Ministero degli Affari Esteri
e della Cooperazione Internazionale
FARNESINA

MINISTERO DELL'AMBIENTE
E DELLA TUTELA DEL TERRITORIO E DEL MARE

Laboratorio di Elettrochimica
dei Materiali per l'Energetica

Supercapacitors: key systems for energy sustainability

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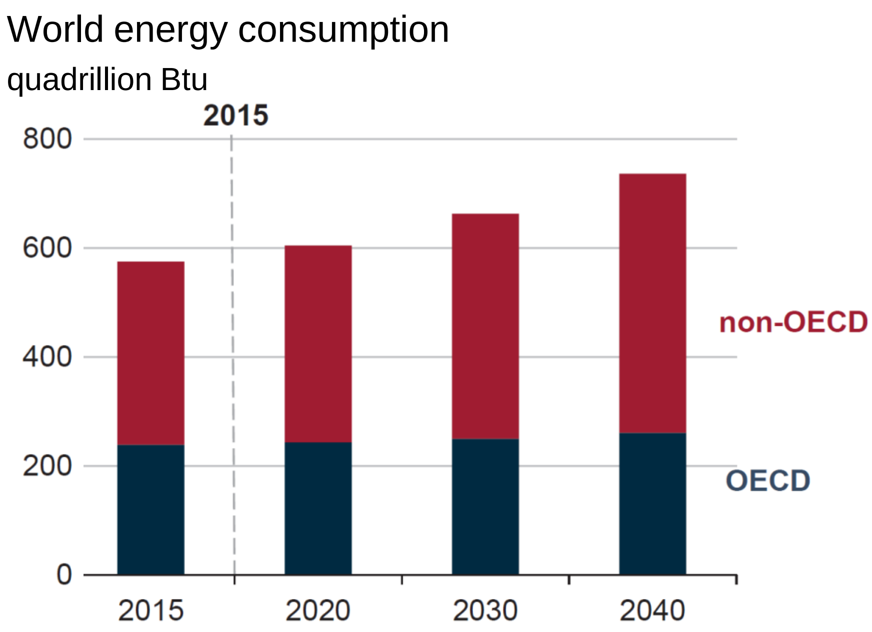
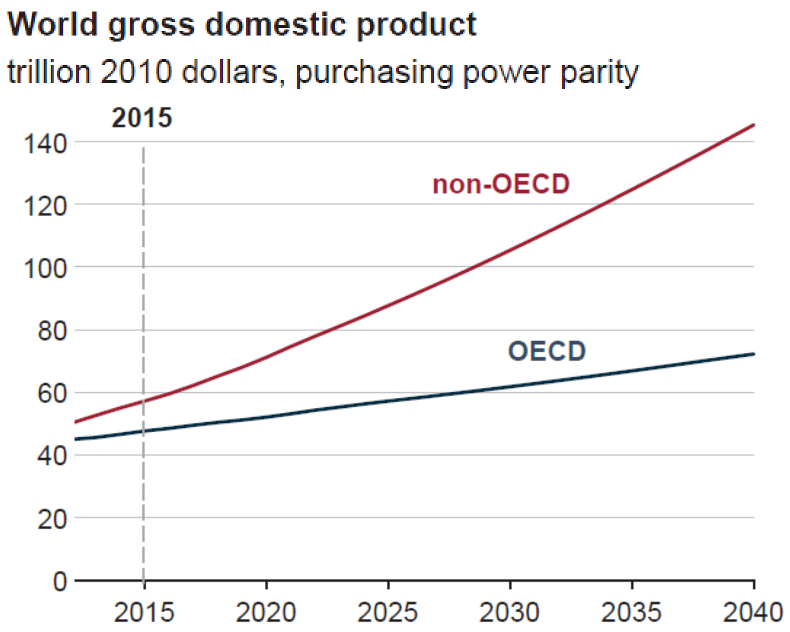
International Energy Outlook 2017

