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FLOW BATTERIER PÅ VEJ IND I KOMMERCIEL DANSK SERIEPRODUKTION

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Background

- Associate Professor – Department of Engineering
  -Research in batteries and solar energy conversion

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- Co-founder of VisBlue – commercialisation of flow batteries

Søren Bødker
Co-Founder & CEO,
Sales and daily operation

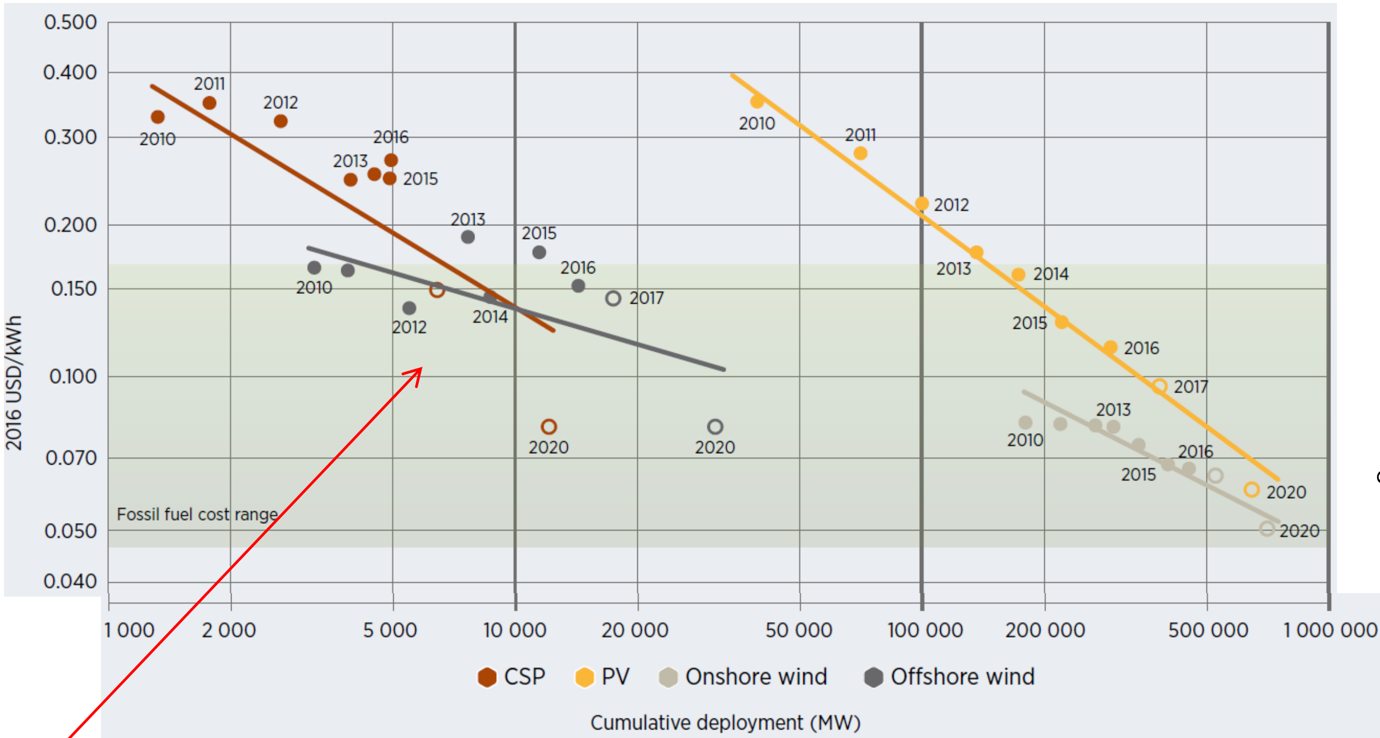
Adelio Mendes
Co-Founder & Technical advisor
Full professor, University of Porto

Anders Bentien
Co-Founder & Technical advisor
Associate Professor, University of Aarhus,

