Ultracapacitors • Microelectronics • High Voltage Capacitors

Ultracapacitor – a Dynamic and Efficient Power Storage Device for Automotive

IQPC
3rd International Congress Advanced Battery Technology
June 22nd - June 25th

MORE POWER.
MORE ENERGY.
MORE IDEAS.™

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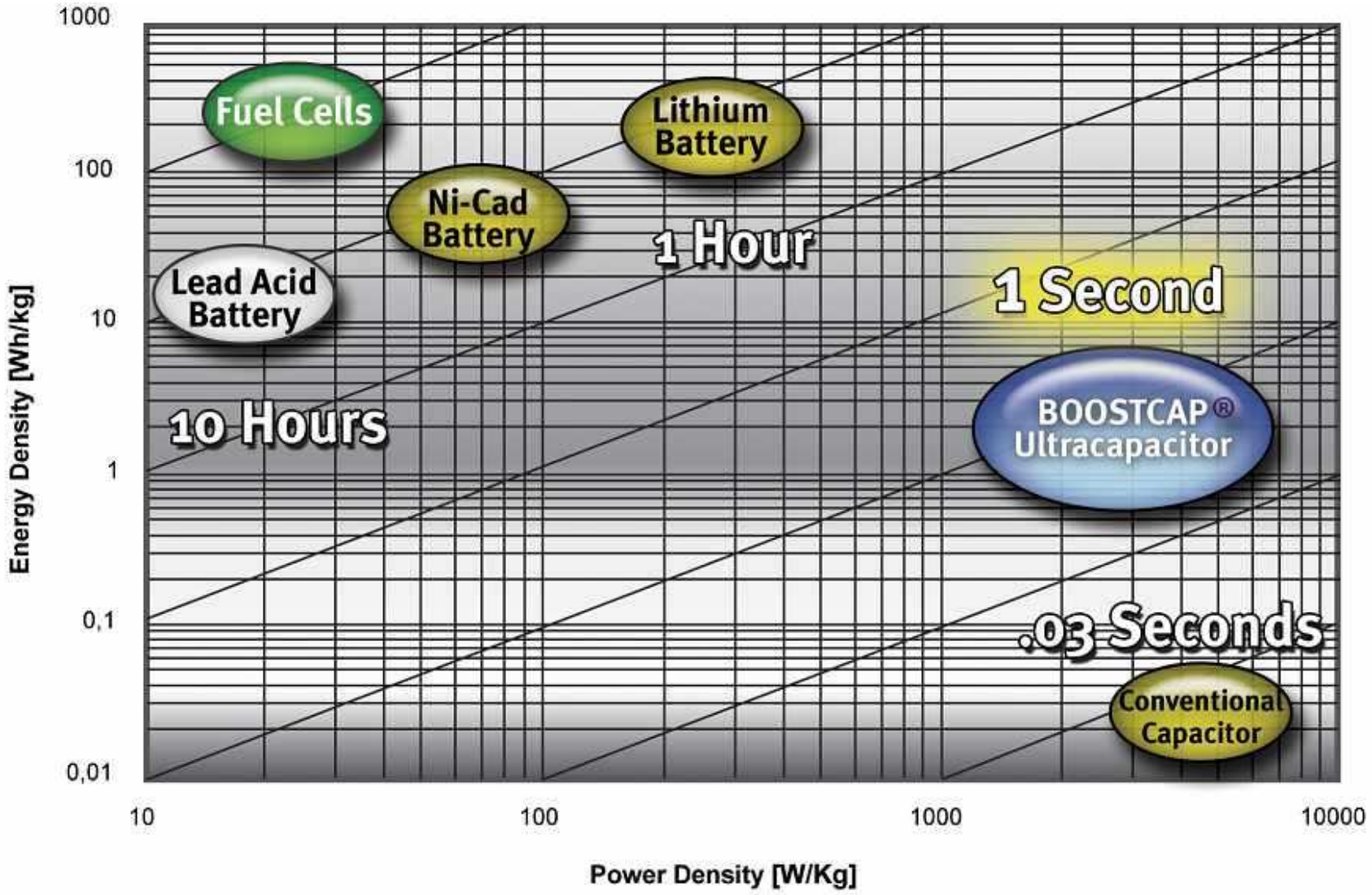
- Ultracapacitor
  - Ultracap History
  - Technology & Design
- Ultracapacitors in Automotive
  - Applications
  - Micro & Mild Hybrid System
  - Combination of Ultracapacitors and Batteries
  - Back-Up

