State of the art and future trends of supercapacitor technology

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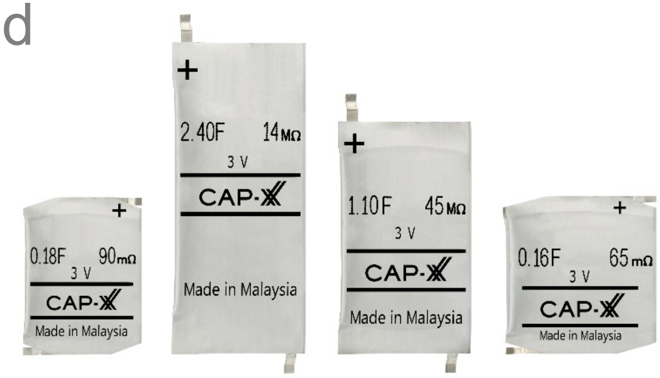
Agenda

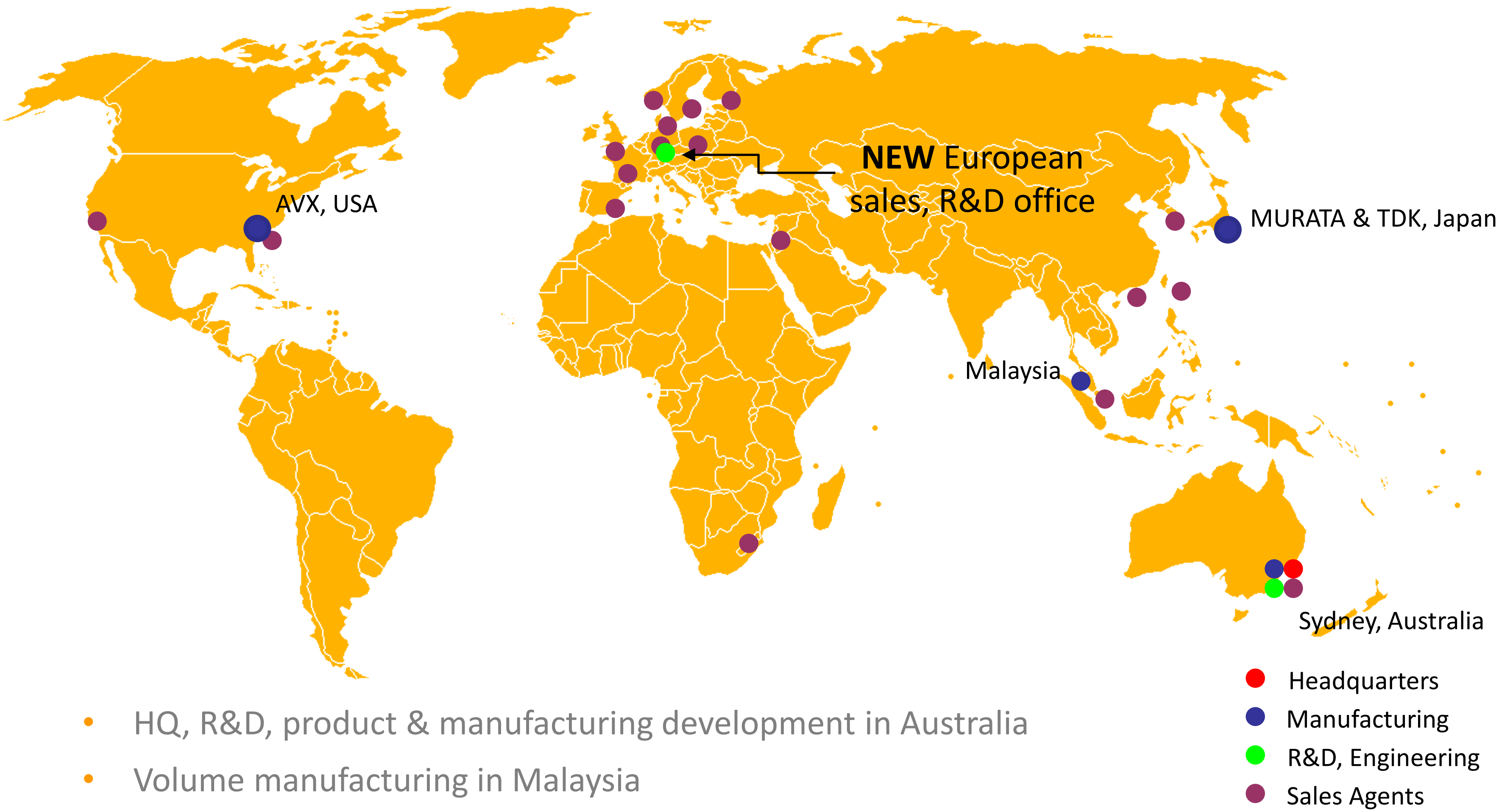
- CAP-XX: about us
- Fast growing markets for supercapacitors:
  - IoT
  - Transportation
- Summary/Conclusions

About CAP-XX

- Global supercapacitor supplier
- Market leader in prismatic, high power supercapacitors
- Dual strategies of IP licencing and product sales
- Strong IP licensed to multinationals Murata, AVX & TDK
- Target applications are high growth markets – US$100m +p.a.
- 25+ million CAP-XX supercapacitors sold
- 3V supercapacitor cells available soon

