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Knowledge Innovation Community

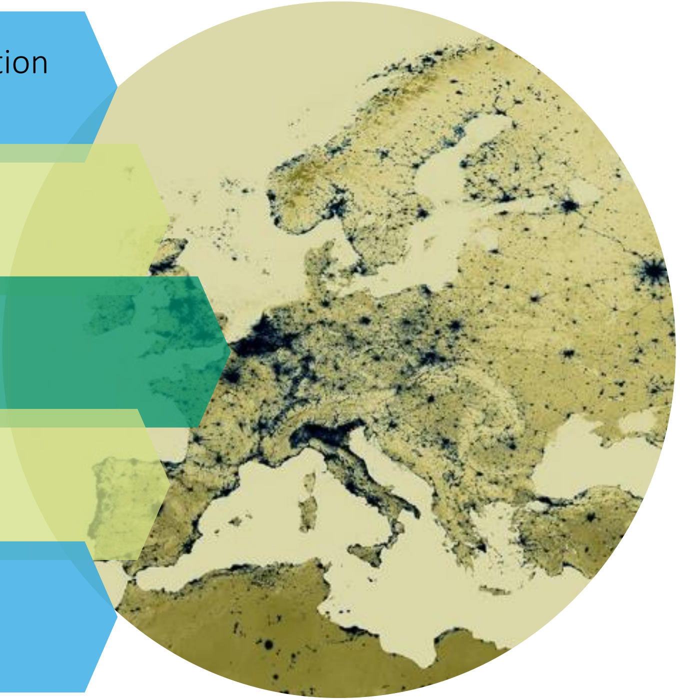
Webinar | 30 September 2020

The Role of Ultracapacitors in the Energy Transition

Johan Söderbom, Thematic Leader for Smart Grid & Energy Storage, EIT InnoEnergy

Who we are

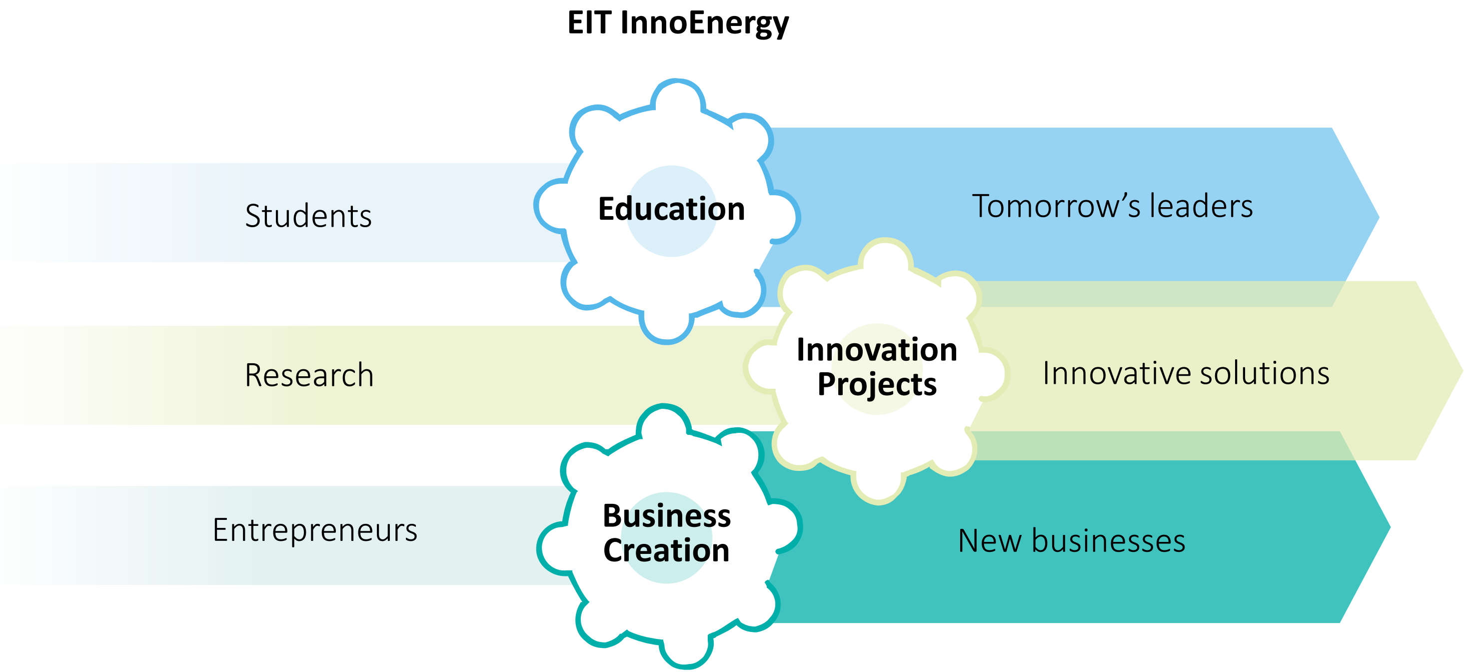
- Europe’s engine for innovation in sustainable energy
- Empowering every stage of the innovation process
- Investing in people, technologies, businesses
- Established 2010: supported by the EIT
- Public-private partnership aiming for financial sustainability