Morten Madsen
Co-Founder & Controller
BSc.EE

visblue
energy in the flow

Levelized Cost of Electricity (LCOE) - Renewables

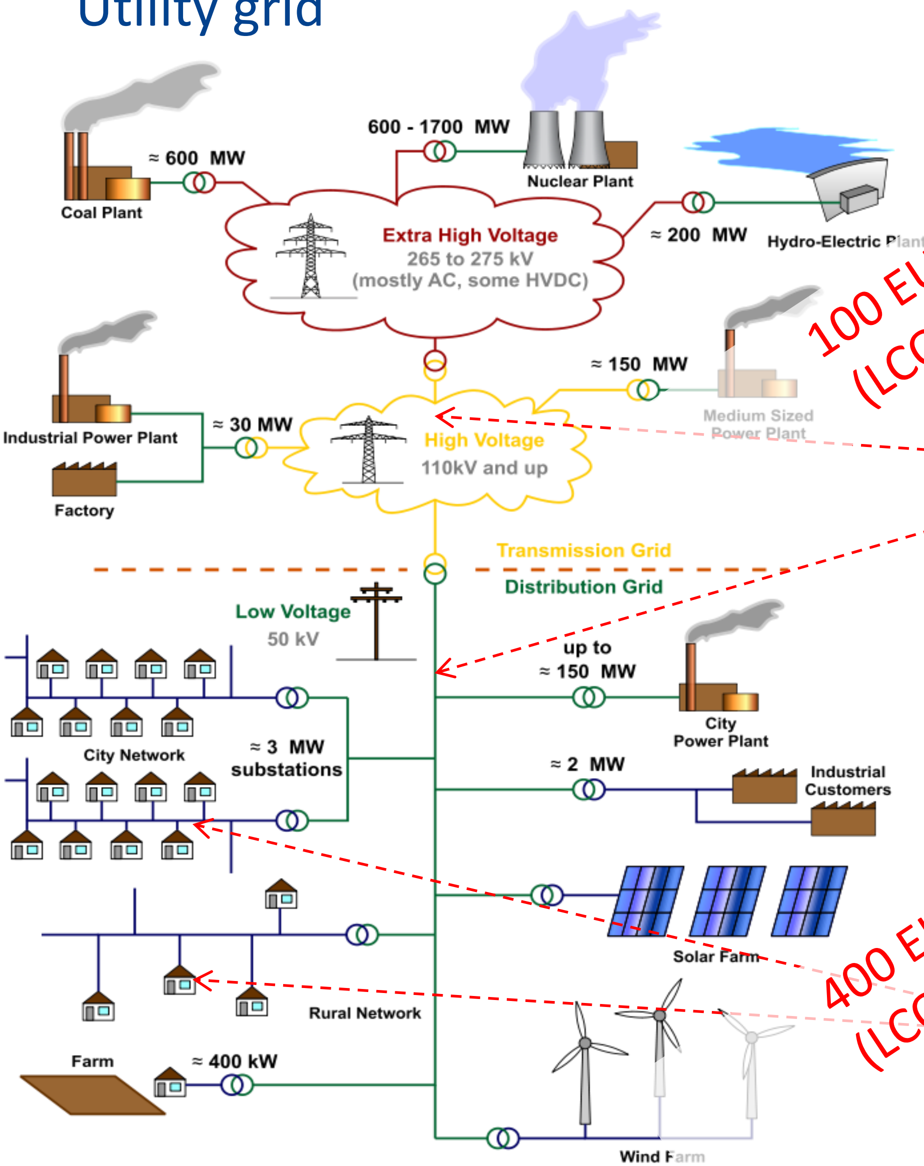


Source: Renewable Power Generation Costs in 2017 (International Renewable Energy Agency)

- LCOE of renewables are now comparable to fossil based electricity
- Still decreasing
- Only one major challenge

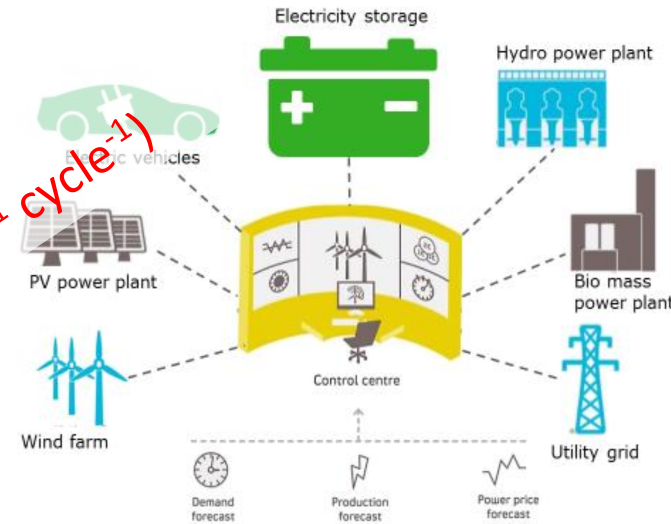
Battery applications in the utility grid