Dynamic Ultracap Compared to Other Storages



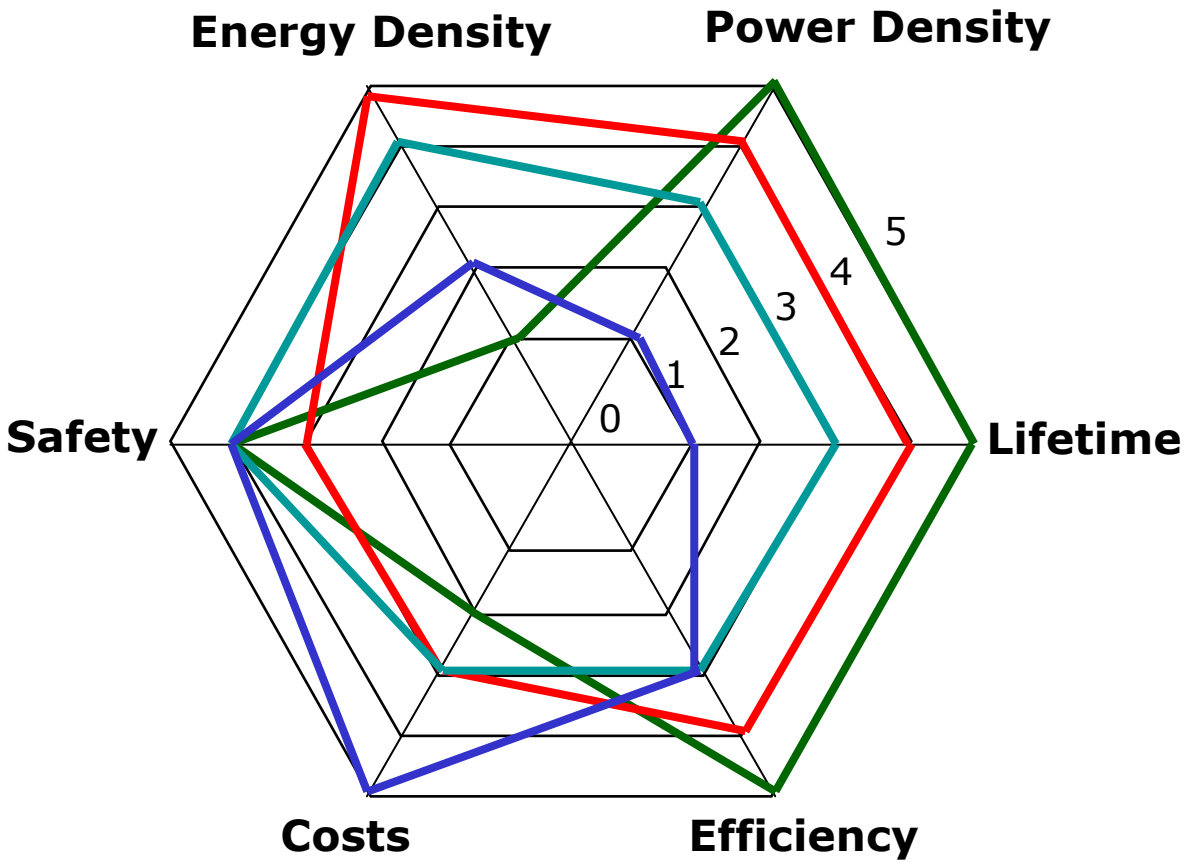
Storage Technologies

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

Ultracapacitor Technology

- Basic material: Carbon
  - Carbon is one cost driver of Ultracaps
  - Raw material: Coconut shells (among many others…)

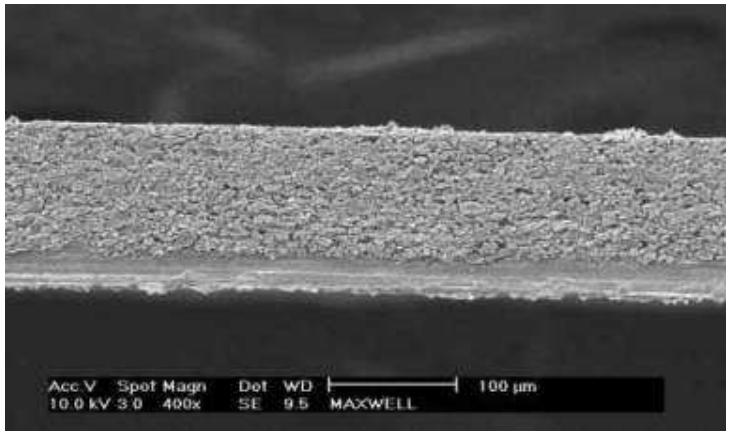
Grind

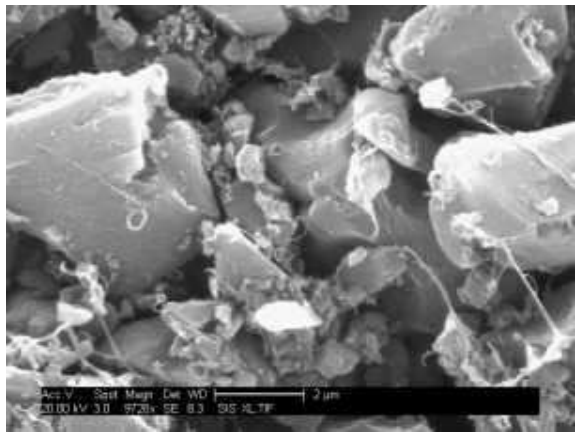
Activation

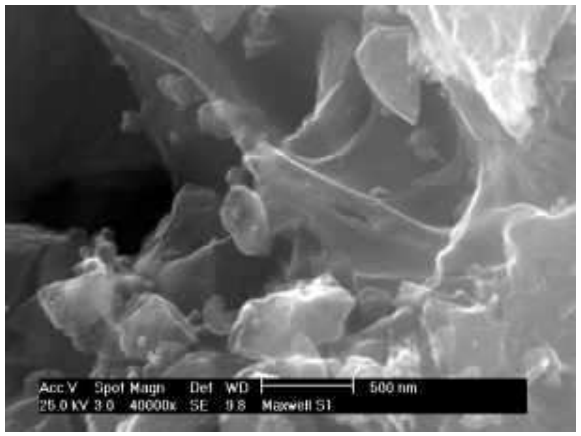
Electrode fabrication

Coating
Rolling/Kneading/
Pasting

BOOSTCAP® Electrode







The Pacific Connection

Mature Product?