Development of Countries strongly depends on availability of **ENERGY**



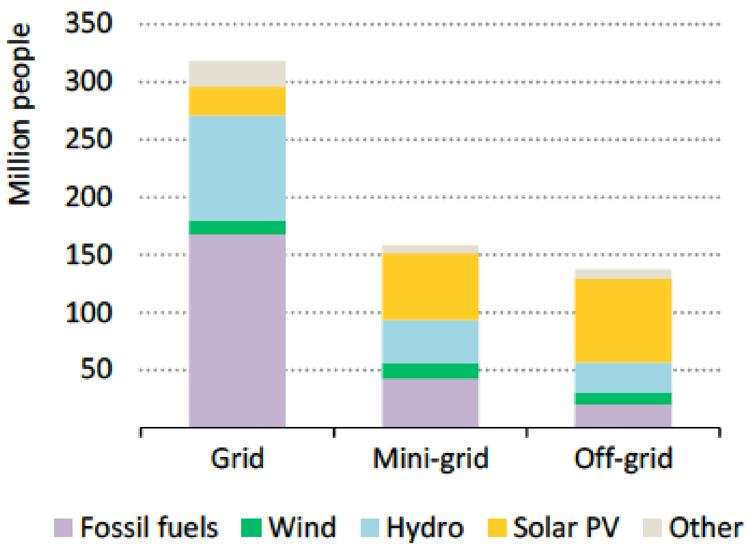


OECD = Organization for Economic Cooperation and Development

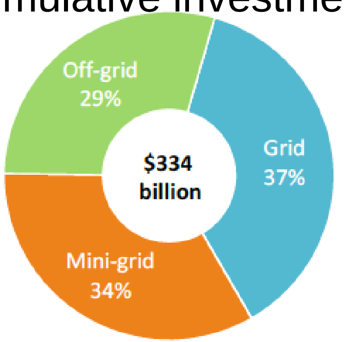
Renewable energy sources

New Policies Scenario 2017-2030

Cumulative population accessing to electricity

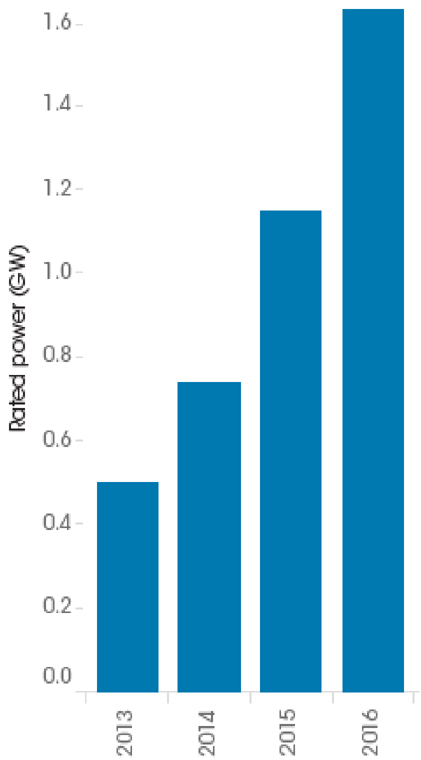


Cumulative investment



Global Electrochemical energy storage capacity trend

IRENA International Renewable Energy Agency



Italy

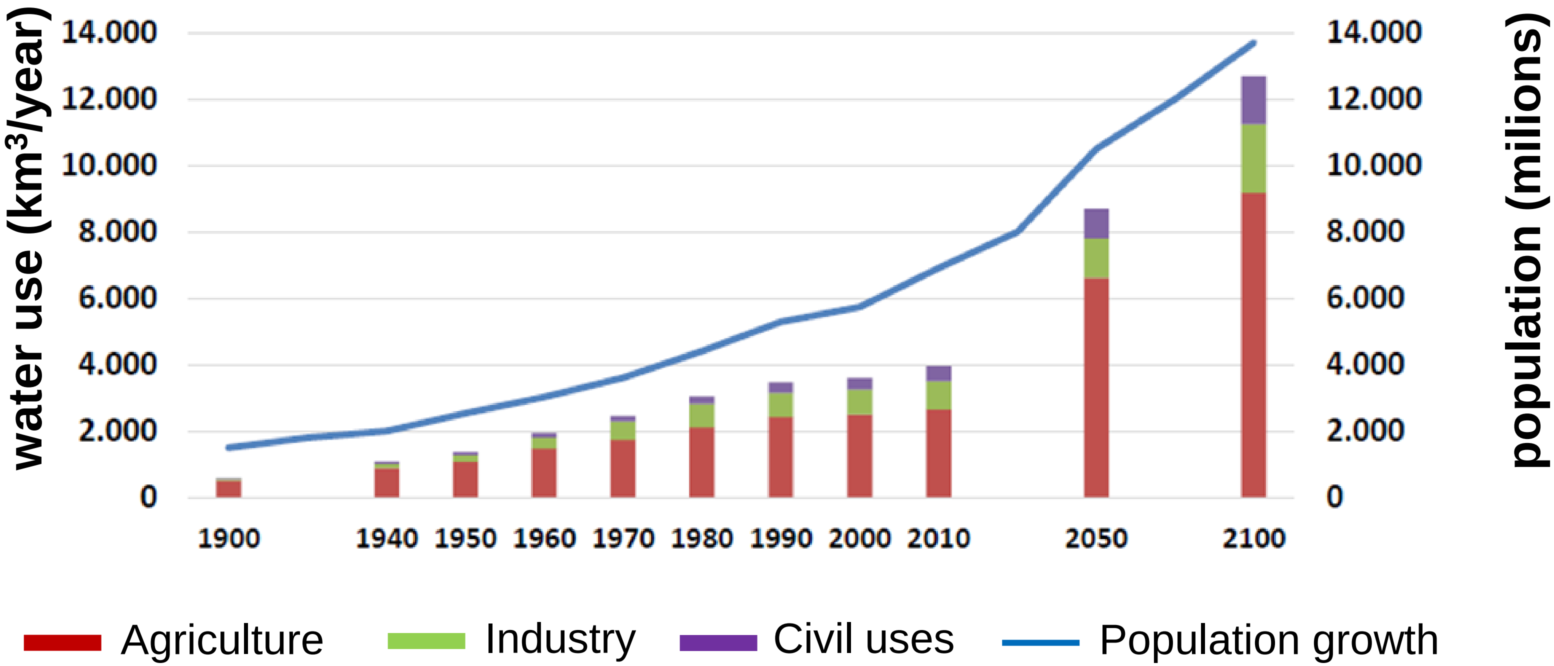
75 MW Li-ion, Na-Ni, Flow batteries and Supercaps (pilot plants -250 mln €)