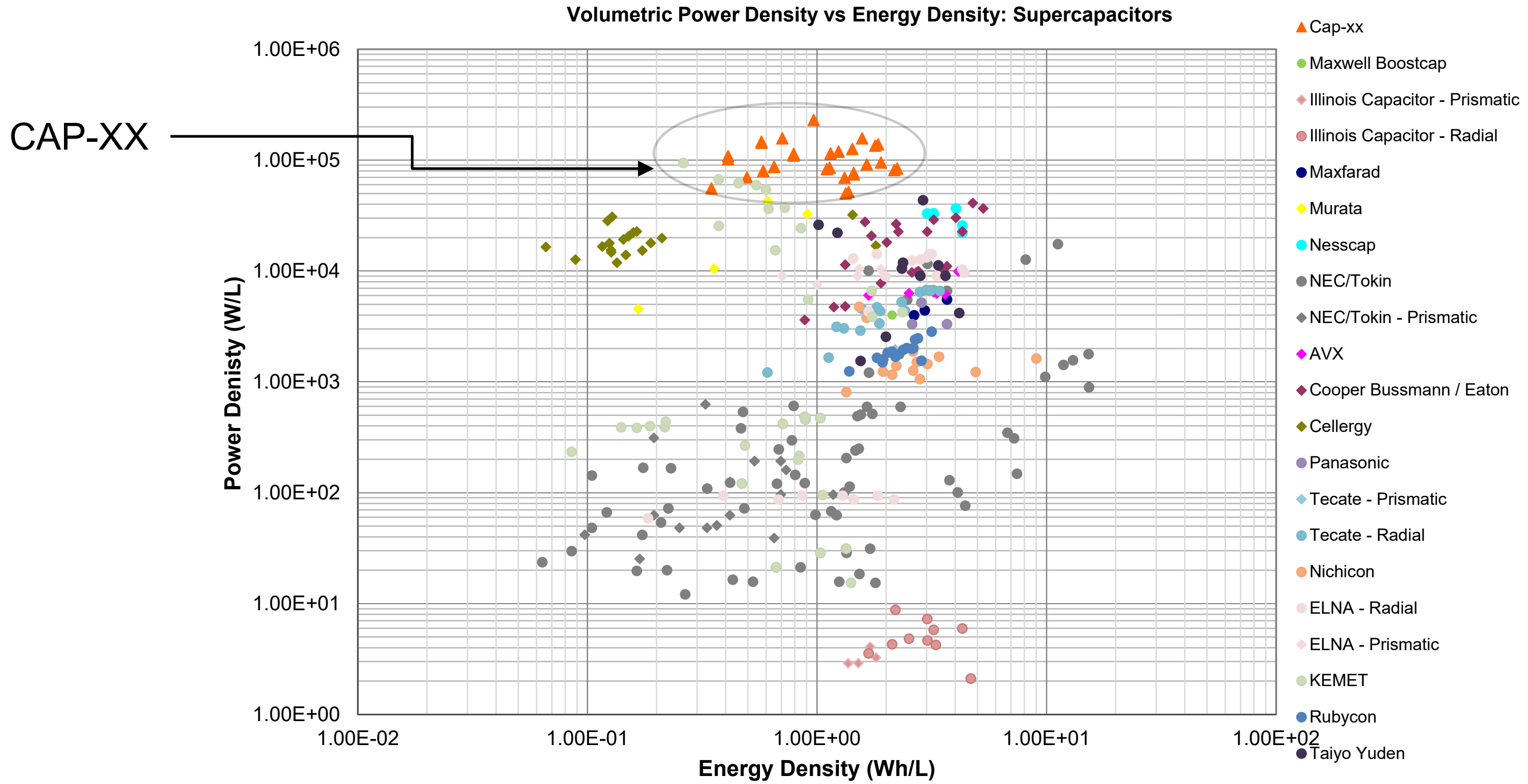


About CAP-XX



- HQ, R&D, product & manufacturing development in Australia
- Volume manufacturing in Malaysia
- Global market coverage via CAP-XX and local sales agents

CAP-XX's competitive advantages



- best in class power density (110KW/L)
- High energy (high capacitance)
- Very high power (low ESR)
- Efficient packaging

Current Supercapacitor Markets

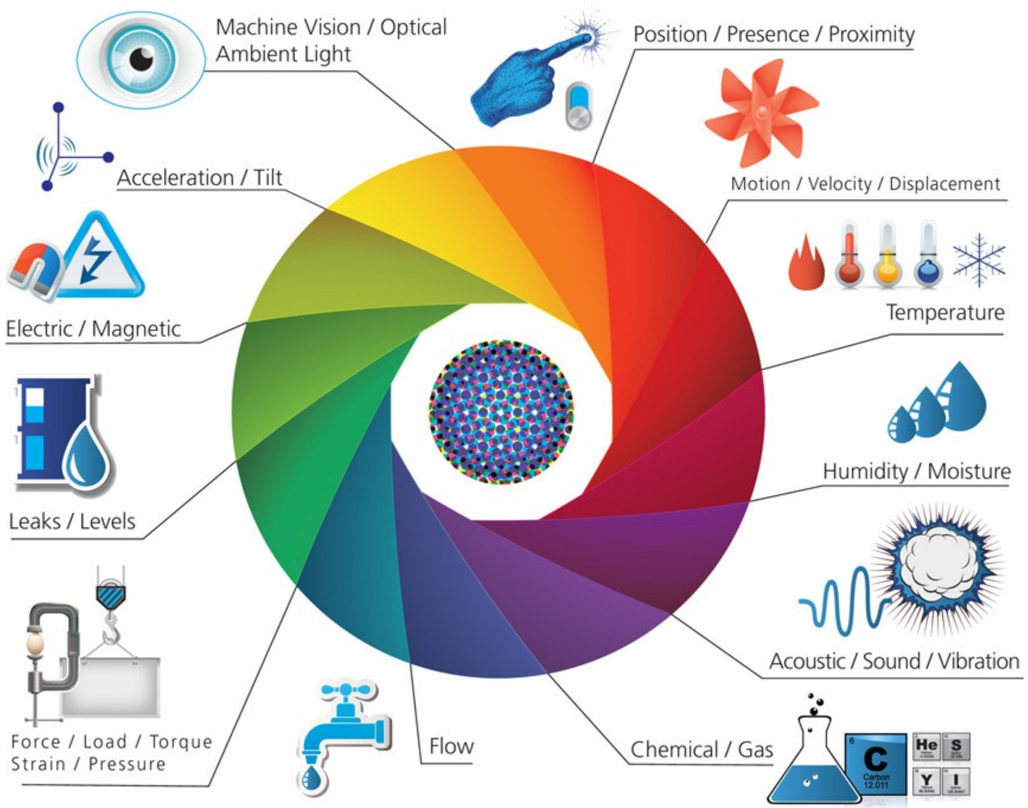
- **Industrial/Commercial Electronics**
  - ✓ Portable POS, PDAs & PCs
  - ✓ Location trackers & RFID tags
  - ✓ M2M condition monitoring (AMR, etc.)
  - ✓ Smart home/Smart building
  - ✓ Medical & Military devices
  - ✓ Security & electronic locks