Utility grid

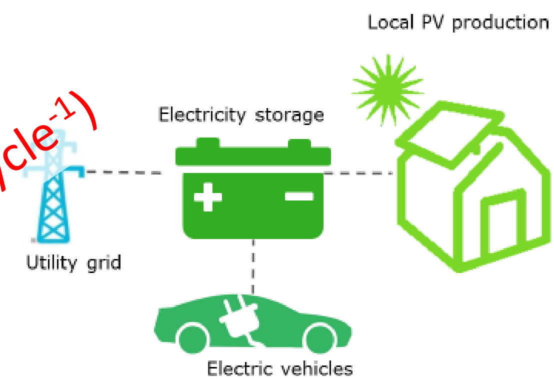


100 EUR kWh^{-1}
(LCOS= 5¢ kWh^{-1} $cycle^{-1}$)

400 EUR kWh^{-1}
(LCOS= 20¢ kWh^{-1} $cycle^{-1}$)



- Virtual power plants



- Residential buildings with PV

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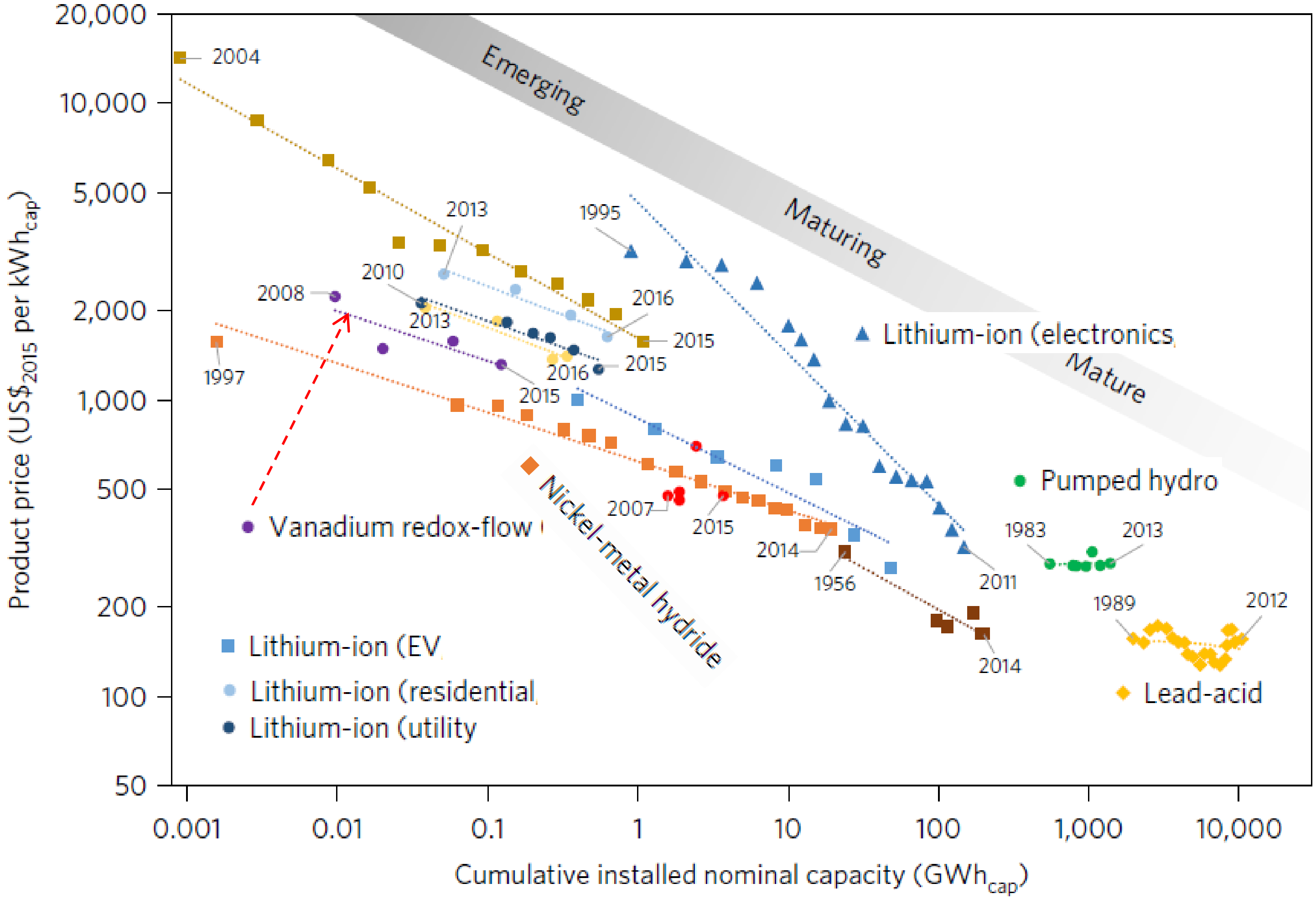
Storage costs



- Significant cost reductions with maturity
- Can batteries reach 100 EUR kWh^{-1}?

nature energy
ANALYSIS
PUBLISHED: 10 JULY 2017 | VOLUME: 2 | ARTICLE NUMBER: 17110

The future cost of electrical energy storage based on experience rates

O. Schmidt[1,2]*, A. Hawkes[3], A. Gambhir[1] and I. Staffell[2]

Stationary vs Mobile applications

	Stationary -Renewables	Mobile -Consumer electronics -Automotive
Energy density (kWh/kg)	Less important	High importance
Charge/discharge speed	Less important	High importance
Cost	High importance	Less important

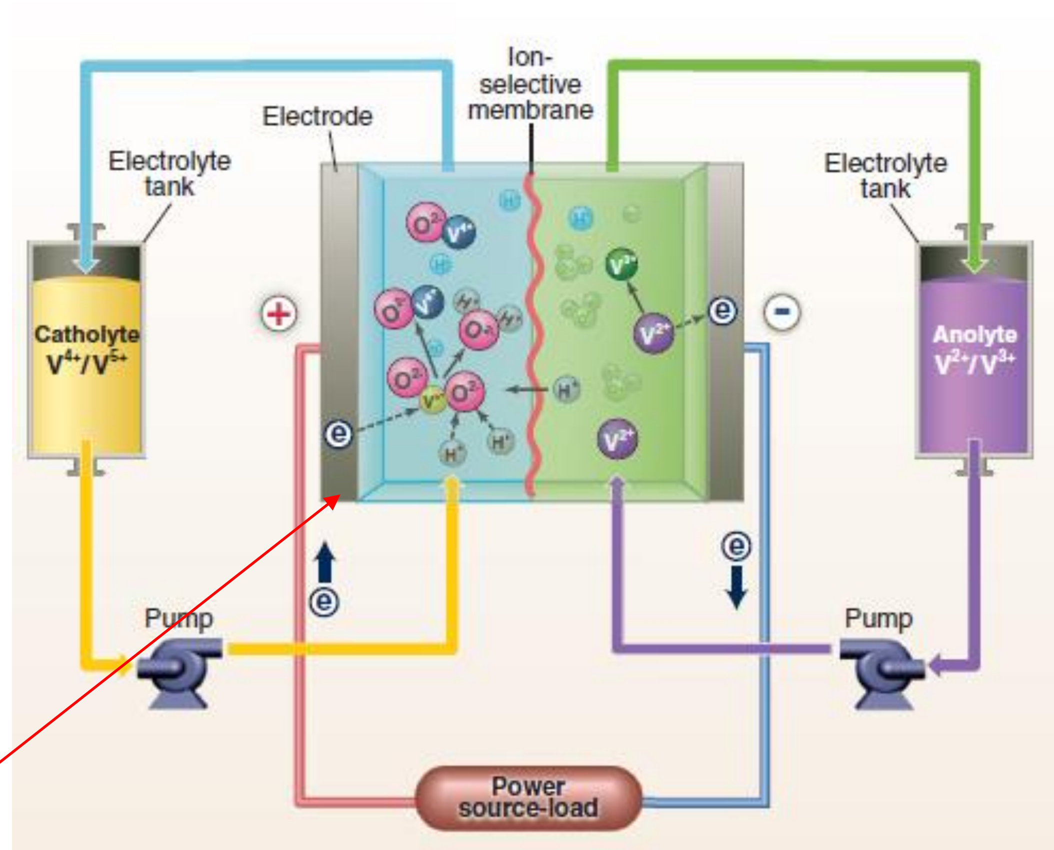
Main points

- Battery research has been driven by mobile applications
- In future renewable applications cost is the most important parameter