Ultracapacitors >650F

20 years of Product Innovation

The 4 year long road …

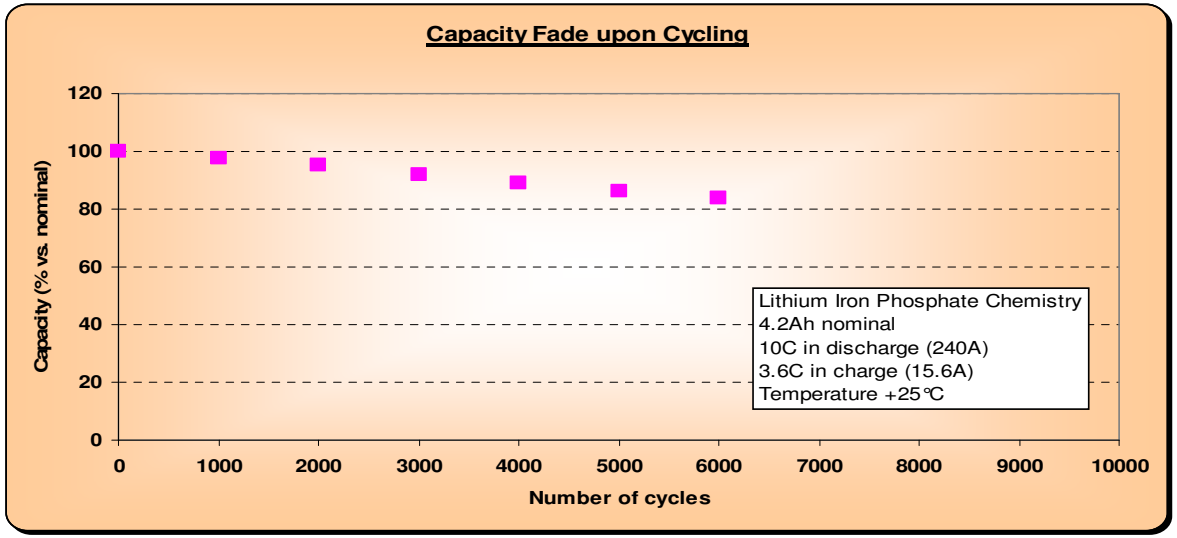
Major Milestone

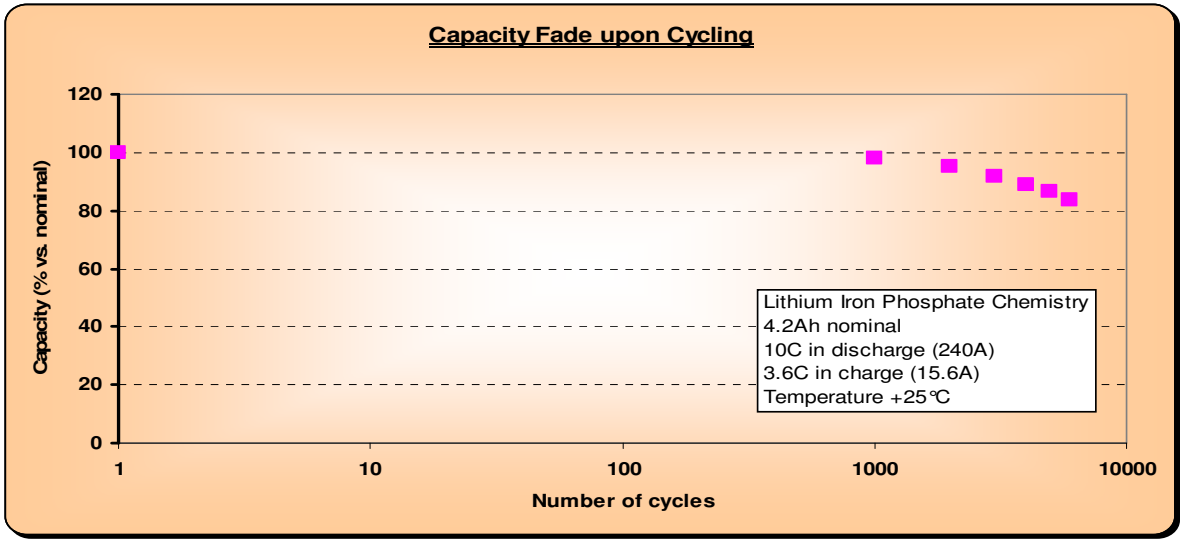