- **Consumer Electronics**
  - ✓ Mobile phones/Smartphones
  - ✓ Digital video & still cameras
  - ✓ Solid state drives (SSD)
  - ✓ e-Book readers & tablet PCs
  - ✓ MP3 players & speakers

- **Clean-tech: Energy/Utility**
  - ✓ Energy harvesting storage/smoothing: Solar, Vibration; Wind, Thermal, RF
  - ✓ Smart grid & grid smoothing
  - ✓ UPS & PFC

Future Key Markets

Internet of Things

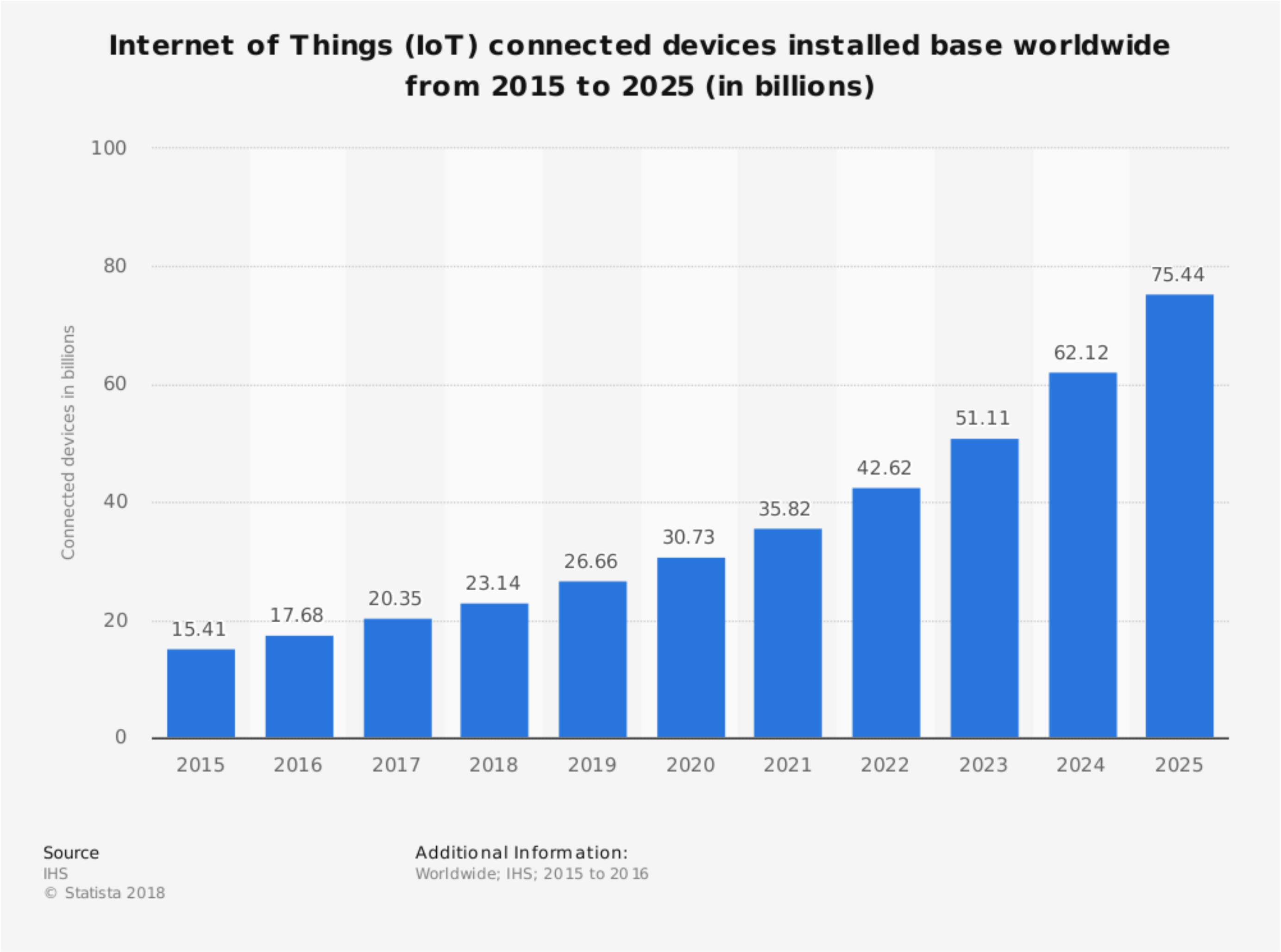


Source: IoT infographic

Transportation

Sources: Bombardier, Chinabuses,

1. IoT market growing exponentially



Many IoT applications use low power energy sources (small batteries & energy harvesters)

- Connected electronics (smart home, wireless sensor networks)
- Wearable electronics (activity/fitness bands, watches, healthcare)
- Portable electronics (smart cards, smart tags, key FOBs, handhelds)