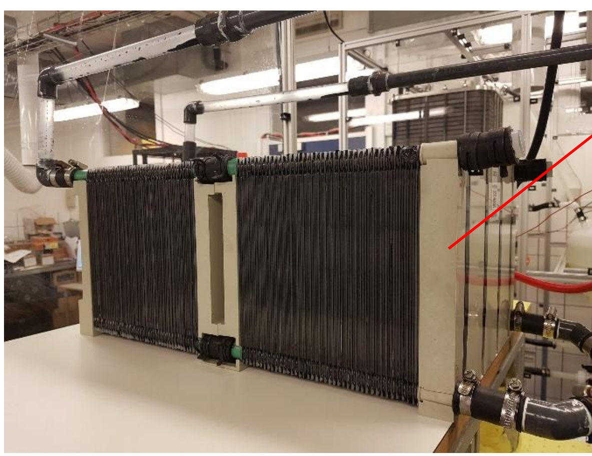
New battery chemistry and design is needed

VANADIUM REDOX FLOW BATTERIES

- Electricity stored in dissolved vanadium – state-of-art
- Pumped into a stack (electrochemical flow cell)
- Independent scaling of power & capacity
- Fully charged V^{5+} and V^{2+}



Flow battery during discharging



Stack of cells (1.25 V/cell) -> 48 V

Outline

- Opportunities
- Cost Challenges
- Technical Challenges
- Battery systems
- Summary

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Opportunities of VRFBs

- Very robust
  - Can be turned of and left for months without power
  - BMS is simple (keep cell voltage < 1.6 V/cell)
  - Single cell monitoring is not necessary on single cell level

- Long life time (> 10-15) years
  - In principle no chemical degradation – Same solution on both sides

- Easy recycling of vanadium – Remove tanks

- Aqueous based - High fire safety

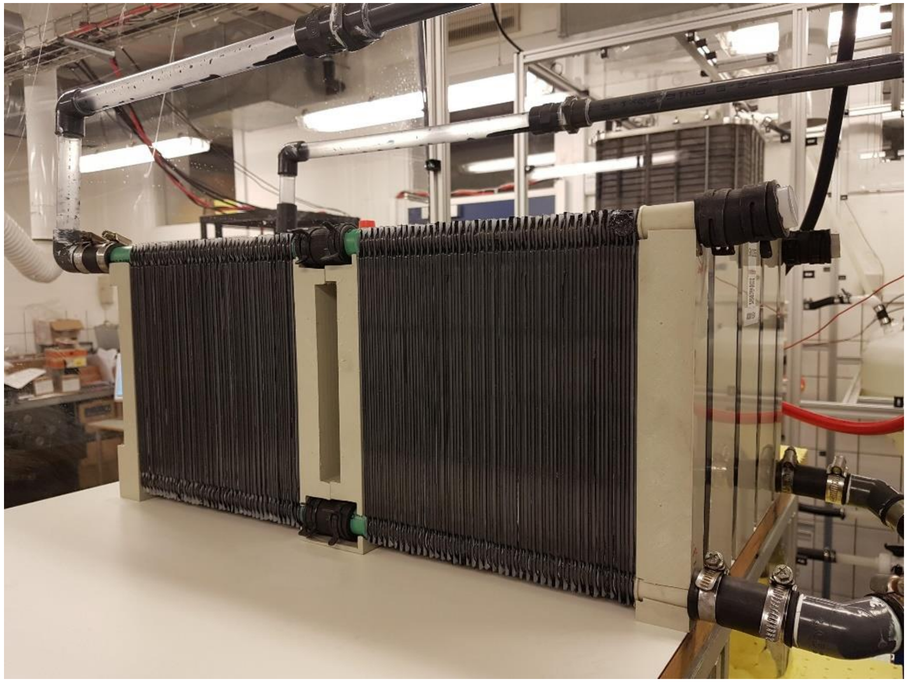
- Temperature stable – Vanadium electrolyte can be operated up to 35^oC

- Low cost potential – Vanadium electrolyte is 200 EUR kWh^{-1}

Stack Cost

State-of-art

- Max Power density ~ 200 mW cm^{-2}
- Cost 1000 EUR kW^{-1} - raw materials costs is only a fraction



Cost reduction potential

- More efficient design
- Mass production

Realistic short term goal ~ 500 EUR kW^{-1}

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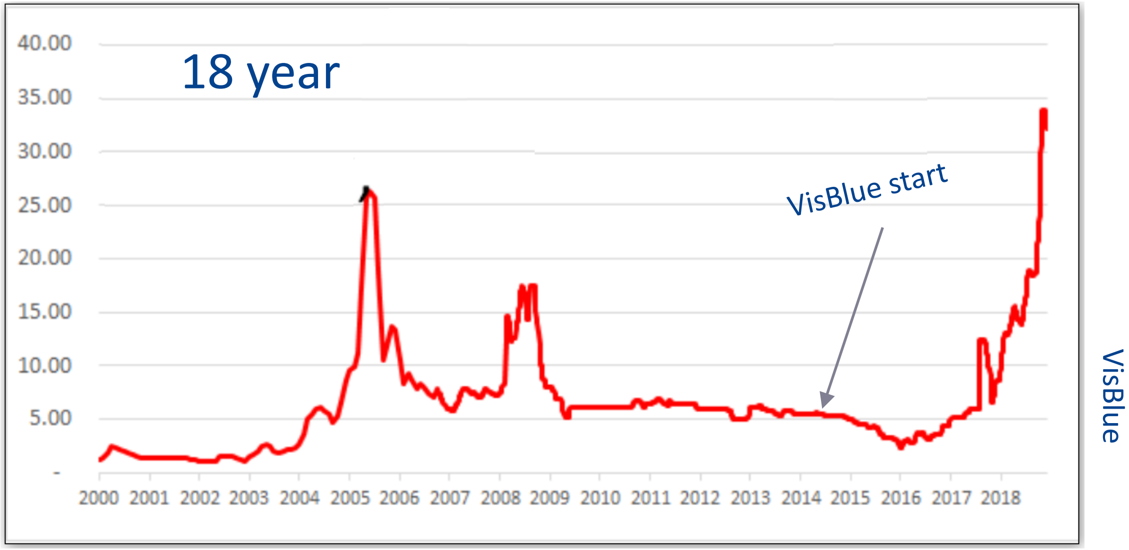
Vanadium Cost