1,000,000 th large Cell *

* large = >650F

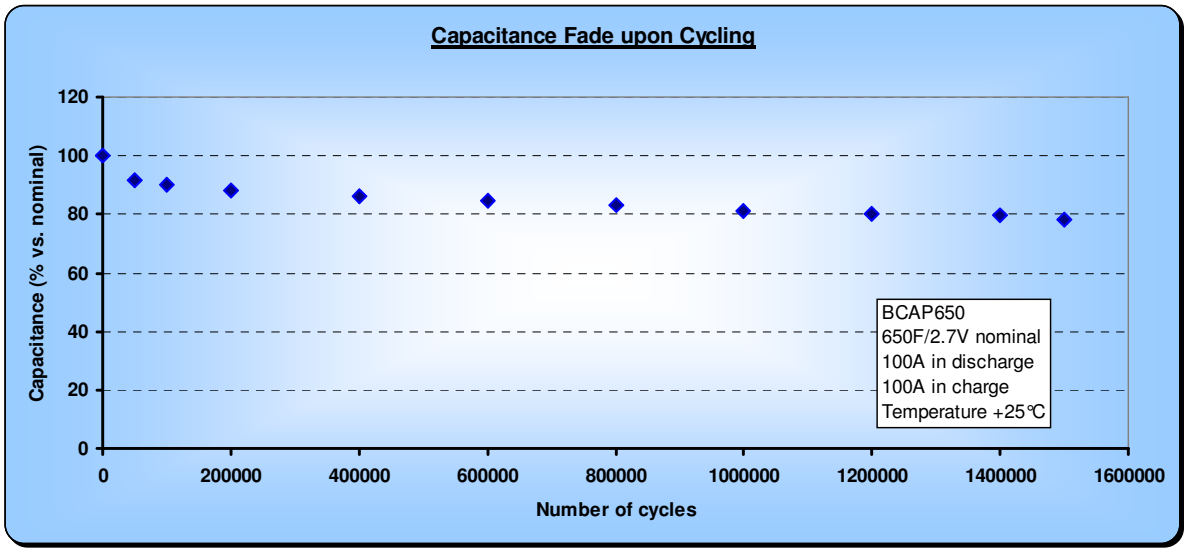
December 2009

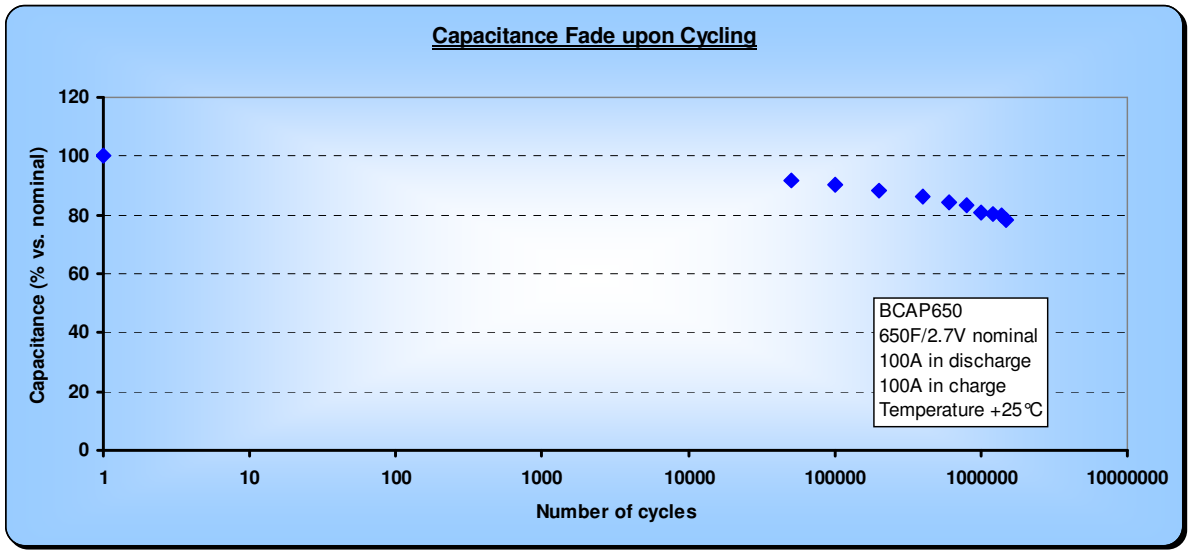
Technology comparison (LFP)