… but need to support peak power loads

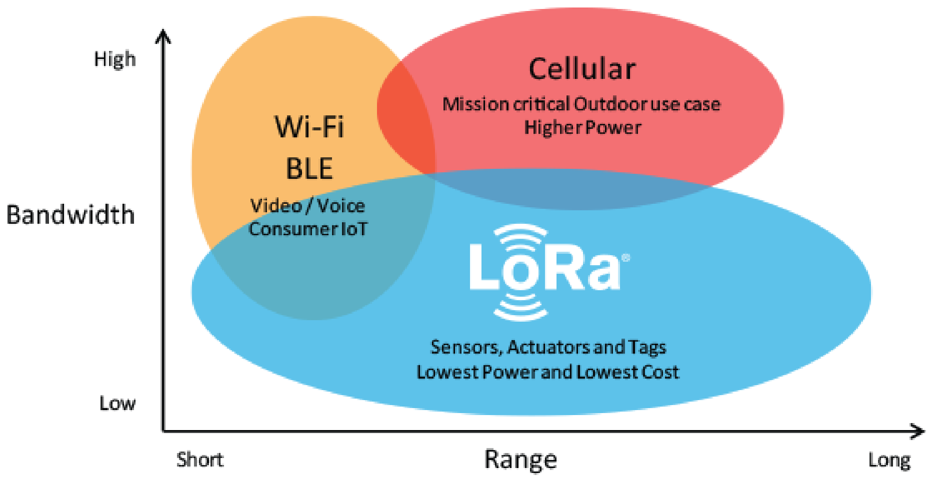
- RF transmissions
- E-Ink and OLED displays
- Haptic feedback & vibration alerts (with electric motors)
- GPS acquisition
- Data acquisition, storage, MCU start-up etc

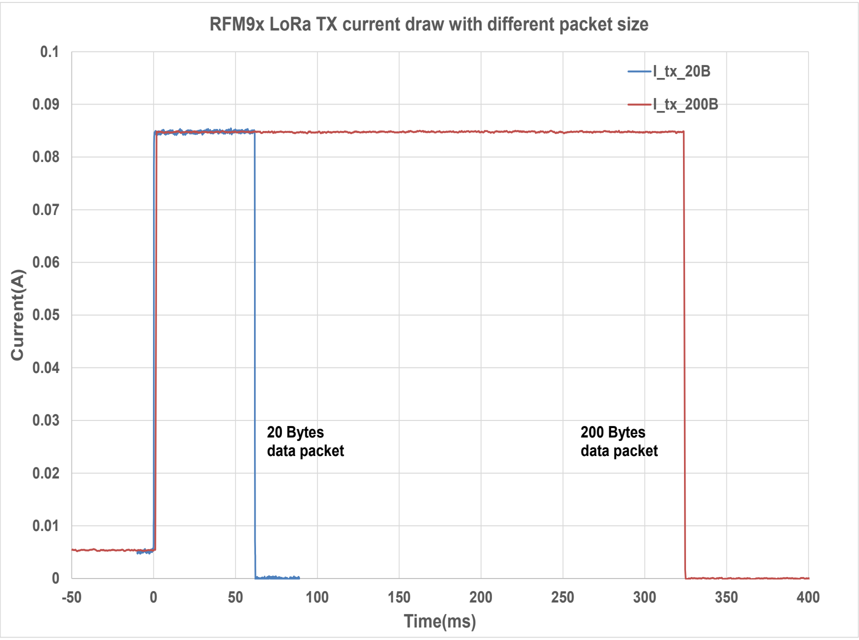
Supercapacitors enable energy harvesting for IoT applications

- CAP-XX Supercapacitors are an ideal power buffer. They:
  - Do not require complex charging circuits, they will accept whatever current you can deliver (you just need over-voltage protection)
  - Have very low leakage current (< 1µA) so can be charged at very low power
  - Have low ESR so can deliver the power required to capture and transmit data
  - Have high C so can store the energy required

Example: LoRa network

- Low Power Long Range proprietary technology
- 5Km line of sight, campus wide reporting of data
- data rates are below 50kbps