Price history of V_2O_5



- Ready to use vanadium electrolyte ~ 150-200 EUR kWh^{-1} (bulk quantity)
- Cost partially determined by V_2O_5
- Large amounts of V_2O_5 - Likely to fall (100-150 EUR kWh^{-1})
- Unlikely with < 100 EUR kWh^{-1}

BoP/Assembly - Cost

BoP – Balance-of-Plant

- Pumps
- Control
- Monitoring
- Power electronics

Assembly

- Currently assembled by hand

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Mass production

BATTERY RESEARCH AT AU-ENG

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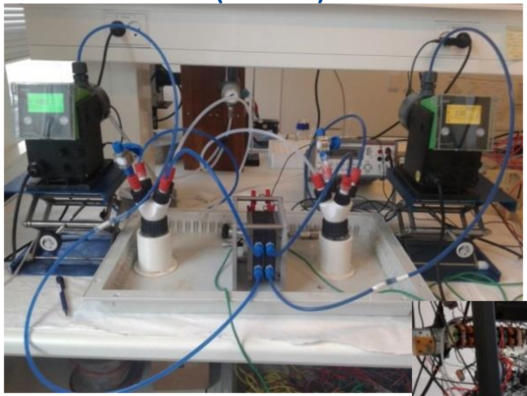
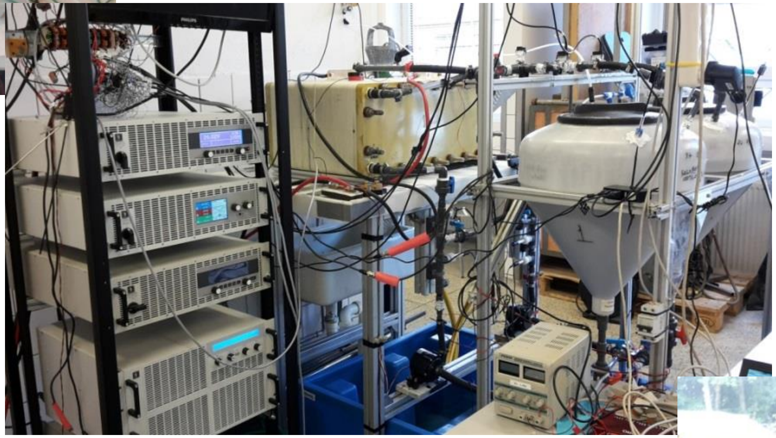
Lab scale (10 W)

AU-ENG



Stack test (5-10 kW)

AU-ENG



System (>10 kW)

VisBlue

VisBlue 40 kWh VRFB

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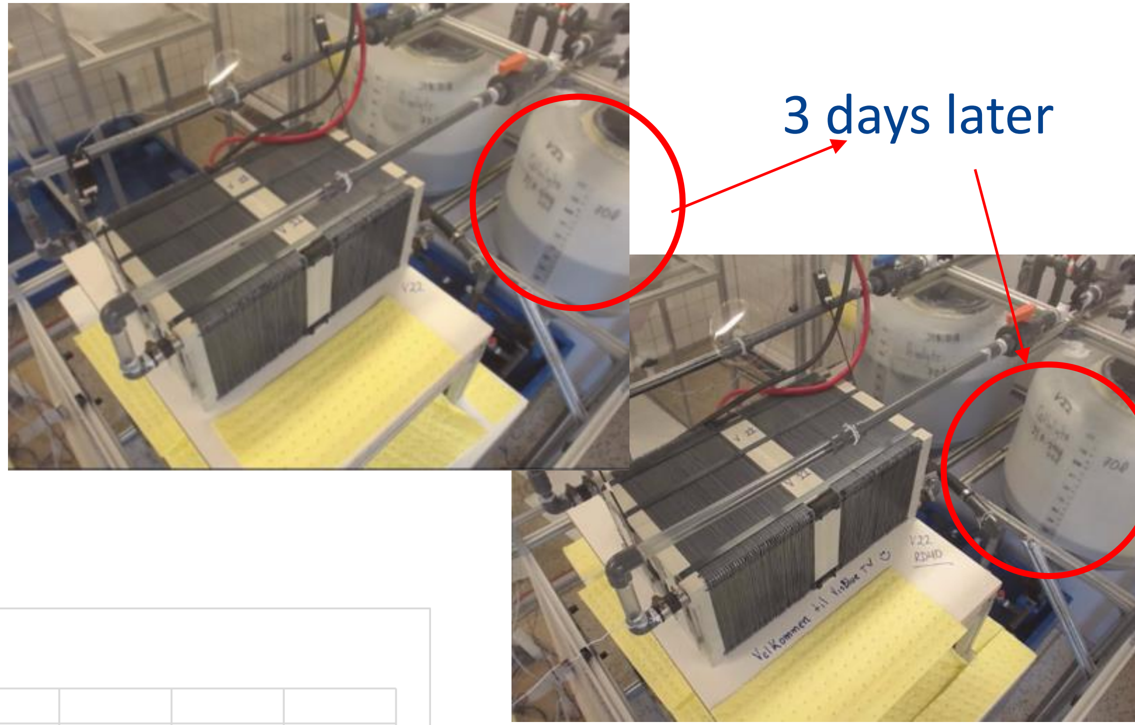
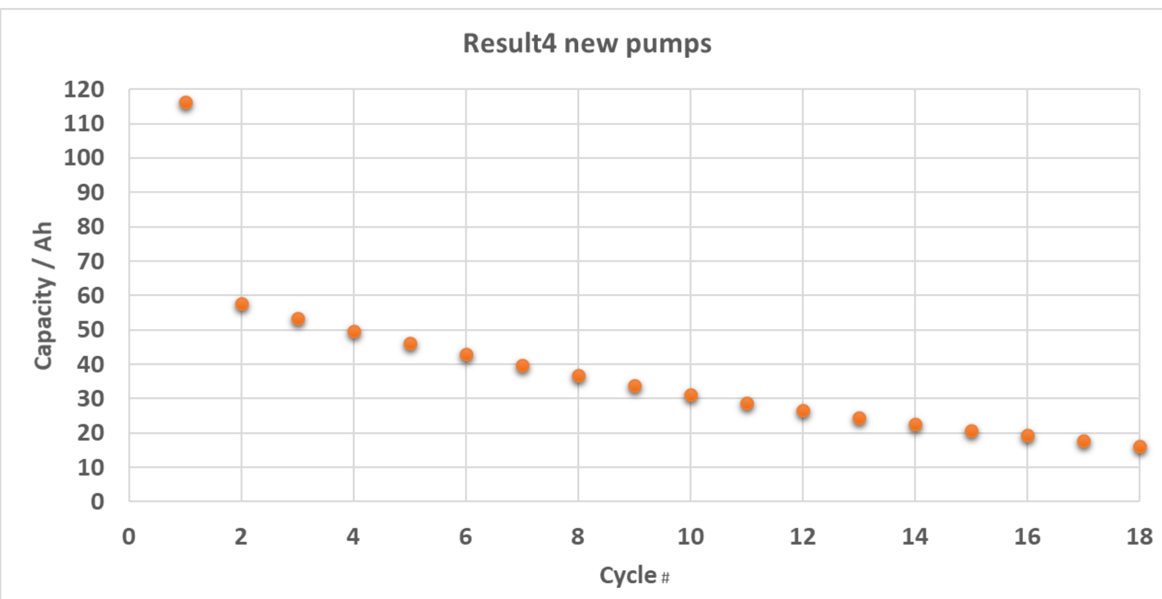
Challenges - Crossover