Our Goals

- Ensure security and safety of supply
- Reduce costs in the energy value chain
- Reduce CO_2 emissions
- Improve European competitiveness
- Remove barriers to innovation
- Encourage sustainable growth
- Create jobs

The Innovation Engine for Europe



1200+
Master's student graduates

20+
Online courses

€560M
EIT InnoEnergy investment

€16B
Forecasted revenue

500+
Partners across Europe

€2.5B
Investment raised

330
Start-ups selling

480+
Products supported

The energy landscape is changing rapidly

Rapid introduction of renewable energy resources on the supply side

- PV is competitive on almost all markets and the fastest growing generation resource
- Heavy investments in wind power on shore as well as off shore

All sectors on the demand side is being electrified

- Transportation
- Industrial
- Residential

Challenges arise on several system levels

Generation

- Non controllable intermittent generation

Grid/system

- Balancing at different time scales
- Inertia in the power system

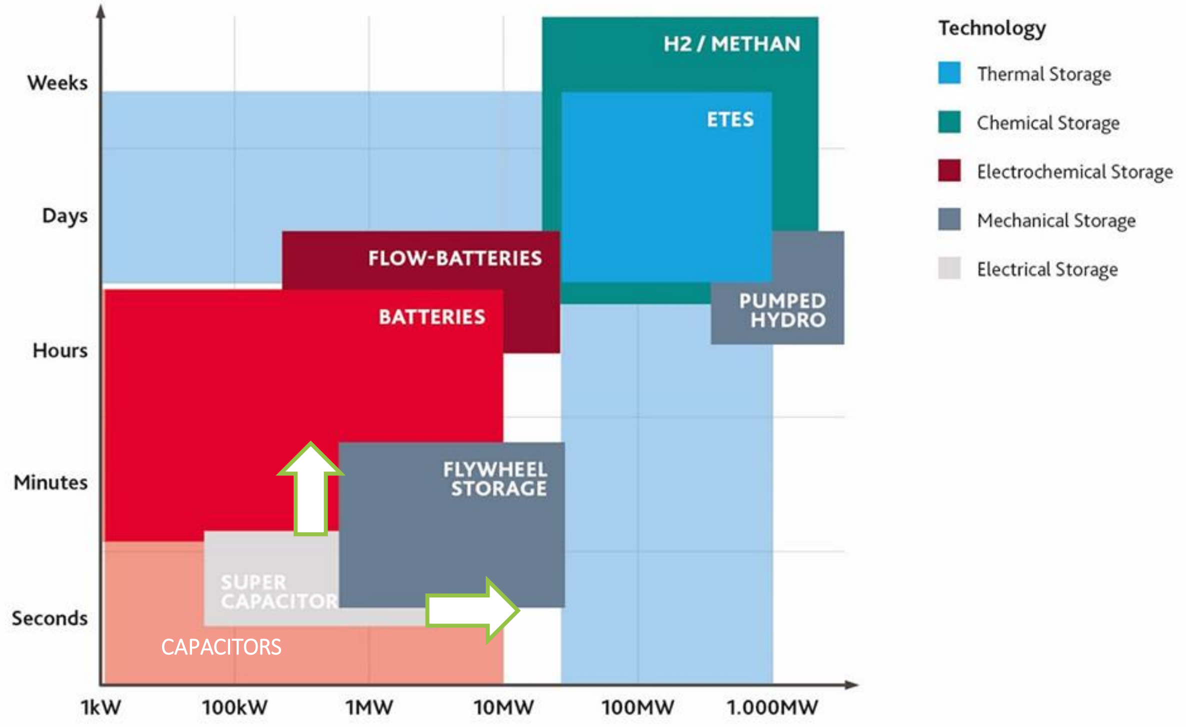
Transportation

- Autonomy
- Efficiency – energy recovery

Industry

- Coping with rapidly changing power demands

Solution to the challenges – Energy storage



Kilde: Siemens Wind Power GmbH & Co. KG

- Batteries have been the go-to-solution for several years
- Li-ion batteries have been pushed by automotive
- New generation of ultracapacitors are stretching the application envelope