www.iea.org - World Energy Investment 2016

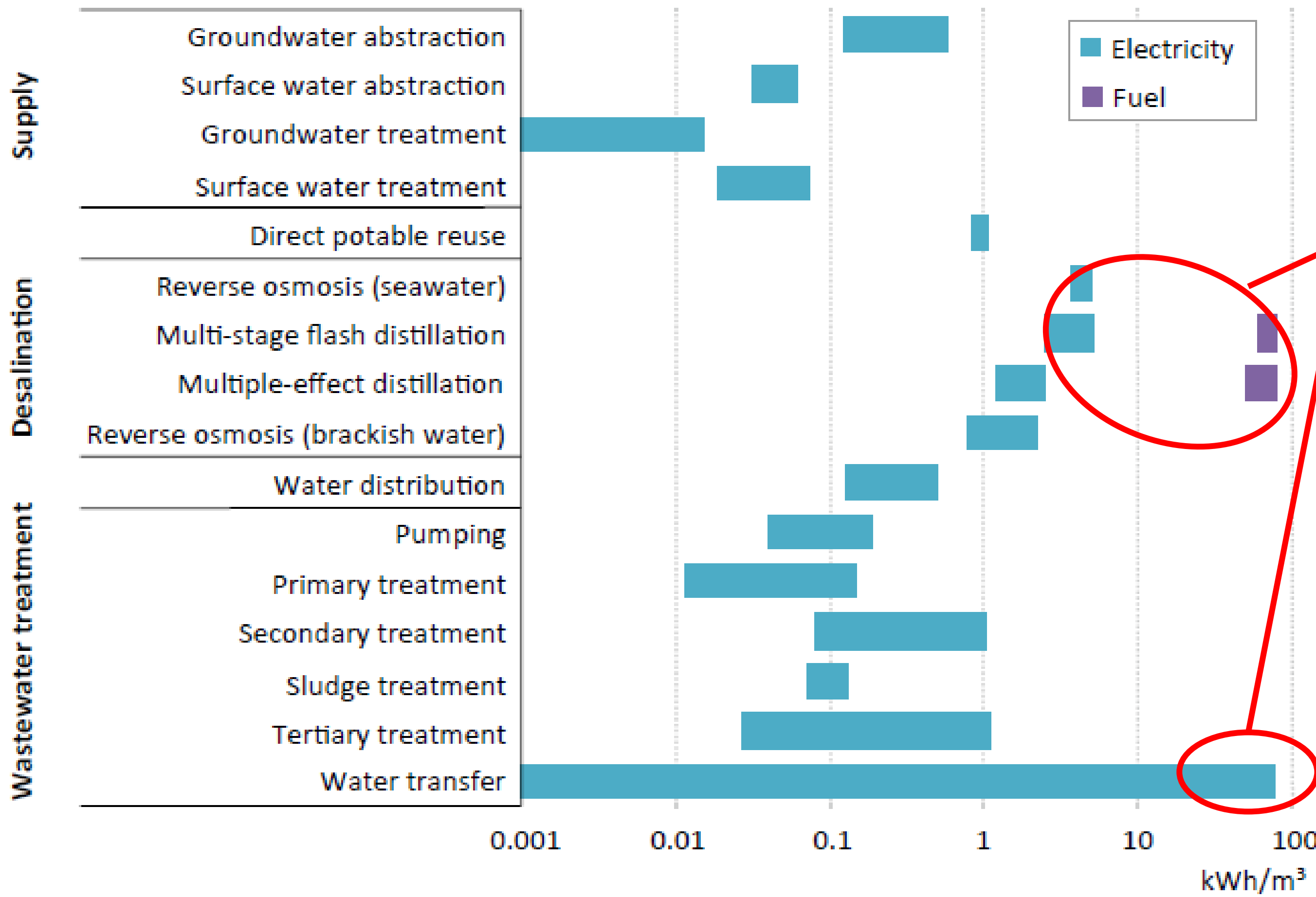
Water Management Report

Development of Countries strongly depends on availability of **FRESH WATER**
3% of water on earth

Demographic growth and water availability

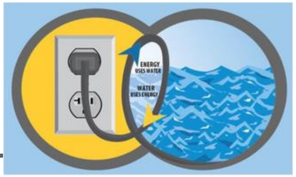


Energy use for water management

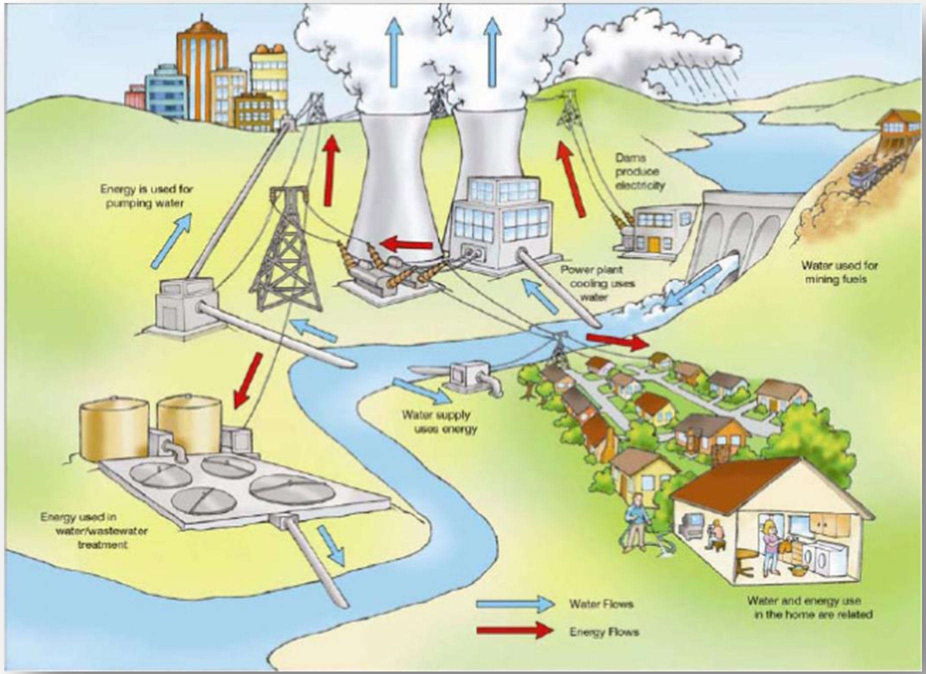


Seawater desalination and wastewater treatment are the most energy-intensive processes in the water sector

The Water – Energy Nexus

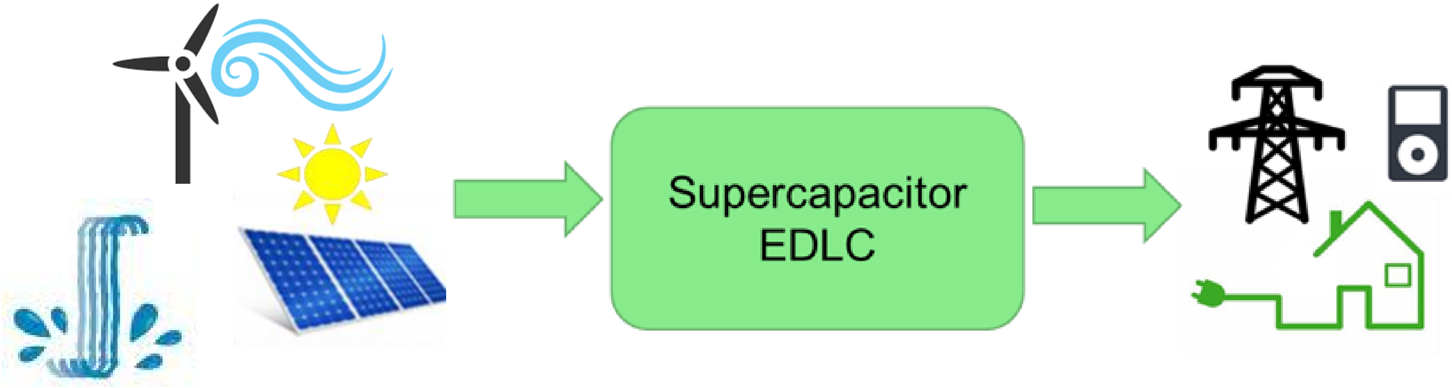


- Water and energy underpin economic and social development.
- Water is needed for each stage of energy production, and energy is crucial for the provision and treatment of water.