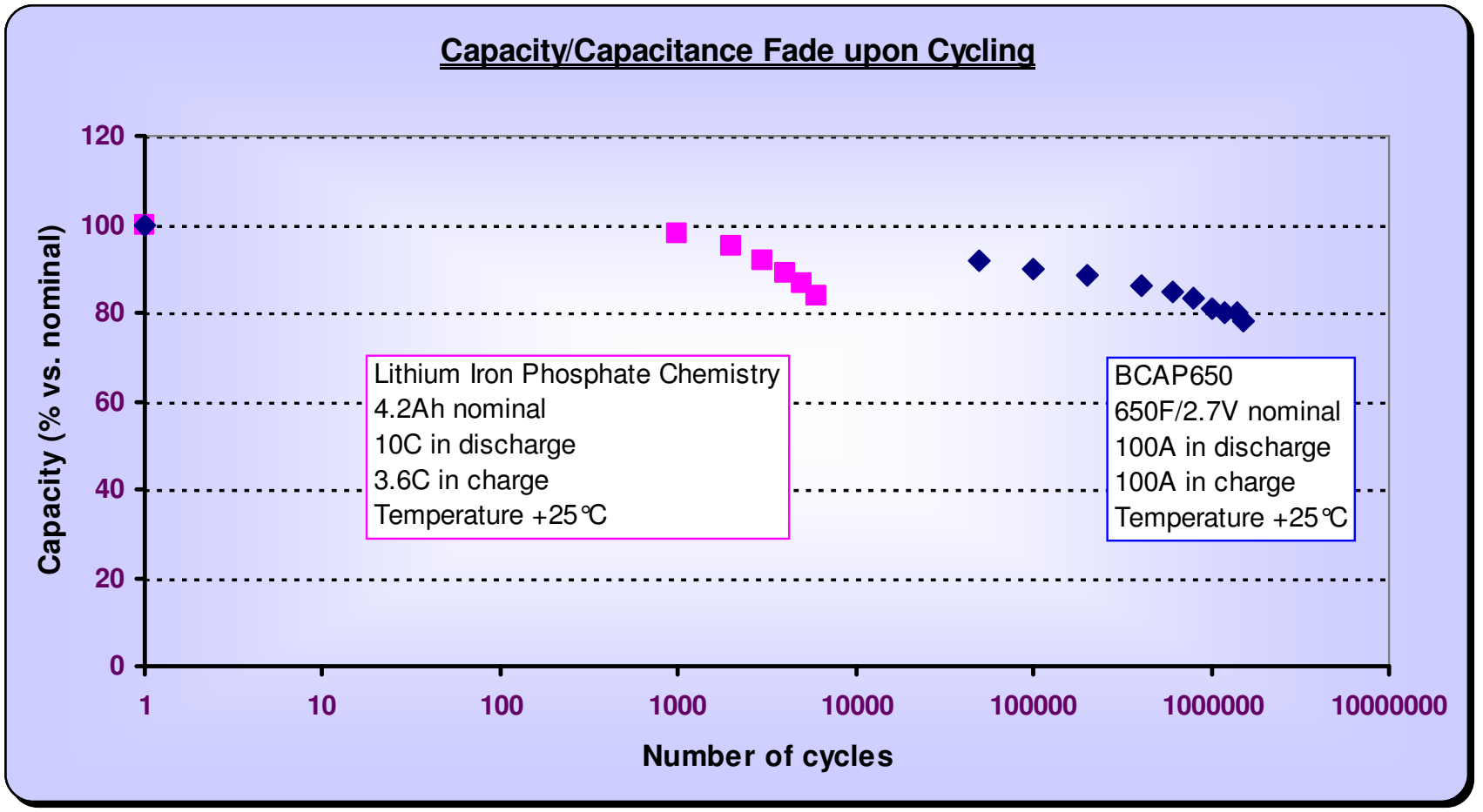


Technology comparison (EDLC)

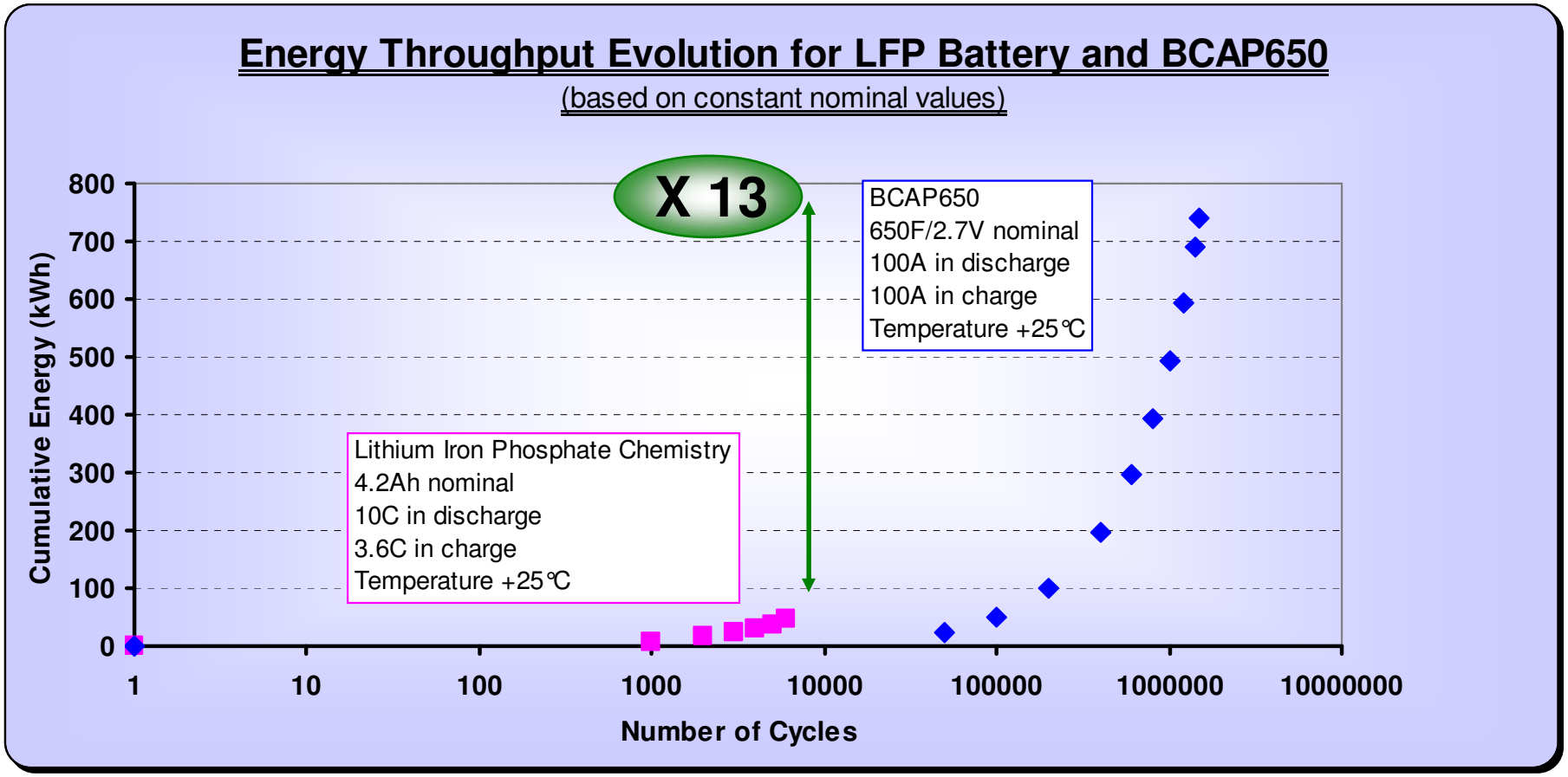




Technology comparison



Technology comparison (LFP vs EDLC)