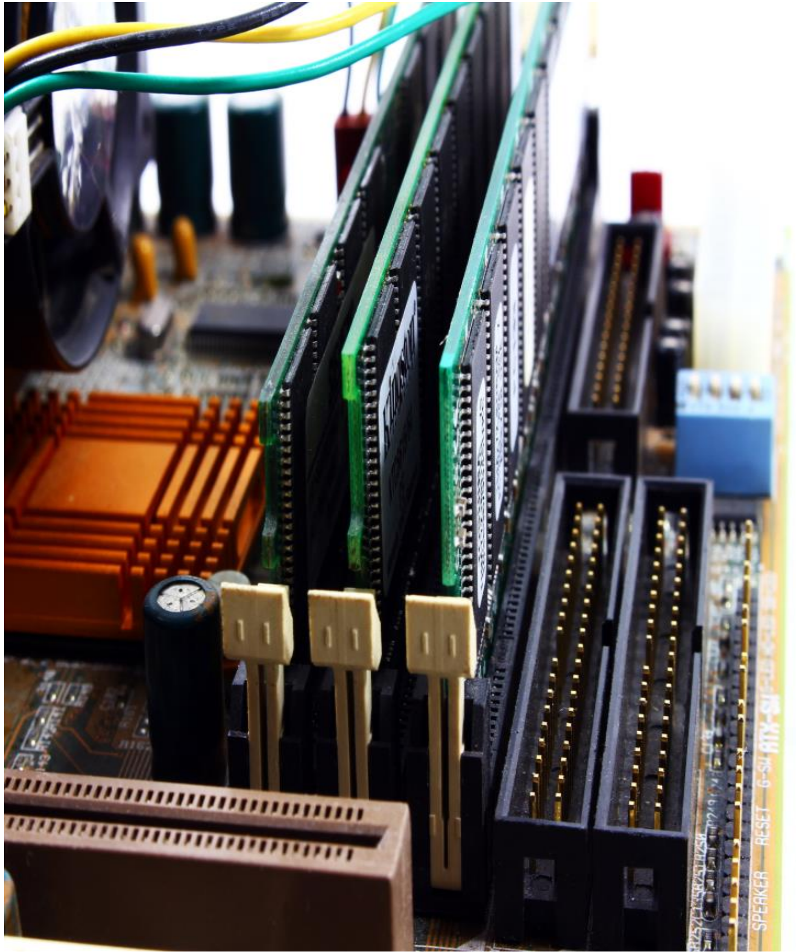
A brief history

Invented in the 1950s

- Technology is not new; invented by General Electric
- Commercialised by NEC of Japan to be used in computers in 1970s

Slow progress in mainstream

- Due to high costs and focus on other technologies like batteries, ultracapacitors have remained in the shadows – low awareness
- More recent focus due to drivers associated with the energy transition towards a lower carbon economy



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The pros and cons

Benefits are numerous and significant

- Extremely high lifetimes, low maintenance, ability to operate in extreme temperatures are key advantages

Key challenges remain

- High cost and low energy density compared to proven technologies like batteries

ADVANTAGES

- Charge/Discharge time: 1-10 seconds, minimum internal resistance
- High Specific Power: 10,000 W/kg
- Cycle life: 100,000 to 1 million
- Service life: 10-15 years
- Charge/Discharge temperatures: -40 degrees Celsius to +65 degrees Celsius
- Efficiency: > 95%
- Low maintenance
- No chemical substances

CHALLENGES

- Cost: $5,000-10,000 per kWh, when compared to $180/kWh for Lithium-ion batteries and $100/kWh for Lead Acid batteries.
- Cell Voltage: 2 to 3 volts
- Low Specific Energy: 35 Wh/kg compared to 100-250 Wh/kg for batteries.
- High self discharge
- Voltage drops with increasing discharge unlike batteries where voltage is stable