Availability of clean water depends on the energy sources of the Countries and on their capability to exploit renewable energy sources

Supercapacitors & renewable energy



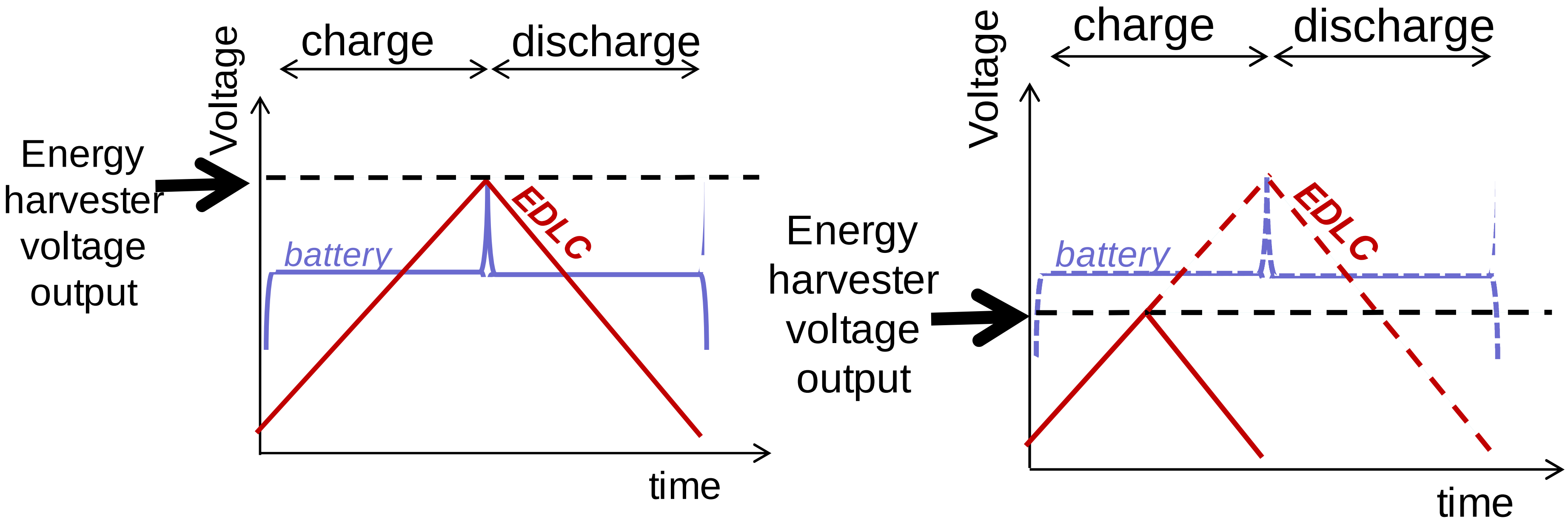
Energy harvesters

✓ Energy from the environment
X Low power and voltage output
X Intermittent

Supercapacitors

✓ Power quality, regulation
✓ Boost up power output

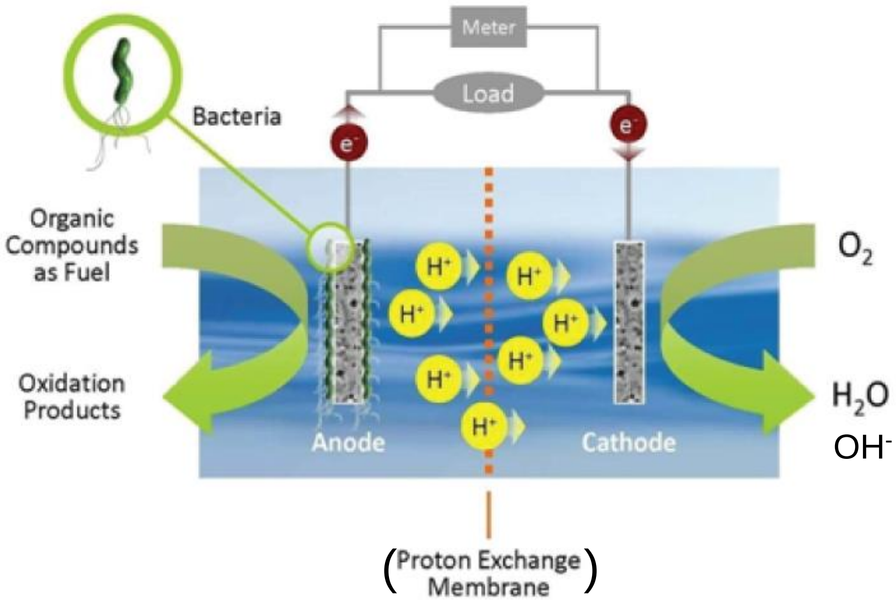
Supercapacitors vs Batteries



- ✓ **EDLCs directly store energy from low voltage harvesters**
- ✓ **For applications having high peak-to-average power demand**
- ✓ **High cycling stability**

Microbial Fuel Cells (MFC)

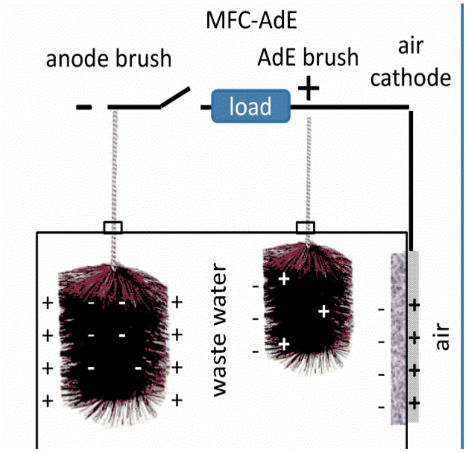
Simultaneous wastewater treatment and electric energy generation



✓Low current and power
✓Low energy quality

MFC is combined with **supercapacitors** to increase power output

Supercapacitive MFC with additional capacitive electrode



THE UNIVERSITY of NEW MEXICO

BILL & MELINDA GATES foundation

Carlo Santoro

Self-sustainable Urinal

Eco-Robot

brl University of the West of England University of BRISTOL Bristol Robotics Laboratory

BILL & MELINDA GATES foundation

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Parkash, J Microb Biochem Technol 2016, 8:3

C. Santoro et al. *Biosensors and Bioelectronics. 78* (2016,) 229

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ISARP Project Italy-South Africa - Grande Rilevanza