- Irreversible crossover through membrane during cycling
- Mix of osmosis/electroosmosis
- Capacity falls rapidly
- Approx. 0.3 L h^{-1} (in 5 kW stack)
- In a real system 10 % will be lost in 2 weeks





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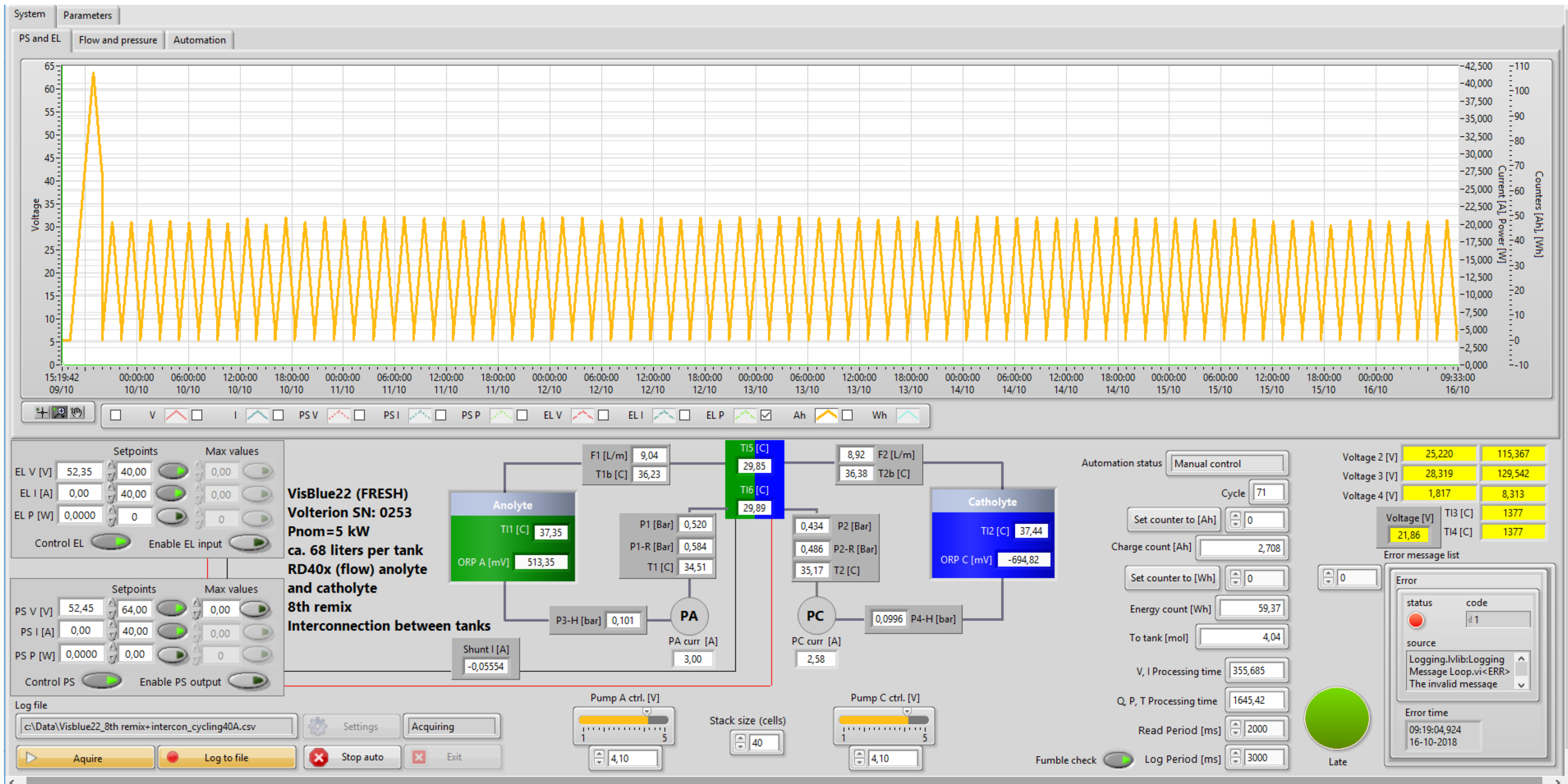
Challenges - Crossover