Mature Application

12,000 turbines in the field

Up to **5** years in operation

From cold climate condition to warm weather locations

Operating up to 8,500 hrs/year (life of car= 6,000hrs)

Mature Application

1,500 + buses in the field
Up to **10** years in operation
Various climates
Hybrid, trolley, all electric variants
Fare generating!!!
Variety of modules

- Large 125V
- Medium 48V
- Smaller 16V
- Custom modules

Mature Application

Global application
24/7/365 type of operation
Various climates
High cycling
Dramatic emission & noise reduction
Variety of modules

- Large 125V
- Medium 48V
- Smaller 16V
- Custom modules

Mature Application

Global application
High reliability **Back-up power**
Instant **bridge power** (1 – 60 sec)
Voltage **sag compensation**
Buffering large momentary in-rush or power surges

Variety of modules

- Medium 48V
- Smaller 16V
- Custom modules

New markets

Auto | **Service**

Industrial | **Exotic**

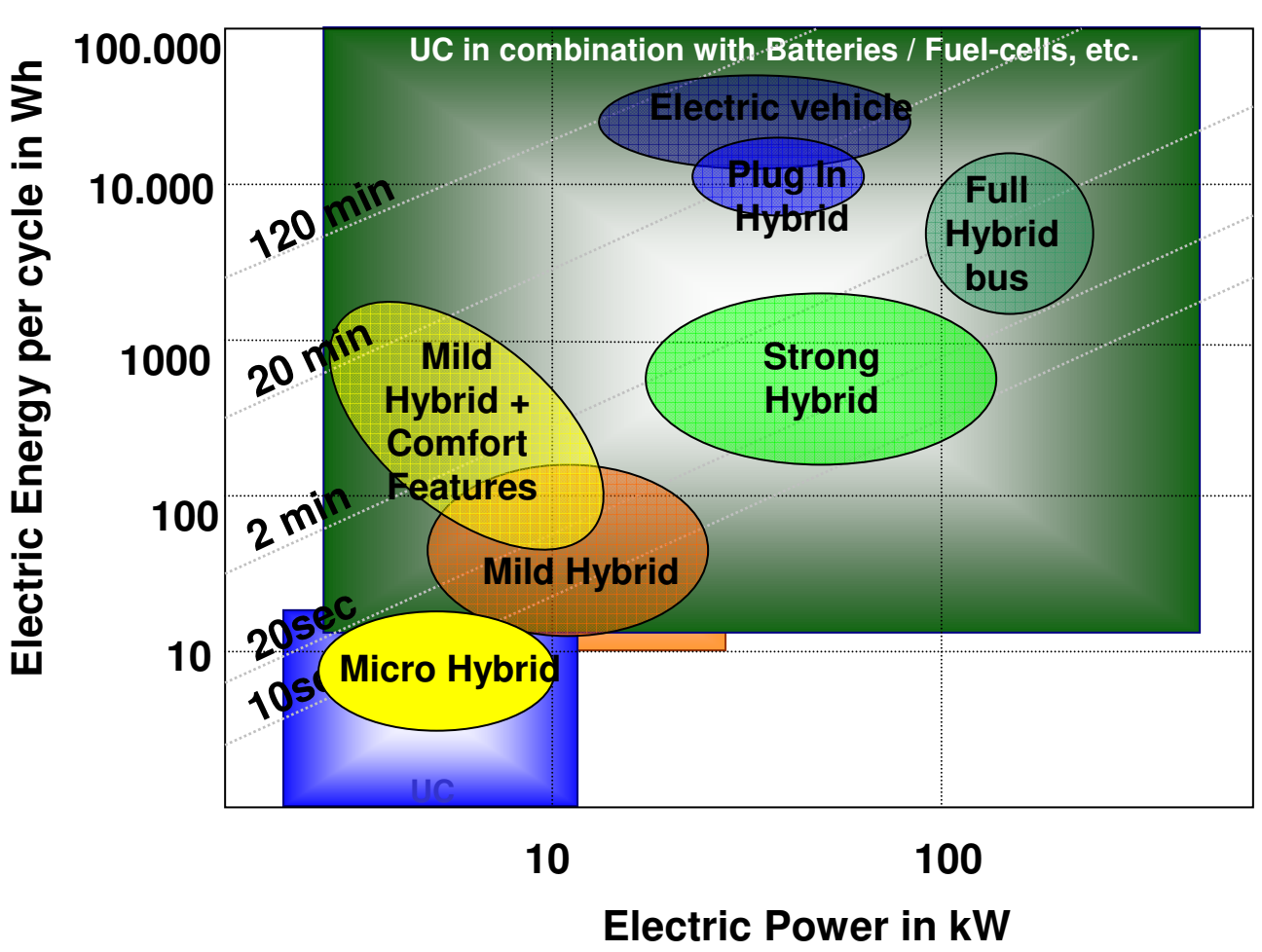
Consequence of Continuous Improvement – K2-Cell