"Integration of High Power Energy Storage Systems for Sustainable Water and Renewable Sources Management"

Bristol Robotics Laboratory

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA

Prof. Carlo Santoro

Prof. Ncholu Manyala

Sustainable Materials, Processes & system design

Low-cost, bio-inspired electrodes and membranes from raw materials and by low-impact production processes

Sustainable Supercapacitor Components

- **Low-cost synthesis of inorganic oxides:**

Binder – free Magnetite by autocombustion

Keyvan Malaye

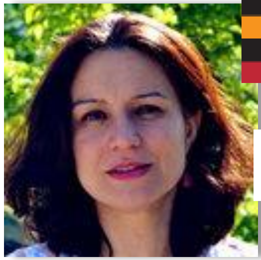
Teheran University

- **Bio-inspired electrode materials**

  Melanin

POLYTECHNIQUE MONTRÉAL

WORLD-CLASS ENGINEERING



Prof. Clara Santato

- **Separators**

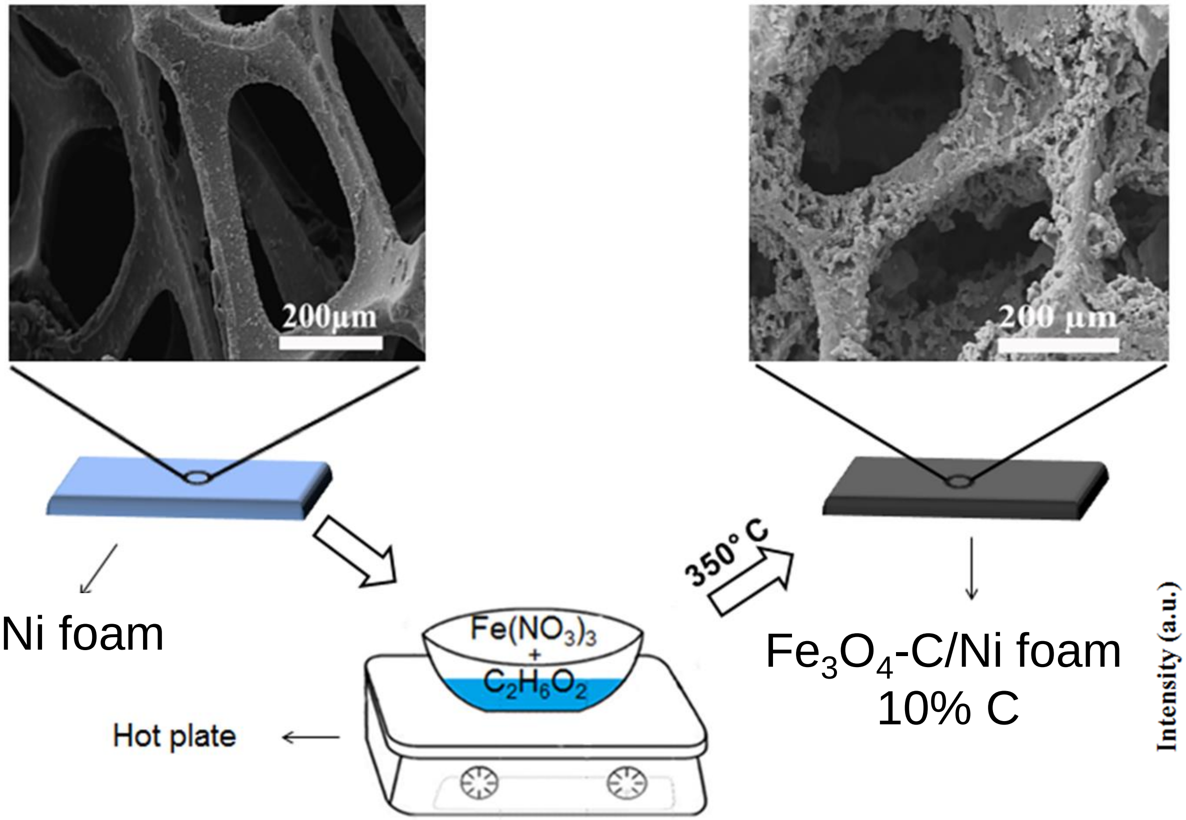
Natural polymers : cellulose, pullulane
Low-cost processing: electrospinning

