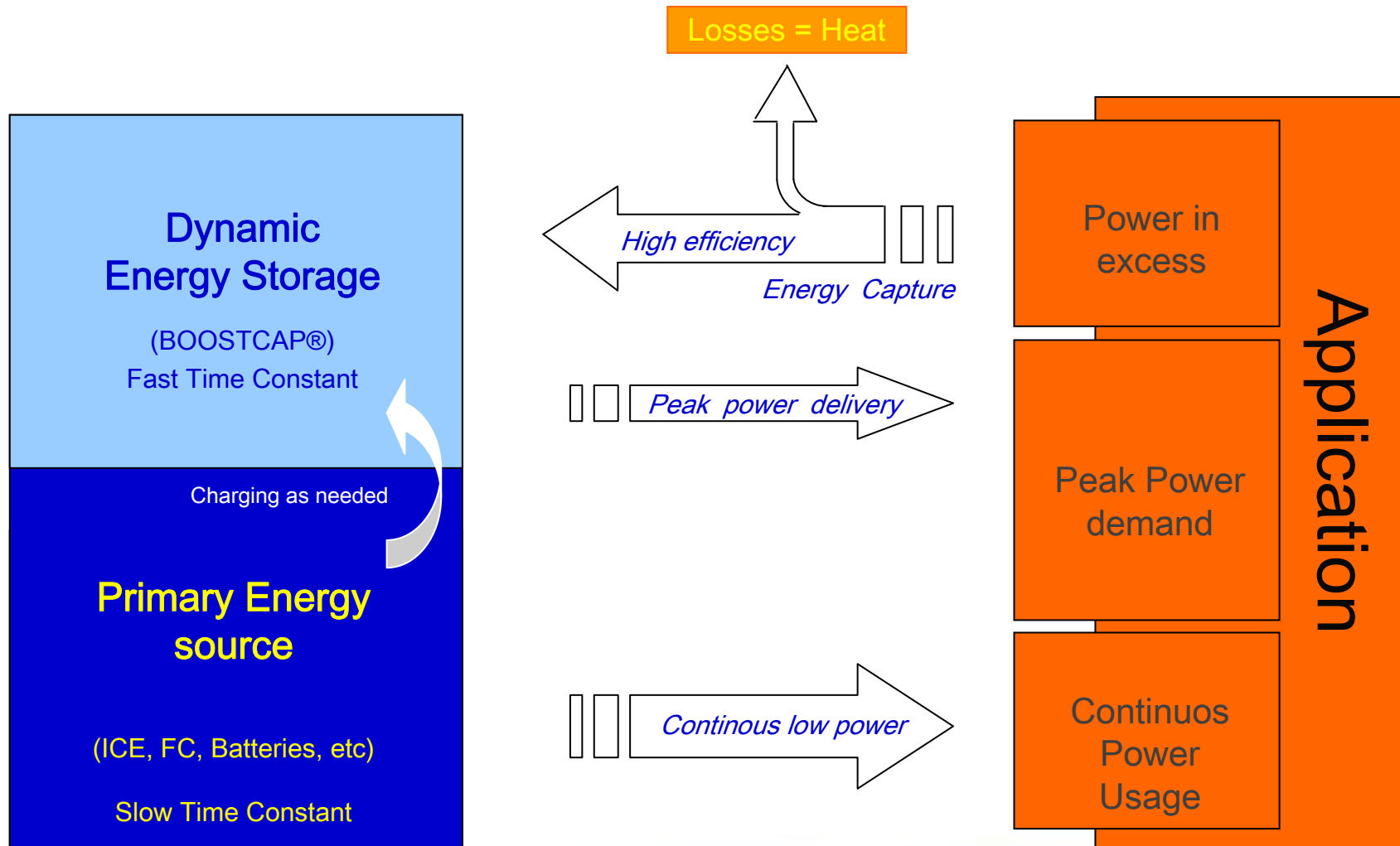
- ⇒ Improved stability of the board net
- ⇒ Less stress of the 12 V battery

Source: BMW AG

Application Model without Ultracapacitors



Application Model with Ultracapacitors



UC / Li-Ion Combination: Current Profile

- Investigate combination of lithium-ion batteries with a dynamically coupled ultracap pack