MC-Cell

K2-Cell

Automotive

Hybrid Markets and Trends

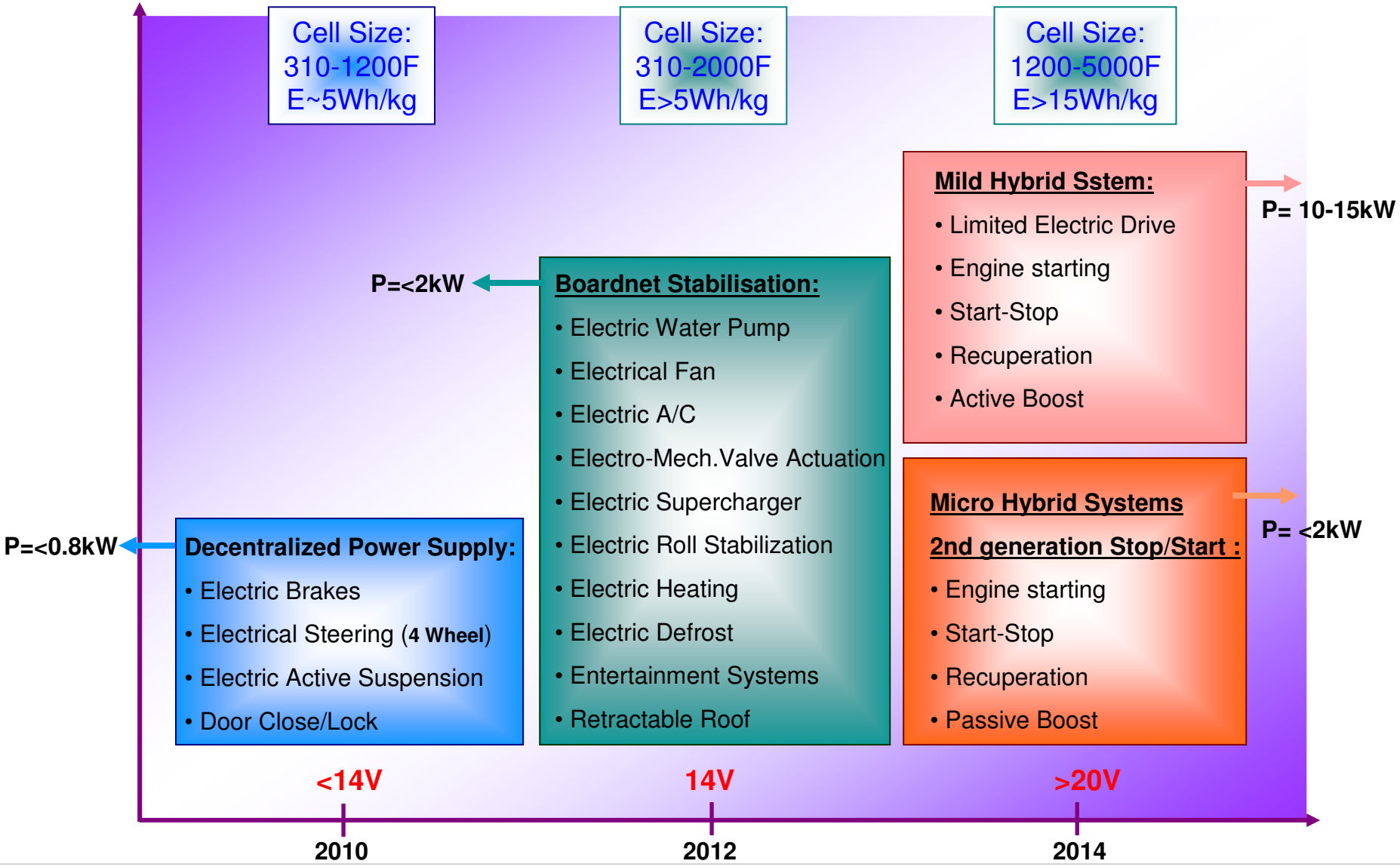


Micro Hybrid:
- <2kW
- 310F – 2000F cells

Mild Hybrid
- <1kWh; 10 15kW
- 7% to 12% FE
- 2000F-3000F cells

Full Hybrid Cars
- 2...20kWh
- 80kW 200kW
- >20PCs of >=3000F cells

Use of UC in Automotive Systems



Potential through Reduction of Parallel Branches

40Wh:

At EOL20: N_40_20%_3000F/2.7V=192/157.9=1.2
At EOL20: N_40_20%_3000F/3.0V=192/176.4=1.1
At EOL20: N_40_20%_5000F/3.0V=192/294.1=0.6 => 1 string
At EOL20: N_40_20%_1250F/4.2V=192/104.1=1.8 => 2 strings

50%!

60Wh:

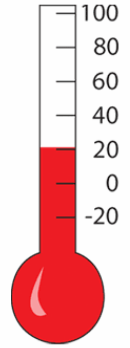
At EOL20: N_60_20%_3000F/2.7V=288/157.9=1.8 => 2 strings
At EOL20: N_60_20%_3000F/3.0V=288/176.4=1.6 => 2 strings
At EOL20: N_60_20%_5000F/3.0V=288/294.1=1.0 => 1 string
At EOL20: N_60_20%_1250F/4.2V=288/104.1=2.7 => 3 strings

80Wh:

At EOL20: N_80_20%_3000F/2.7V=384/157.9=2.4 => 3 strings
At EOL20: N_80_20%_3000F/3.0V=384/176.4=2.2
At EOL20: N_80_20%_5000F/3.0V=384/294.1=1.3 => 2 strings
At EOL20: N_80_20%_1250F/4.2V=384/104.1=3.7 => 4 strings

33%!