Prof. Focarete
Prof. Fabiani

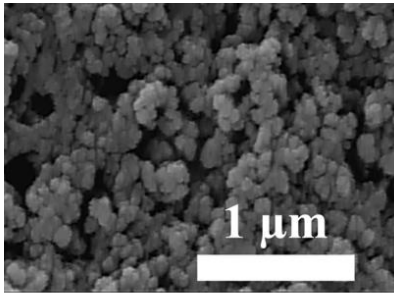
AntonioTerella

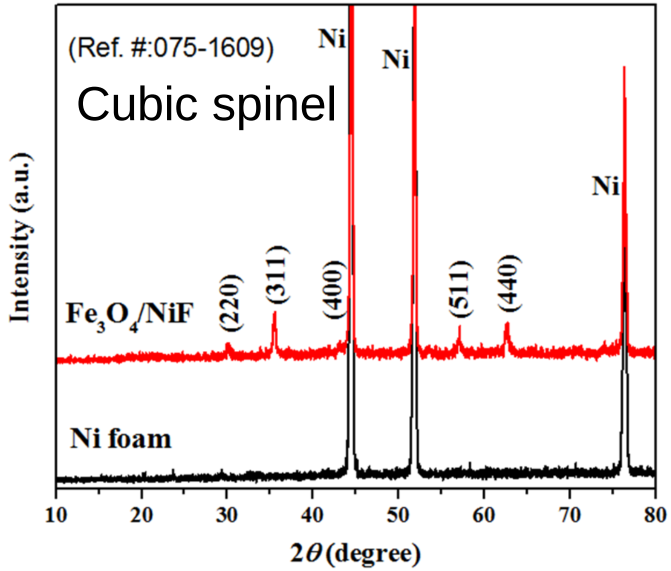
Jacopo Seri

Binder free Fe_3O_4-C/Ni by autocombustion



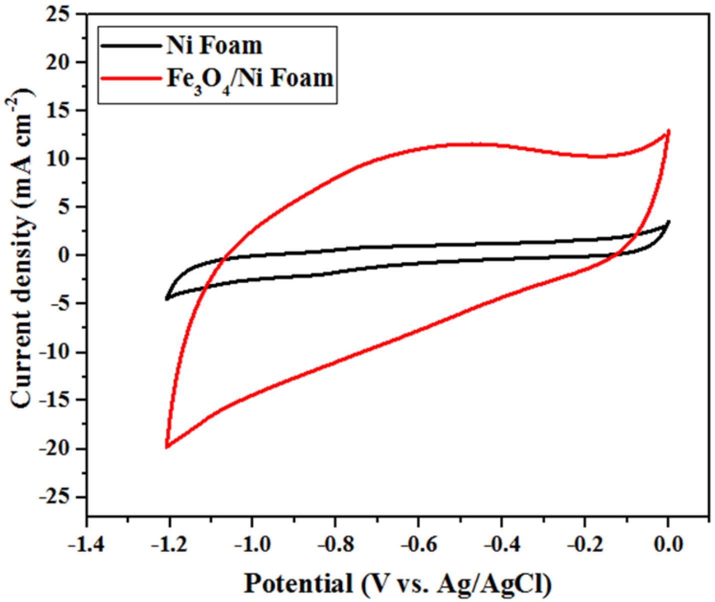
Exothermic reaction between nitrates and ethylene glycol



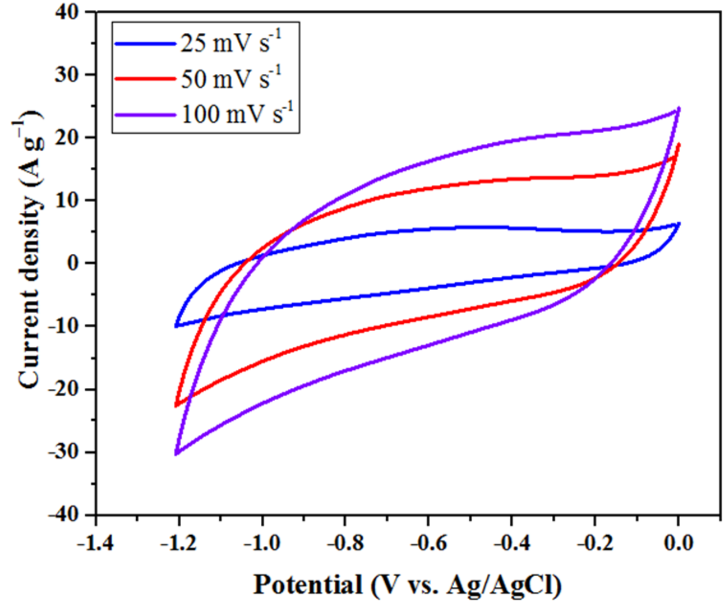


Binder free Fe_3O_4-C/Ni by autocombustion

250 F/g at 0.5 A/g



CVs of Fe_3O_4-C/ Ni Foam and Ni Foam in 1 M KOH at 50 mV s^{-1}



CVs of Fe_3O_4-C/Ni Foam at different scan rates in 1 M KOH.

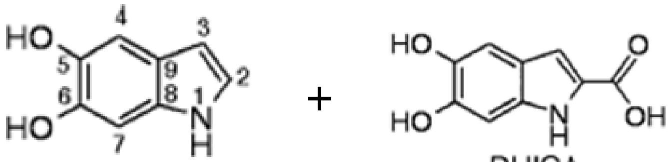
Fe_3O_4-C/ Ni is a promising pseudocapacitive material for negative electrodes of hybrid- or pseudo-capacitors obtained by low-cost processes

Melanin-based supercapacitors

Eumelanin

Natural pigment in animals, plants, human body (skin, eyes, inner ear, brain, hair)

Heterogeneous macromolecule



DHI (HQ) DHICA

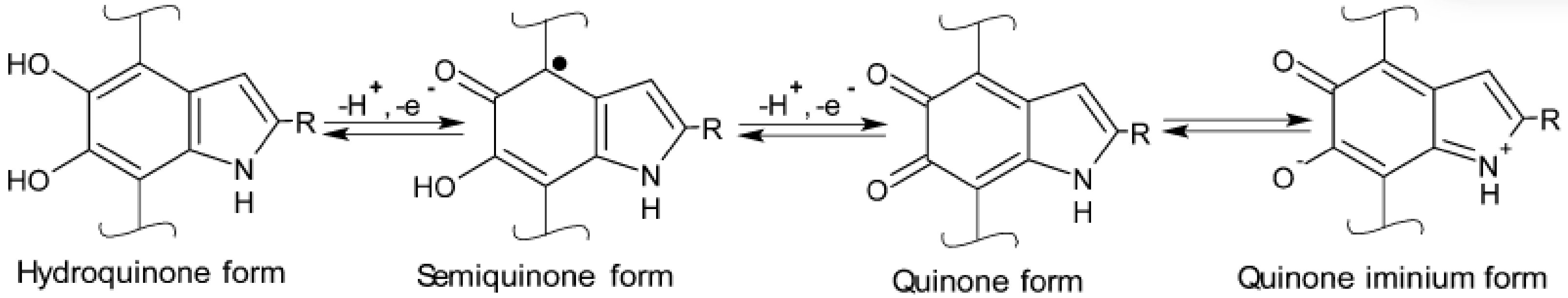
+ redox forms

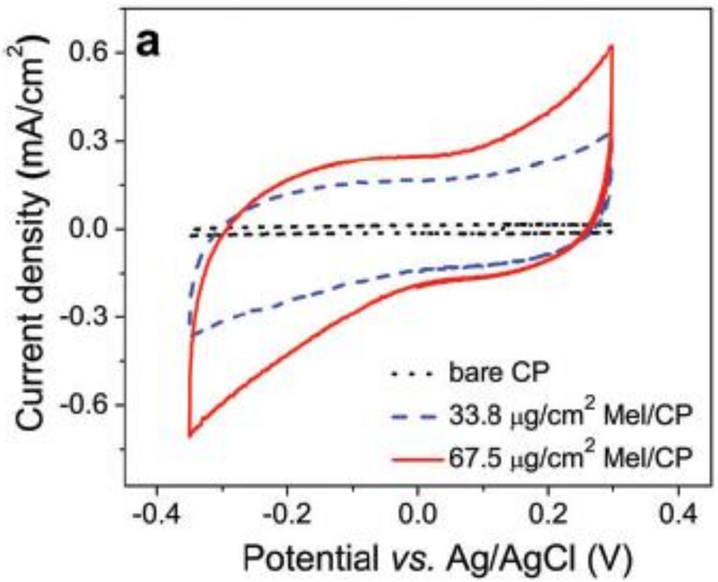
Functional properties: - biocompatible and stable in air and water