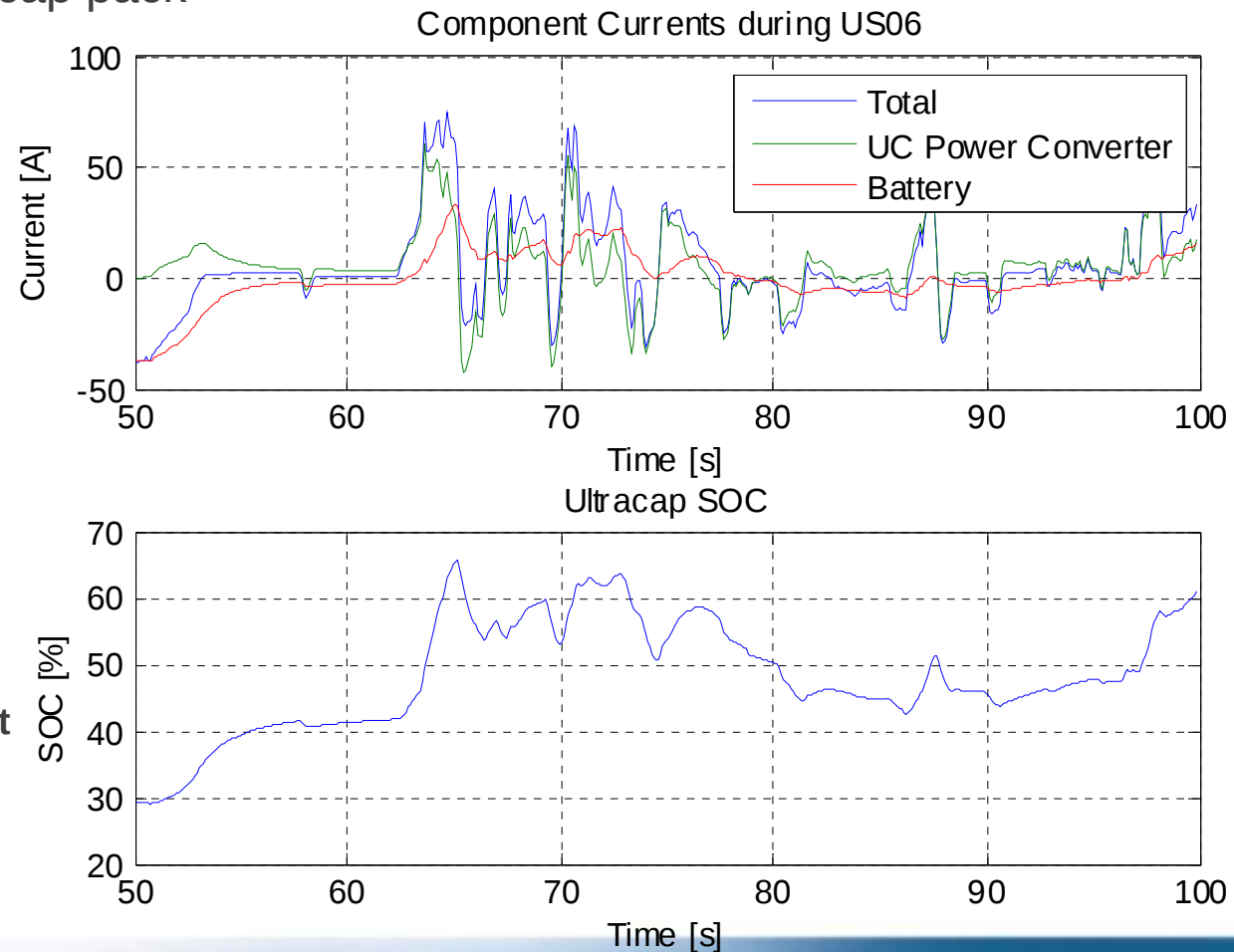
Automotive

Blue line is road load (battery current w/o ultracaps)

Green line is U-cap current (dynamic)

Red line is new battery current- more averaged

SOC is maintained over this current trace, on **US06 segment**



Why / when Ultra Capacitors

Energy need for 1 to 60 seconds

Long life and no maintenance

Cold temperature Capabilities

High peak power demands

Low Power to weight ratio

Low ESR needs

Down sizing of primary energy source

Extending battery life

Green image demands