Key industries of application

Technology has wide addressable market

- ultracapacitors will either complement or replace existing technologies e.g. batteries in many applications

Common value drivers across industries

- Need for higher efficiency, lower power consumption and reduced emissions are key
- Need for increased short-term power due to higher penetration of IoT devices and sensors and increasing automation

AUTOMOTIVE

- Increased electrification and automation drives drive demand.
- Increased pressure on batteries leads to the need for alternative and secondary sources of power.
- Energy savings seen as key to vehicle efficiency and reduced fuel consumption.

TRANSPORTATION

- Increased need for higher efficiency and lower emissions pushes electrification of railways, trucks and marine industry.
- As loads increase secondary power sources become mandatory to supplement primary batteries.

POWER GRID

- Higher Renewable Energy (RE) penetration and a decrease in generation from traditional fossil fuels leads to less grid stability.
- Need to compensate for grid stability during peak demand times drives use of alternative sources of power.

INDUSTRIAL

- Increased power requirements from industrial equipment such as cranes, and elevators for heavy lifting and for backup power.
- Penetration of IOT devices leads demand for smaller power sources that have much longer cycle times.

The automotive sector

Electrification and automation to drive need for ultracapacitors to ease load off batteries

- Need for more decentralised short term power in vehicles as more functions become automated e.g. powertrain, engine throttle, cooling fans, oil pumps, doors
- Autonomous vehicles will become increasingly connected to each other and road infrastructure and will need additional devices with short term power needs

AUTOMOTIVE

APPLICATIONS	AUTOMOTIVE
Engine Start-up/Engine Cranking	HIGH
Hybrid and Electric Vehicles	HIGH
Energy Storage/Backup Power Bridging	HIGH
Power Steering	MEDIUM
Ebrake/Kinetic Energy Recovery System (KERS)	HIGH
Lead-acid Battery Hybridisation	HIGH
Autonomous Driving	MEDIUM
Electric Catalyst Heating	LOW
Start/stop	HIGH

The transportation sector

TRANSPORTATION

High attractiveness across rail, bus and truck modes

- Use of engine start-up and start/stop uses are very attractive

Use in electric vehicles

- Hybrid functionality with primary power source such as batteries

APPLICATIONS	TRANSPORTATION				
	RAIL	BUS	TRUCK	MARINE	OFF-ROAD EQUIPMENT
Engine Start-up/Engine Cranking	HIGH	HIGH	HIGH	MEDIUM	HIGH
Generator Control Gradient				LOW	
Hybrid and Electric Vehicles	HIGH	HIGH	HIGH	MEDIUM	MEDIUM
Energy Storage/Backup Power Bridging	HIGH	MEDIUM	MEDIUM	MEDIUM	MEDIUM
Catenary-free Operation	MEDIUM				
Ebrake/Kinetic Energy Recovery System (KERS)	HIGH	MEDIUM	MEDIUM		HIGH
Lead-acid Battery Hybridisation		MEDIUM	LOW		LOW
Start/Stop	HIGH	HIGH	HIGH		LOW
Heave Compensation				MEDIUM	

The power sector

Engine start-up key use case

- High attractiveness in power generation and industry using generator sets

Pitch control for wind turbine holds good opportunity

- ultracapacitors used for ‘feathering’ of blades to allow optimal performance and avoid damage
- Offshore wind sector to experience huge growth

POWER GRID

APPLICATIONS	POWER		
	GENERATION	T&D	INDUSTRIAL
Engine Start-up/Engine Cranking	HIGH		HIGH
Pitch Control for Wind Turbine	MEDIUM		
Generator Control Gradient	MEDIUM		
Frequency Response/Synthetic Inertia		MEDIUM	
Energy Storage/Backup Power Bridging	LOW	LOW	MEDIUM
Peak Load Shaving	MEDIUM		MEDIUM
Variable Speed Drive (VSD) Backup			MEDIUM