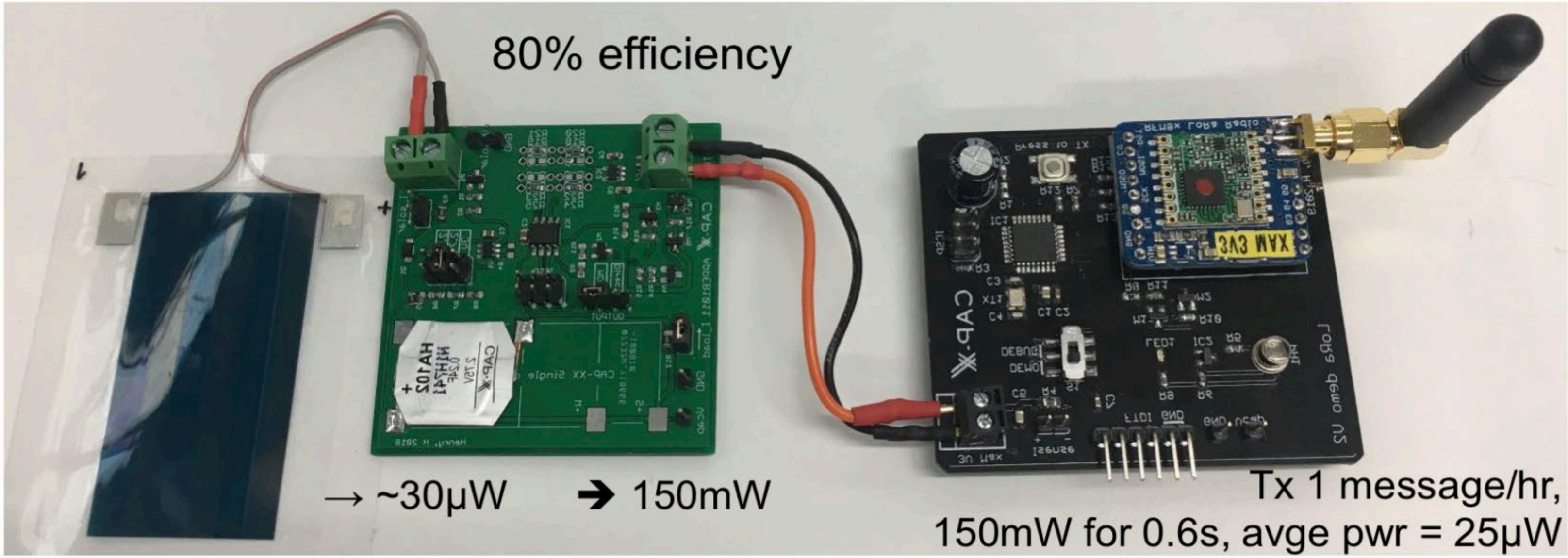
Supercapacitor: an ideal power buffer

- Supercapacitor charged at low average power
- Supplies peak power bursts (low ESR)

And/or

- Backup power in case of energy loss (high C)

Regulate duty cycle so Avge Pwr Out ≤ Avge Pwr In



CAP-XX

OTHER APPLICATIONS

SMART METERS

MEDICAL

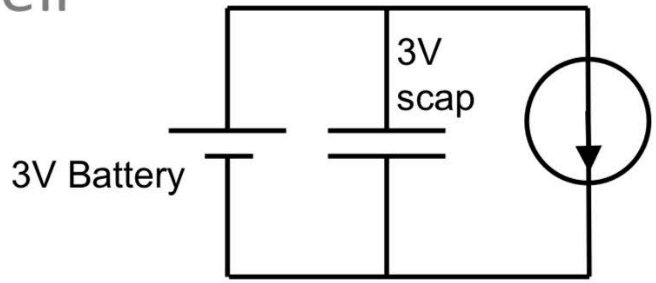
SMART CREDIT CARDS

ELECTRONIC LOCKS

3V supercapacitor cell

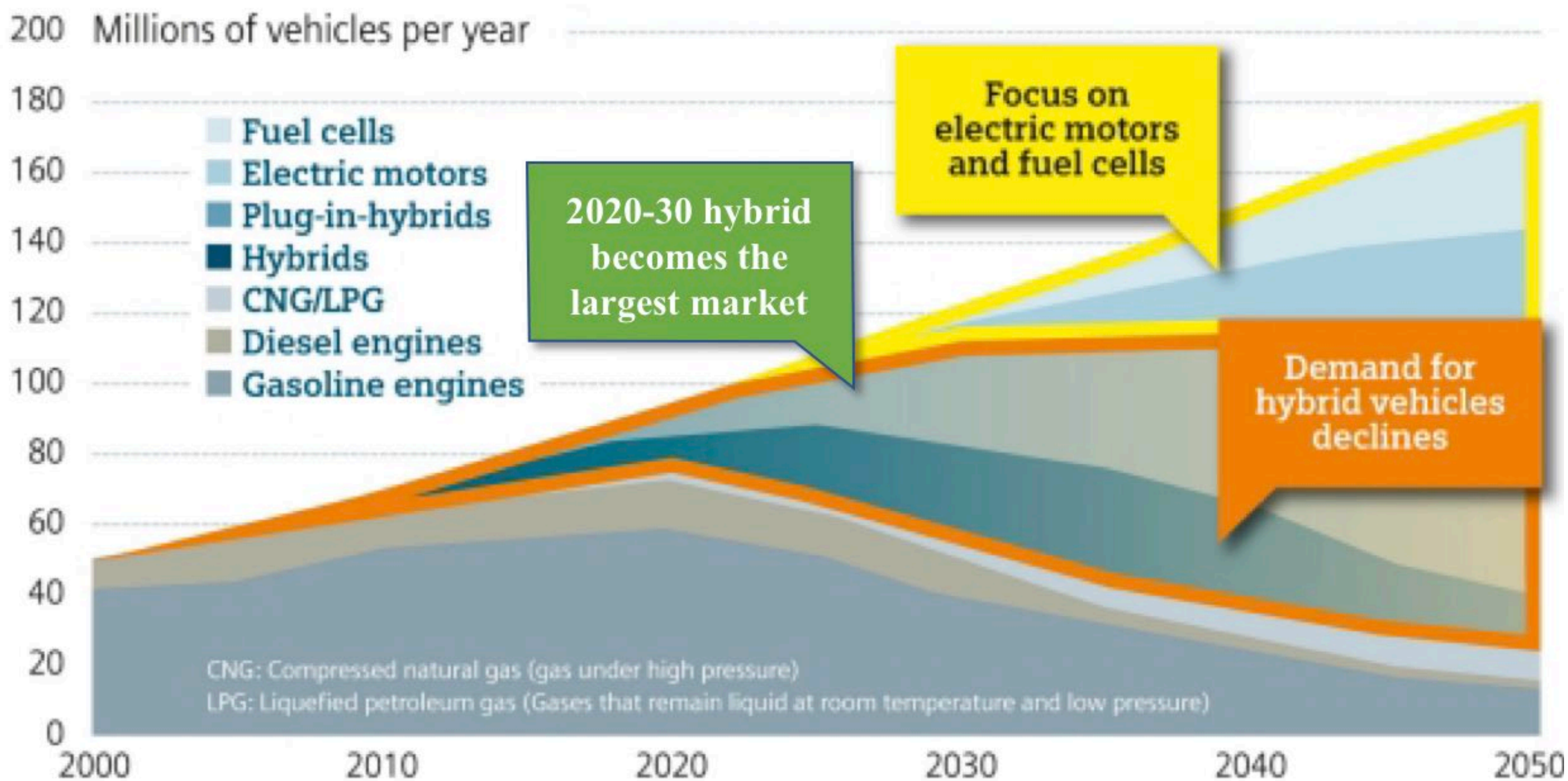
- Target specs:
  - 3V, -20°C to +70°C
  - 500mF
  - ESR < 200mΩ
  - IL < 2μA