- UV-vis absorption, **metal chelation**, antioxidant
- **electron and proton conductive when hydrated**
- **reversible redox processes**

melanin as active material in energy storage systems

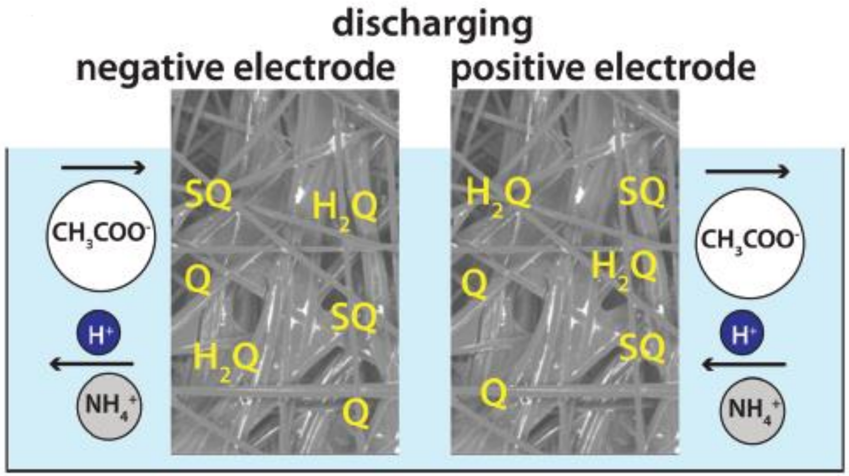
Melanin-based supercapacitors



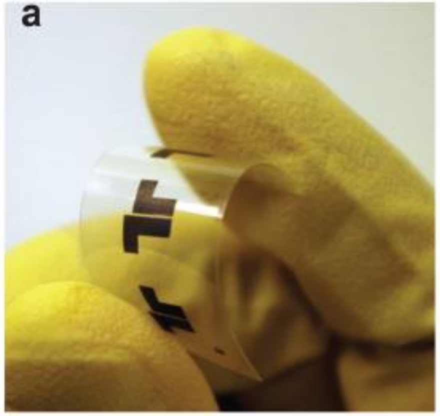


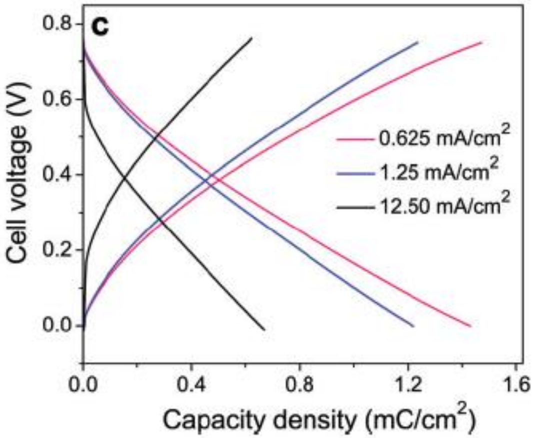
170 F/g at 5 mV/s

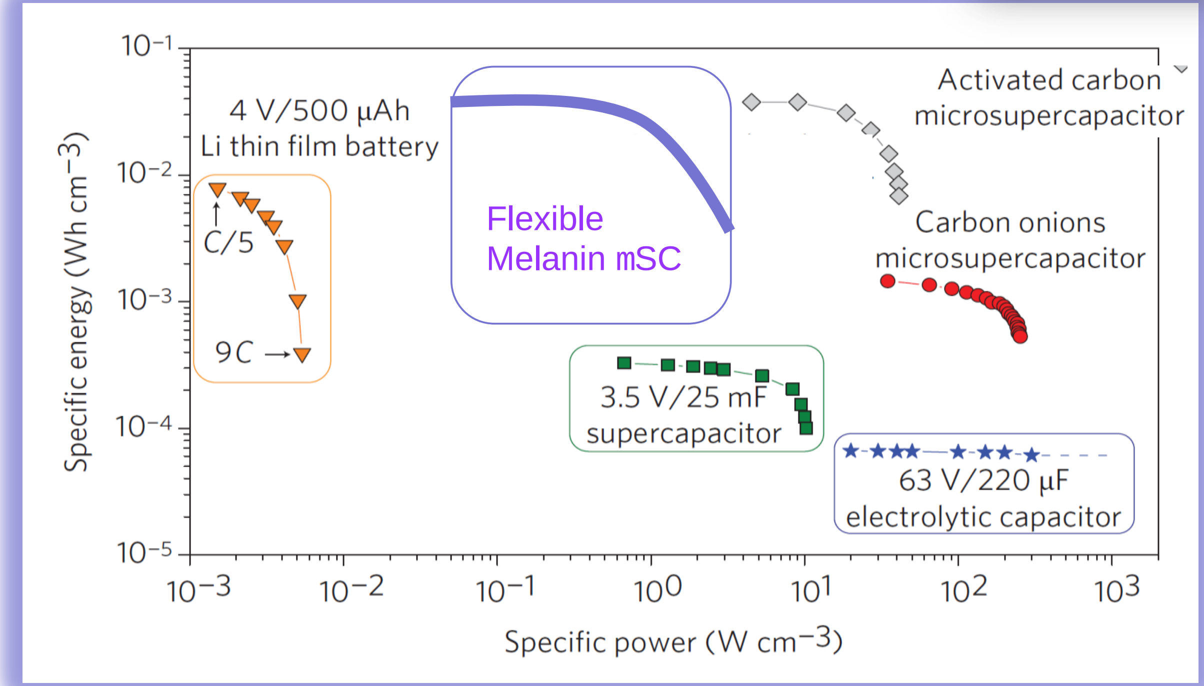
in NH_3CH_3COO – pH 5.5



Melanin-based supercapacitors

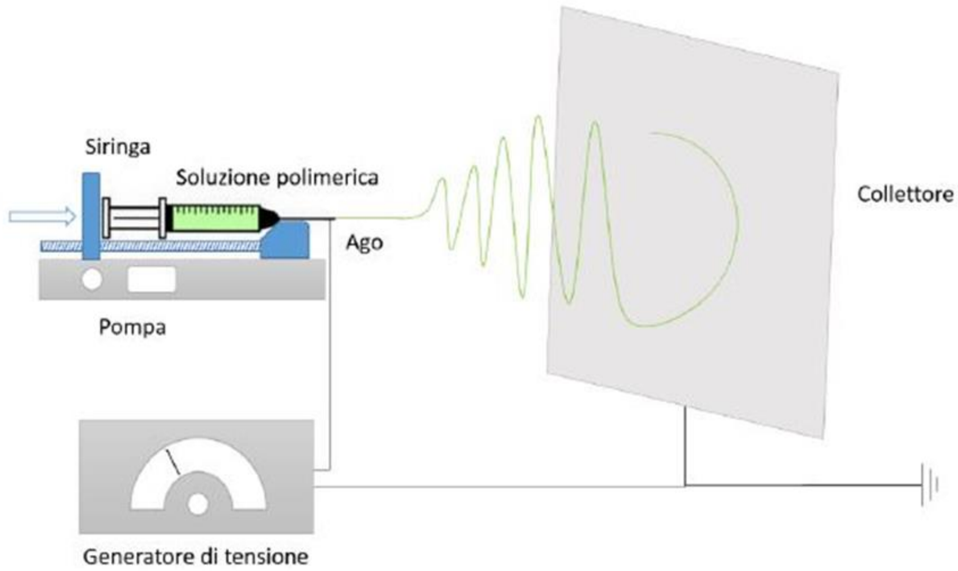


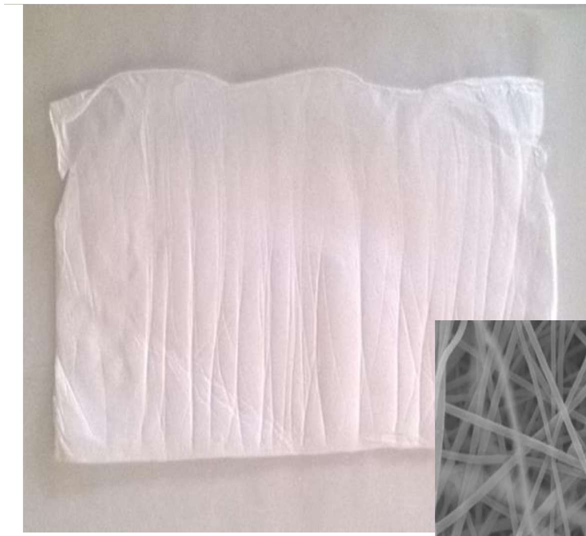


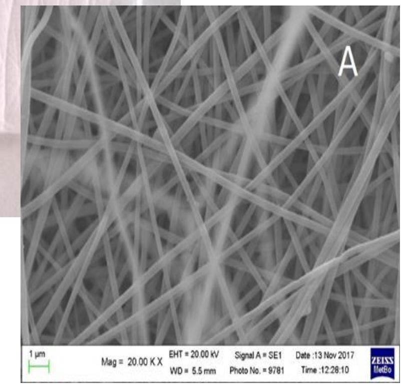


Melanine is a strategic material for biocompatible and biodegradable power sources.

Electrospun polymer separators







Solution: Polymer powder 23% w/V in H_2O
Flow rate: 0.9 mL/h
Voltage: 18 kV
Distance needle-collector: 20 cm

thickness: 140 µm

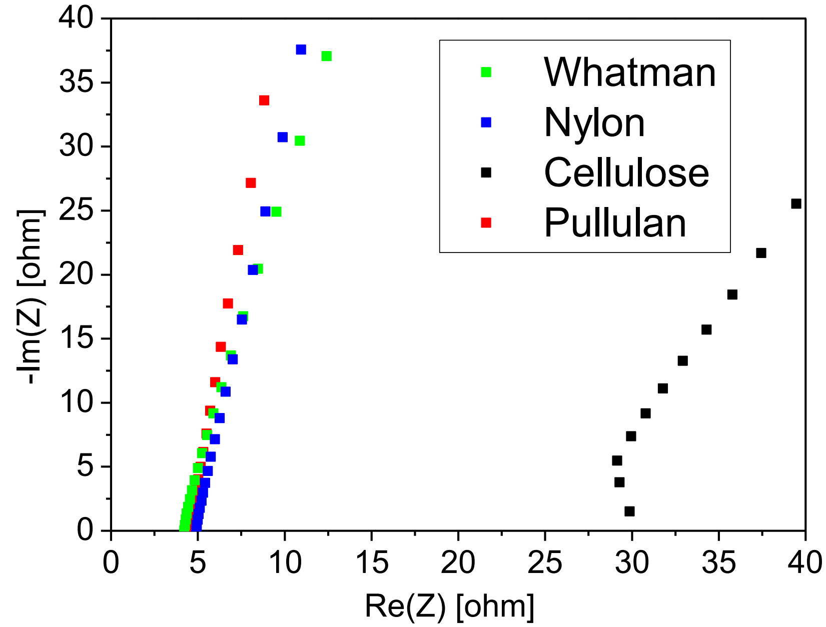
fiber diameter: 0.34 µm

Electrospun polymer separators

MacMullin Number : $$N_M = \frac{\rho_{eff}}{\rho_0}$$

Electrolyte
LP30 = LiPF$_6$ 1M – EC:DMC 1:1 wt.

Sample	Thickness [cm]	Resistivity ρ_{eff} [ohm*cm]	N_M
LP30	---	82.5	1
Whatman®	0.042	99	1.2
Pullulan	0.014	112	1.4
Nylon	0.004	159	1.9
Cellulose	0.002	23312	283



ρ_{eff} = ionic resistivity through the membrane

ρ_0 = ionic resistivity of electrolyte

Electrospun natural polymers can be used as separators and enable green energy storage

Take home message

- Supercapacitors are key systems within the Water – Energy Nexus and for Countries development

- Melanine and natural polymers, and novel materials synthesis & processing approaches, like inorganic oxides obtained by autocombustion, and electrospun membranes, can be exploited to develop low carbon foot-print supercapacitors, therefore enabling

low-cost and environmental friendly technologies

Acknowledgements

Acknowledgements