Solution

- Shunt tube between tanks -> Small loss in coulomb efficiency
- Over 7 days: No capacity loss and volume difference



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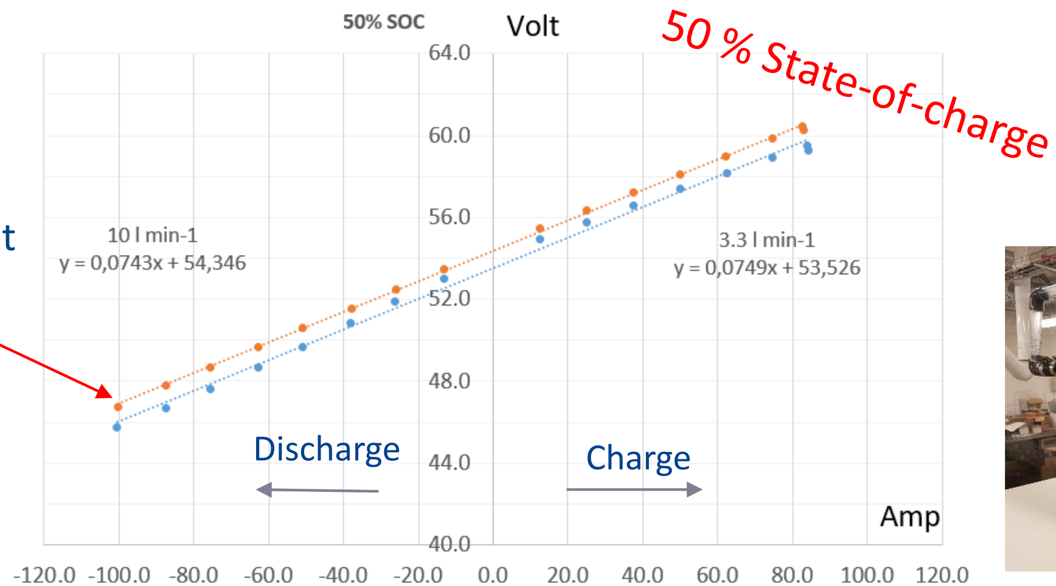
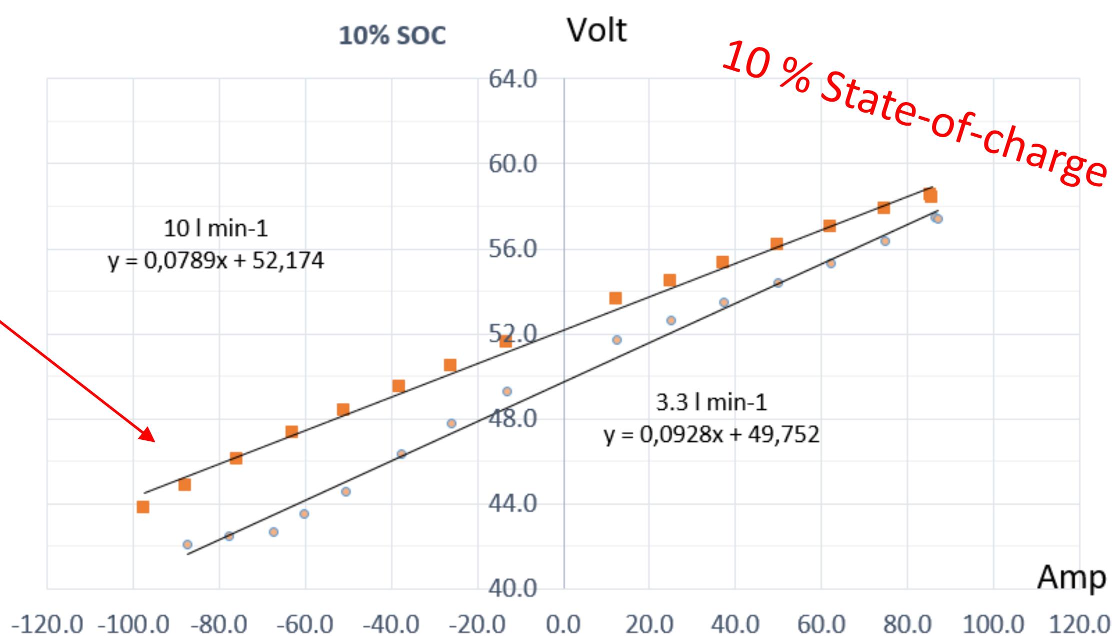
Challenges – Energy efficiency