The industrial sector

INDUSTRIAL

Wide addressable market

- Cranes, elevators and IoT devices very attractive

Key applications

- Backup power bridging
- KERS
- Prime power for IOT devices

APPLICATIONS	INDUSTRIAL							
	CRANE	ELEVATOR	LOGISTICS	MEDICAL	OIL & GAS	DATA CENTERS	POWER TOOLS	IOT DEVICES
Engine StartUp/Engine Cranking	HIGH		MEDIUM					
Powering Autonomous Guided Vehicles (AGVs)			HIGH					
Hybrid and Electric Vehicles	MEDIUM		MEDIUM					
Energy Storage/Backup Power Bridging	MEDIUM	HIGH		HIGH	MEDIUM	MEDIUM	MEDIUM	HIGH
Peak Load Shaving	MEDIUM							
Ebrake/Kinetic Energy Recovery System (KERS)	HIGH	HIGH			HIGH			
Lead-Acid Battery Hybridisation	LOW							
Start/stop		MEDIUM	MEDIUM					
Heave Compensation					MEDIUM			
Prime Power for IOT Devices & Tools							HIGH	HIGH

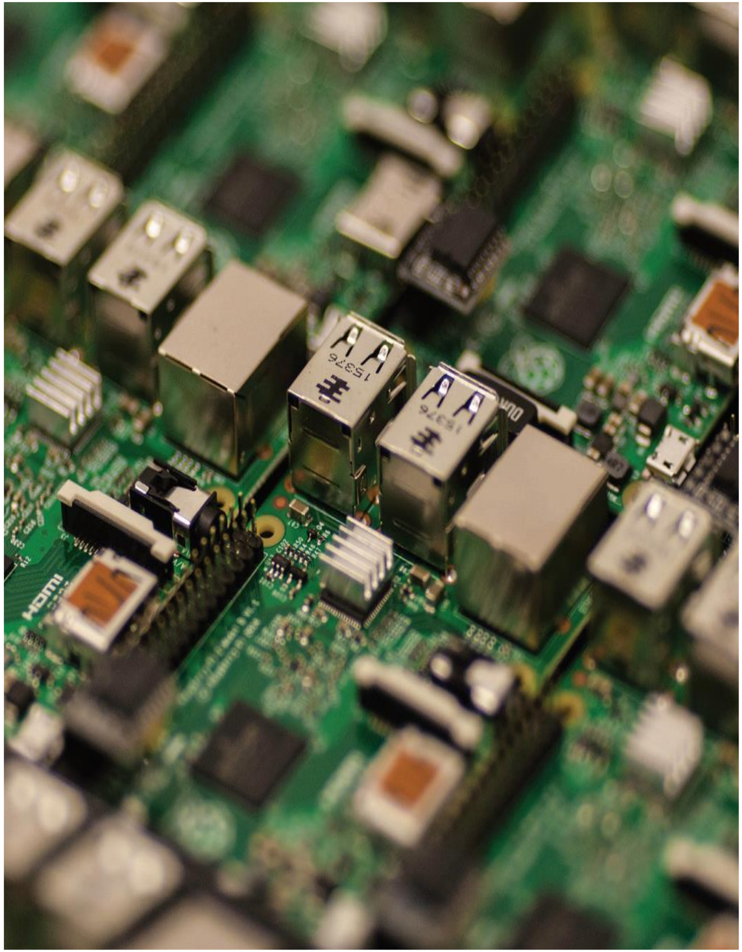
A bright future exists for ultracapacitors

A more competitive technology

- Costs of ultracapacitors are expected to be reduced significantly (30%), energy density is expected to increase in the coming decade
- New types of ultracapacitors such as graphene and lithium-ion-based solutions will soon be available

The demand drivers for ultracapacitors will intensify

- Focus on the energy transition will amplify and need for greener technologies will increase
- Trend towards electrification and automation will drive the need for short term, high power devices which are well catered for by ultracapacitors



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Key Use Cases for Ultracapacitors

Thomas Houareau. 30 September 2020

Why ultracapacitors?