- HA130 size (20mm x 18mm x 1.7mm)
  - Fits over CR2032 coin cell
- Place directly across a 3V coin cell
  - No extra circuit required
- Higher energy for EH apps
  - 3V→ 2V 50% more energy than 2.7V → 2V



2. Transportation market: evolution

Source: IEA



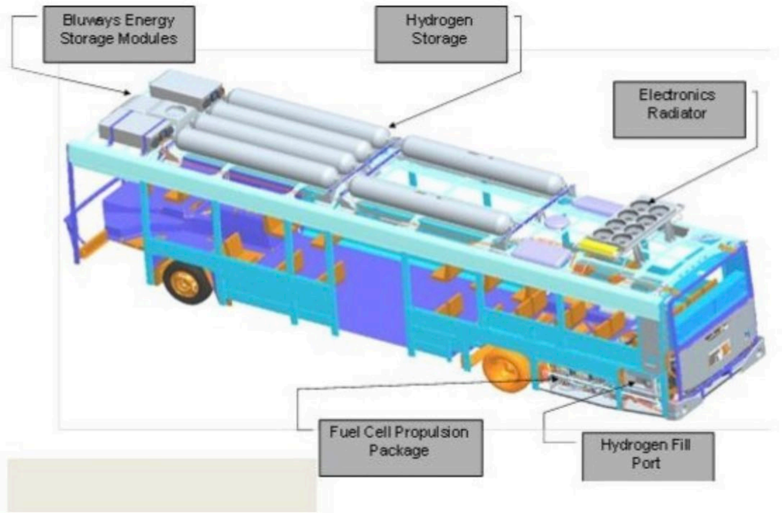
Short term growth: supercapacitors for electric & fuel cell buses

Source: ES Components

Supercapacitor electric buses are very common in China. The Chinese company Sunwin, a joint venture between Volvo and China's largest automaker SAIC had already made a big publicity stunt in 2010 by providing **61 electric buses using supercapacitors** to serve the World Expo 2010 of Shanghai.

Wright bus: Deployed in London

The figure shows 6 tanks, but only 4 tanks were required to cover the mileage on the RV1 line in London



Fuel Cell System: 75 kW
Supercapacitor system: 240 kW
Hydrogen storage system: 4 tanks, 350 bar
Full tank capacity: 33 kg

Large Cylindrical Cells in Portfolio

Low-cost cylindrical cells in different size/capacitance options

Rated Voltage: 2.7V
Temperature Range: -40°C to +65°C

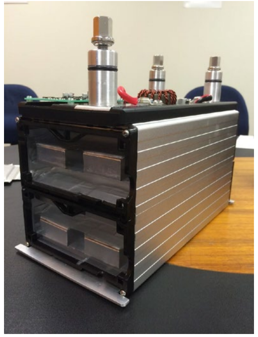
CAP-XX Part no.	Capacitance (F)	ESR Max @ 1KHz (mΩ)	ESR Max @ DC (mΩ)	Dia (mm)	Length (L1) (mm)	DCL[1] max @ 72 Hrs (mA)	Mass[2] (gm)	Power[3] Density (W/kg)	Energy[4] Density (Wh/kg)
GY12R760051VS657R	650	0.7	0.8	60	51	1.8	219	4993	3.01
GY12R760074VS128R	1200	0.4	0.6	60	74	2.5	297	5078	4.09
GY12R760085VS158R	1500	0.33	0.5	60	85	3	345	5395	4.4
GY12R760102VS208R	2000	0.25	0.4	60	102	3.5	408	6126	4.96
GY12R760138VS308R	3000	0.22	0.3	60	138	5.2	551	5475	5.51

CAP-XX truckStart module

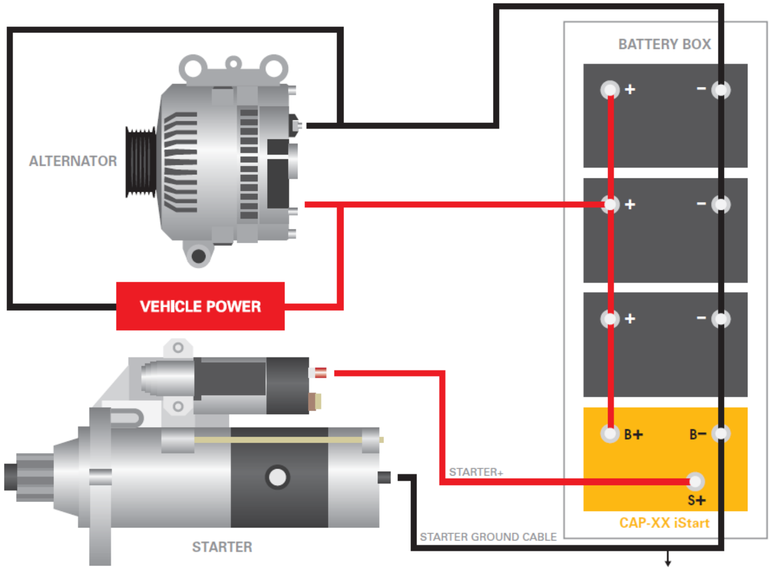
CAP-XX truckStart Specifications

Vehicle Type	Medium and heavy Duty (Class 4 – 8)
Diesel Engine Size	Up to 16L
Voltage	Input Voltage (B+ terminal) 8V – 16V Output Voltage (S+ terminal) 13.8V – 16.2V
truckStart Capacitance (min @ -20°C)	850F
truckStart ESR (max @ -20°C)	1.4mOhms
Cold Cranking Amps[1]	1800 CCA (3 sec crank)
Peak Power[2]	46.9KW
Recharge Time, truckStart module fully discharged	6 mins, 50A from battery @ 12V
Recharge Time, between cranks	3.5 mins, 50A from battery @ 12V
Dimensions	BCI Group 31 13” L x 6 13/16” W x 9 7/16” H 330mm L x 173mm W x 240mm H
Terminals	SAE 3/8” – 16 UNF. B+, B-, S+
Environmental	Designed for Heavy truck battery box environments
Weight	14.7lbs (6.7Kg)
Current draw	50A average battery current when charging < 10mA when fully charged