Key Influencers of Reported Cycle Lifetime



- Cycle chosen
  - Maximum Voltage
  - Minimum Voltage
  - Duty Cycle and time at maximum voltage

- Environmental Conditions of the lifetime characterization
  - Temperature and time at temperature
  - Humidity

- Current
  - Reported in both charge and discharge
  - Time dependent effects

End Of Life = Service Life

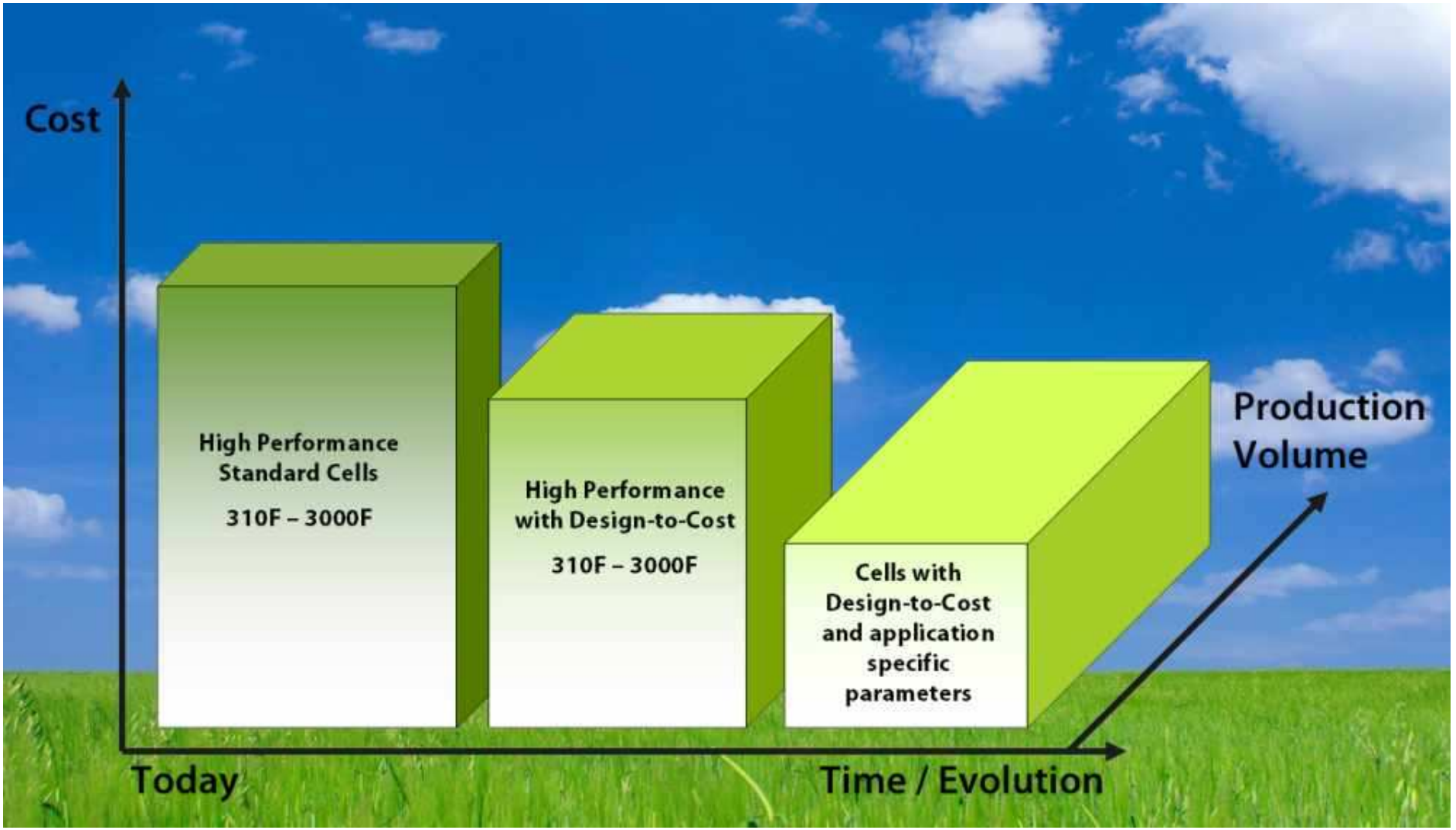
We must talk about service lifetime of ultracapacitors – not failure lifetime!

- Definition – service life is the period of useful lifetime before a predetermined end point is reached (interpreted from the ASTM definition of durability and serviceability).

- Failure lifetime implies parts have run to failure which is not generally achievable due to the long expected life.

- Must use accelerated lifetime models to predict service life.

Outlook


Cost
High Performance Standard Cells
310F – 3000F
High Performance with Design-to-Cost
310F – 3000F
Cells with Design-to-Cost and application specific parameters
Production Volume
Today
Time / Evolution

Conclusions

- Mature markets are expanding
- New markets are popping up
- Product line-up is evolving to meet wave of demand
- Auto applications are real

Ultracapacitor Technology is well proven

- not just by Maxwell

Thank you very much for your attention!

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