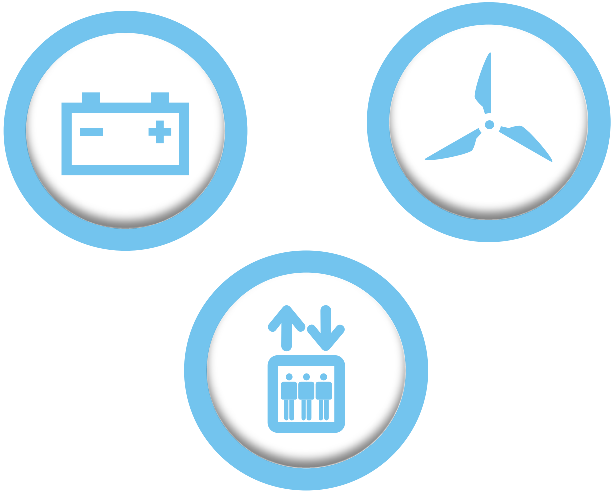
Sweet spot

- Need for high power, short term energy
- High number of operations/cycles
- Multi functional needs e.g. power supply, voltage regulation,
- Extreme environments
- High operational load factors (ROI)

But challenges remain …

- Price and energy density
- Change in equipment design architecture to include ultracaps

Currently, still make a good business case in some applications!



Use Case: Lead Acid Battery Replacement

Used as power source for electrical + electronic equipment

- Lead acid replaced on average every 2 years, more often in larger vehicles sometimes
- Provides power for starting, lighting and ignition systems + when insufficient supply from charging system

The future – batteries not feasible for full load applications

- Rising trend towards electrification and automation will increase loads on batteries
- Without ultracaps, batteries will have to get larger and be replaced more often

Use Case: Lead Acid Battery Replacement

LEAD ACID BATTERY VALUE DRIVERS

- Long life time: > 10 years substantially reduces operating costs due to frequent battery replacements
- Fast charging/discharging: < 10 seconds
- Higher efficiency: > 95%
- Lower weight helps reduce vehicle drag
- Lower operating temperatures: -40 degrees to +65 degrees Celsius
- Increases fuel efficiency in vehicles by 5% to 10%
- Carbon materials used by ultra-capacitors offer low pollution and good electrical conductivity thereby increasing sustainability of power source

Hybridisation is the solution

- Well suited to work alongside batteries NOT replace them
- Moving from stop/start applications to engine throttle, cooling fans, oil pumps, doors, A/C, seating, windows …

The future

- EVs expected to reach 125M by 2030, so will the need for secondary power to reduce load on battery
- New fast charging infrastructure required for ultracaps

Use Case: Pitch Control in Wind Turbines

Used for 'feathering' of wind turbine blades

- 30% of turbines already installed with ultracaps – first installed in 2006 by Enercon
- Optimal performance or reduces damage by pitching to zero
- Power requirements are in seconds

Outlook for wind power

- Key renewable energy source – 55-70GW to be added yearly to 2025
- Offshore segment most growth – still emerging technology

Use Case: Pitch Control in Wind Turbines

PITCH CONTROL VALUE DRIVERS

- Higher reliability resulting in reduced downtimes, which are up to 25% with more complex battery operated pitch control systems
- No chemical substances leading to lower fire hazard and higher safety
- Lower operating temperatures: -40 degrees to +65 degrees Celsius able to operate in more hostile, offshore environments
- Low maintenance requirement and long replacement time reduces operating costs given the remote locations of many wind farms

Able to replace batteries

- Help operators reduce overall operating costs through less maintenance – critical for the industry trying to compete with cheaper dirtier fuels e.g. coal
- Less hardware required e.g. cooling & heating systems

Offer new value opportunities

- Ability to operate in more extreme environments will allow operators to prospect for new sites

Use Case: Elevators, Cranes, and Power Tools

Wide number of applications in industry

- Key use case is KERS that is used in equipment operations reduces power demand for cranes and elevators
- Increasing micro grids in ports with large cranes and increases need for power balancing and peak shaving needs
- Ideal use in power tools e.g. drills that can be quickly recharged, have longer lifetimes from high cycles, and operate in extreme environments

Use Case: Elevators, Cranes, and Power Tools

ELEVATORS AND CRANES VALUE DRIVERS

- Energy Efficiency – 34% efficiency in case of cranes and 70% in case of elevators
- No hazardous materials – reducing risk of fire
- High power efficiency of 90%
- Long life time: > 10 years
- Fuel efficiency: 5 to 10% for cranes
- Fast charging/discharging: < 10 seconds
- Start/Stop: 20% less starting time
- Enable power tool operations at very low temperatures of -40 degrees Celsius

Reduces energy requirements

- Decrease power consumption, and less emissions – 34% reduction from Skeleton trials
- Leads to smaller diesel engines for start up needs