6000F,
0.1mΩ,
2.5V



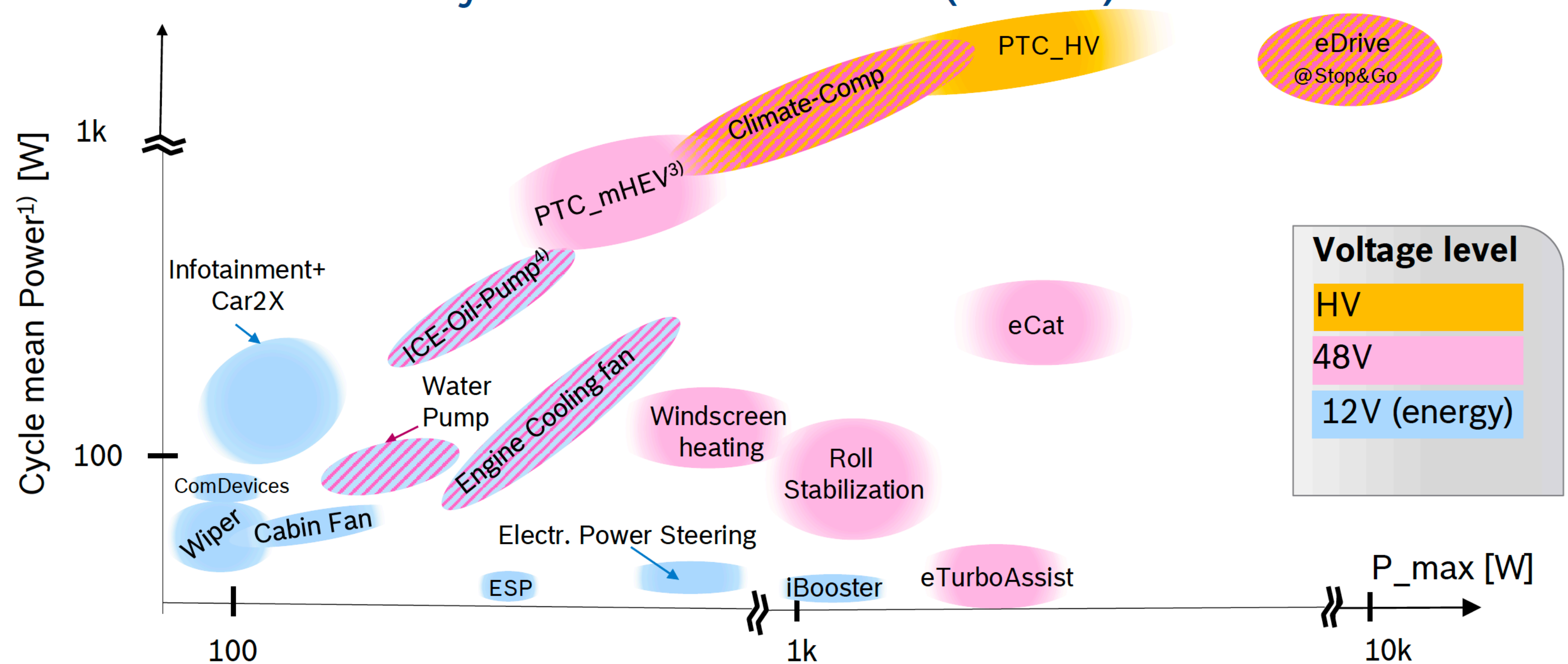
How it works...



Mid-term growth: new components/functions at 48V

48V Power Distribution Networks

Peak-Power and Cycle Power Demand (~2025)