- Voltage almost independent of flow rate by middle SOC



- Non-linear (mass transport effects) by low (and high) SOC



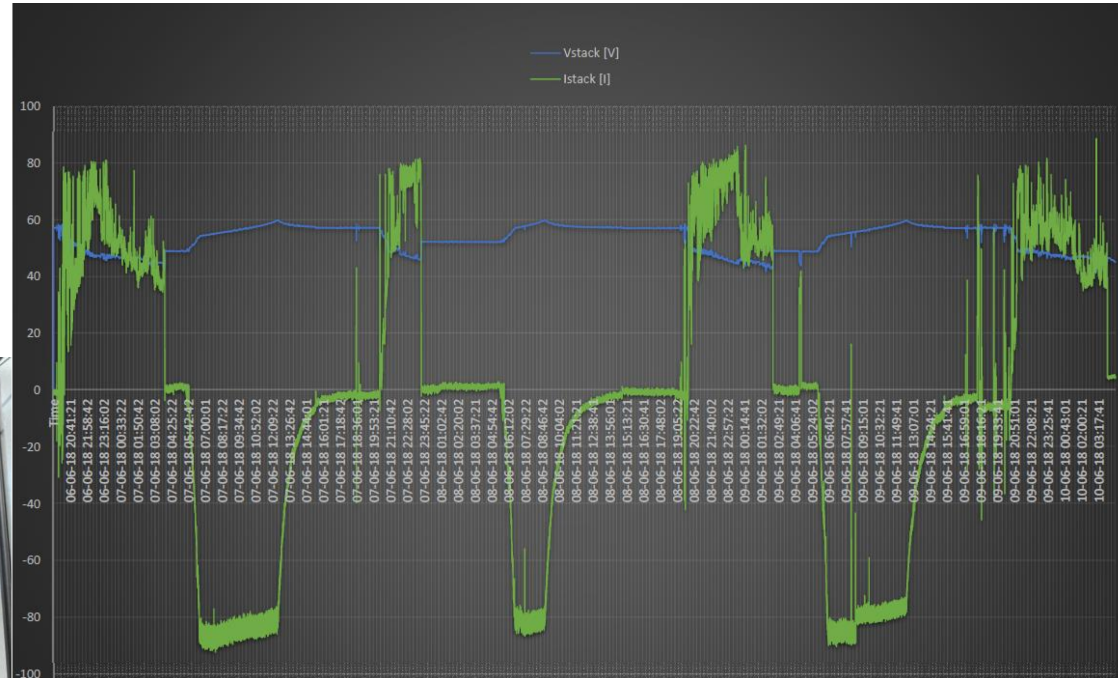
- Lower voltage efficiency

- Intelligent pump control (current, SOC, temperature)

- Significant increase of system efficiency (and capacity)

5 KW/50KWH VISBLUE VRFB @ LIVØ

Full view



Voltage/Current over four days (June 6-10, 2018)

Side - Power electronics

Front - VRFB

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VISBLUE VRFB STATUS

- Q3 2018: 0-series ready (3rd generation prototype)
- Q1 2019 : ~ Cumulative of 2000 kWh have been installed at different locations
- Q1 2019 - : Upscaling of production

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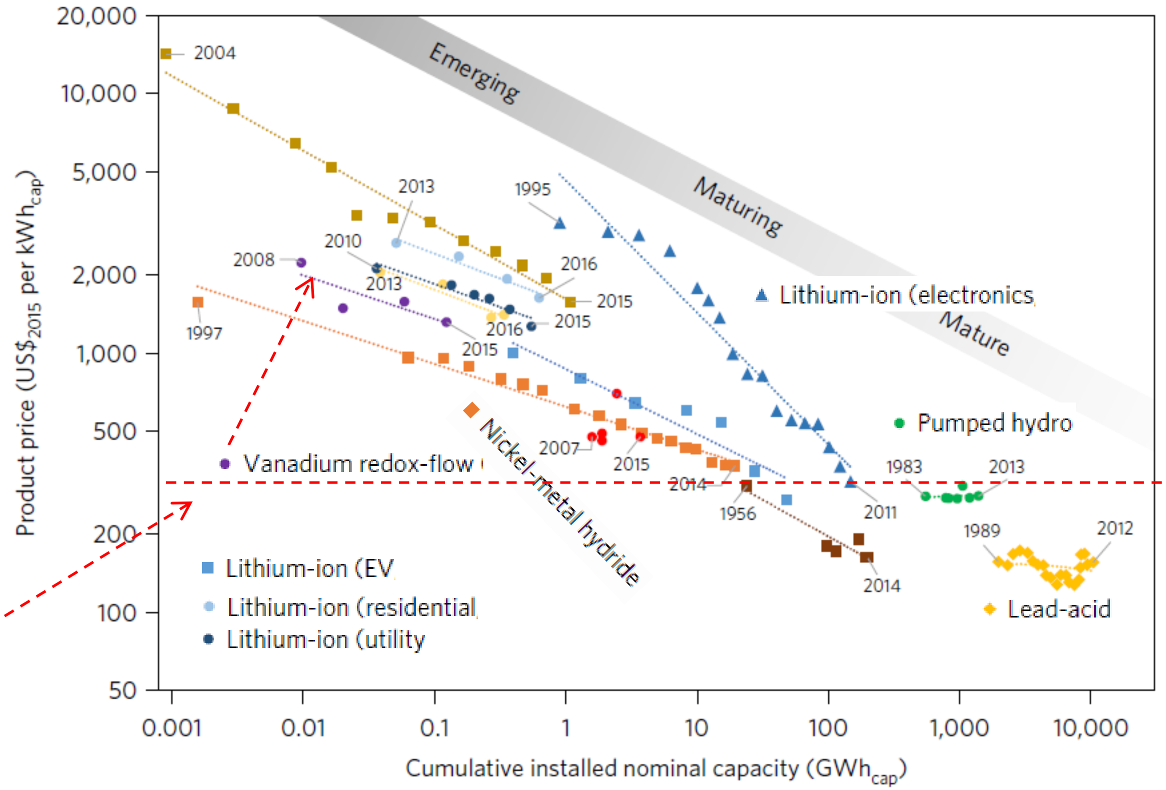
SUMMARY

- Worlds largest battery currently being built is a VRFB (800 MWh)
- VRFBs have potential for long lifetime and low cost
- Mid term: production cost 250-300 EUR kWh^{-1} is realistic



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eniig

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