Cost effective and reliable

- Ideal use in power tools e.g. drills that can be quickly recharged, have longer lifetimes from high cycles, and operate in extreme environments

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Ultracapacitor for hybrid cars

InnoEnergy webinar

Johan Hellsing, PTE

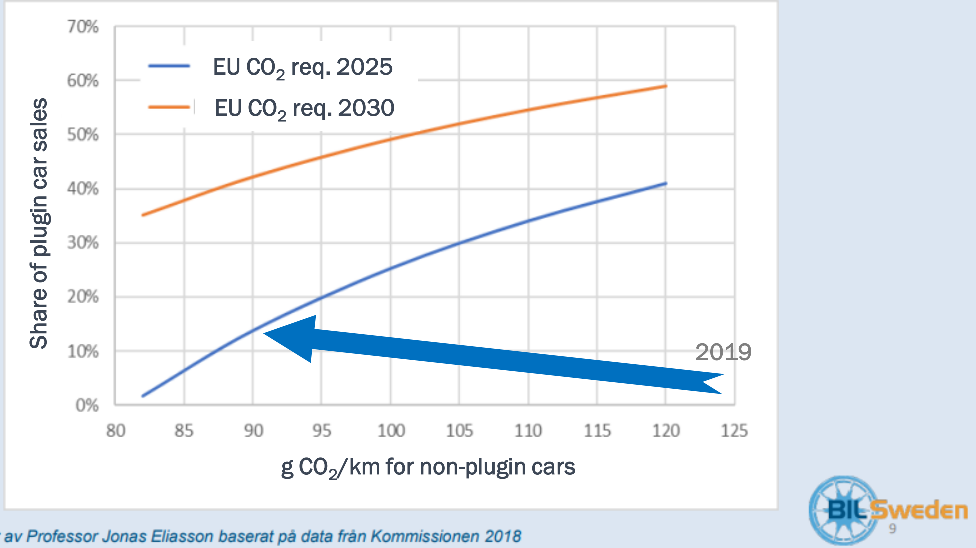
2020-09-30

Automotive industry in transition

- Electrification
- Higher efficiency

EU plugin sales expected to be 10-15% in 2025

90g CO_2/km for the non-plugin cars

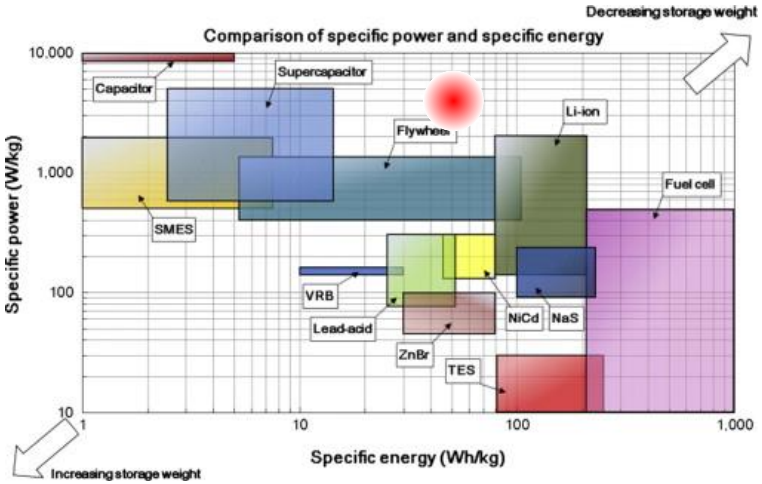


Källa: Beräkningar av Professor Jonas Eliasson baserat på data från Kommissionen 2018

We need strong ambition on electrification (EV) <u>and</u> efficiency (HEV)

Energy storage for HEV

- Energy storage for a HEV (hybrid electric vehicle) should reach 50 Wh/kg, 3-5 kW/kg and be capable of a very dynamic use
- Today we use power optimized batteries: oversizing, limit the dynamic use and must handle a narrow temperature window
- If ultracapacitors can reach this spot, there should be a great market available for them (15% HEV & 30% mild-HEV in EU 2025)



Ultracapacitors are still interesting for 12V power supply systems.
Already in production, and will become more important in autonomous vehicles

What we would need for a HEV

- 50 Wh/kg and 3-5 kW/kg on a pack level
- Higher cycle life
  - (100,000 full cycles)
- Larger temperature window
  - (full performance in −20˚C / +60˚C)