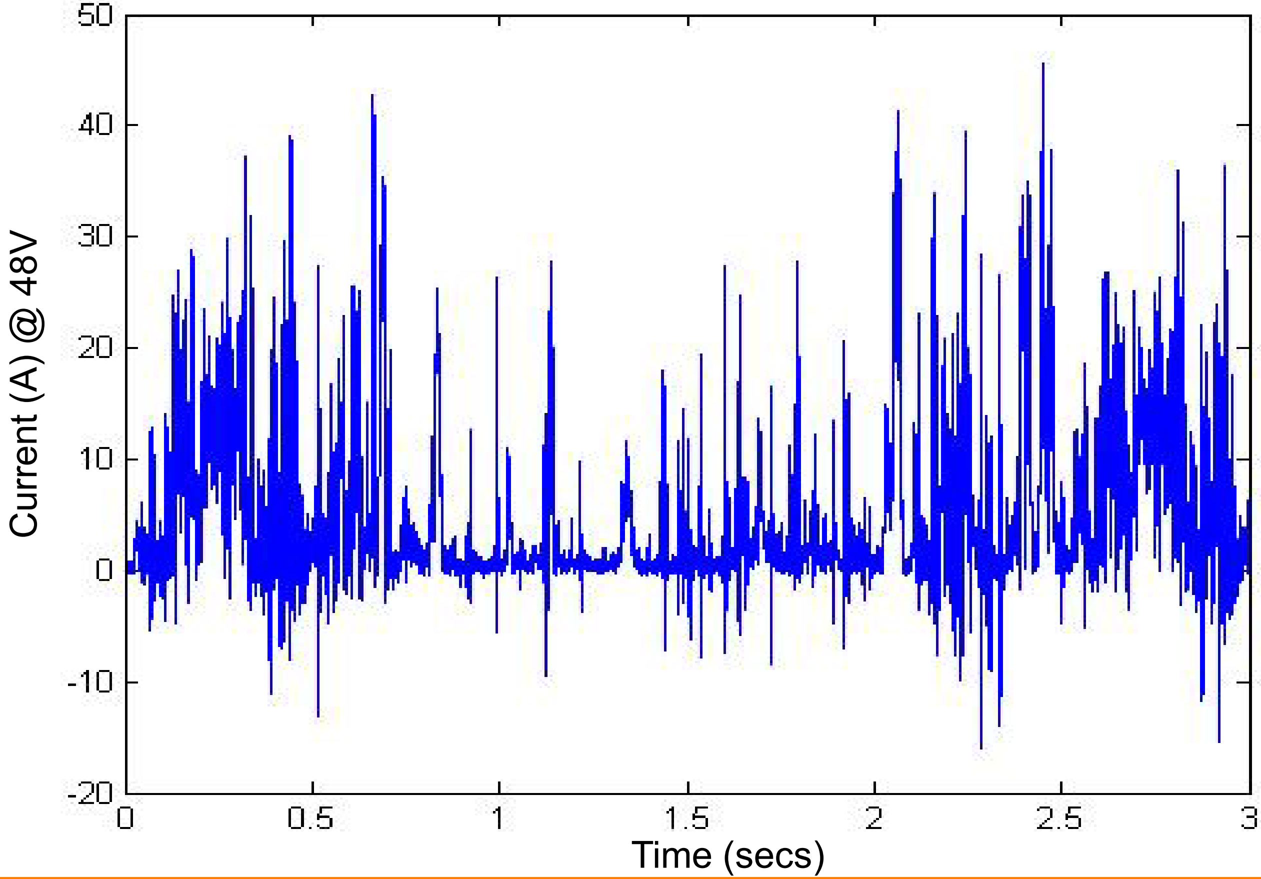
1) 30 min city cycle, 2) TJP: Traffic Jam Pilot 3) PTC-heating resistor in mild-hybrid electrified vehicles
4) ICE: internal combustion engine 5) DA/AD: driver assistance / automated driving sensors+computing

13 C/AIE-Henkel | Nov. 26th, 2018

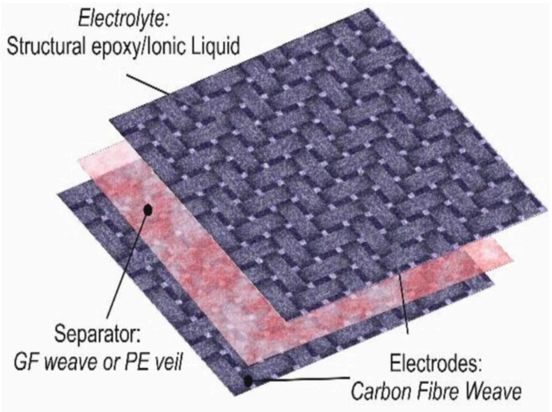
BOSCH

Active Suspension Load

- Peak Power ~2KW
- Regenerative capture as well as power delivery
- Supercapacitor has "no limit" on regenerative power capture



Long term growth: structural supercapacitors

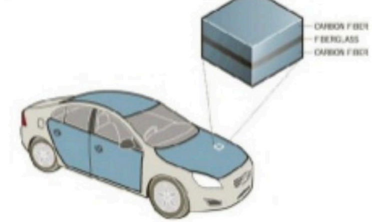


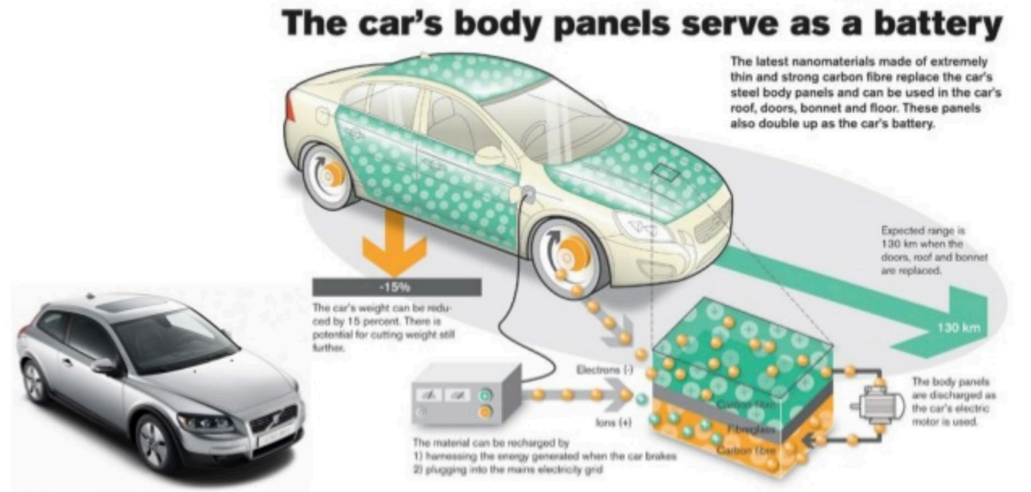
Source: Dr. Natasha Shirshova, Durham University

VOLVO : Batteries in Composite Body Panels

Volvo is developing a special composite material consisting of carbon fiber and polymer resin which will be –

- capable of storing and discharging electrical energy
- holding enough charge for 81 miles of electric driving
- and will recharge faster than the conventional EV batteries used today.





Sources: composite world, Volvo, Imperial College London, Lamborghini

Summary

1. In general supercapacitors are an ideal buffer between a low power energy source and a load with high peak power
2. Supercapacitors enable battery free IoT solutions using low power energy harvesting modules
3. The impact of electro mobility in the transportation sector is expected to create large markets for supercapacitors in the next decade

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