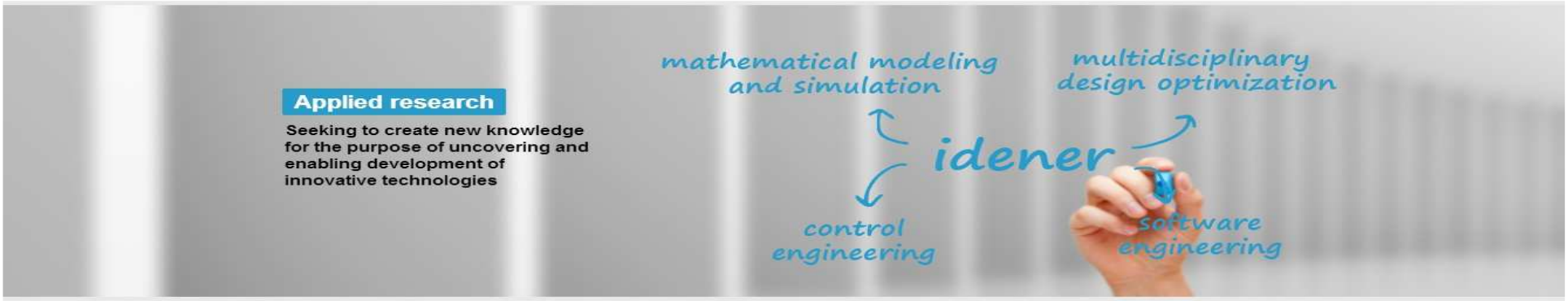

DEVELOPMENT OF ON-SITE POWER GENERATION MODULAR SYSTEM FOR WASTEWATER SLUDGE VALORISATION USING A COMBINATION OF PARTIAL ANAEROBIC DIGESTION AND MICROBIAL FUEL CELL TECHNOLOGIES

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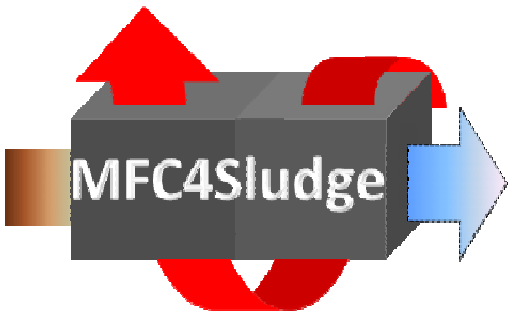
INDEX

INTRODUCTION: MFC4Sludge project

INTRODUCTION: MFC4Sludge project

PROJECT DESCRIPTION

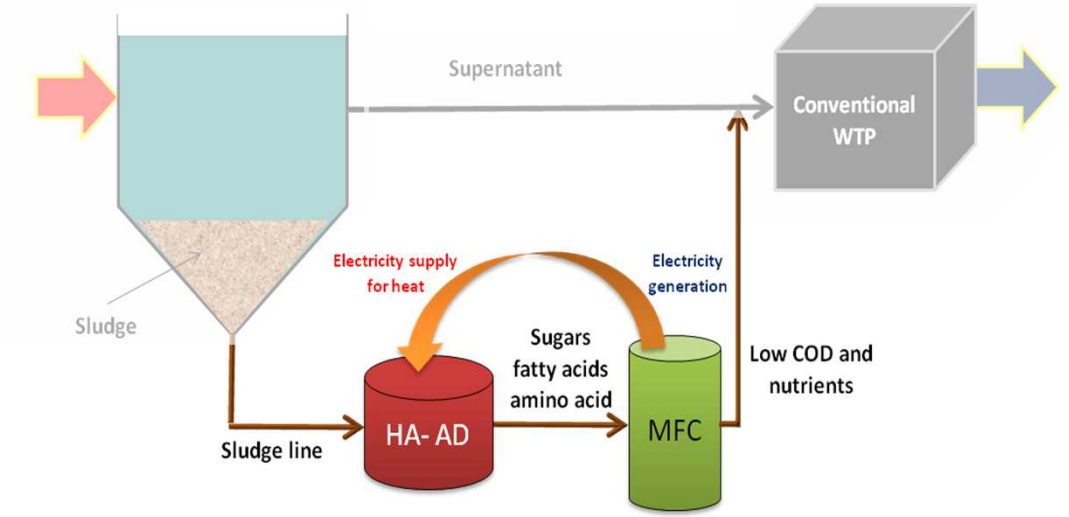
- EU Funded project: FP7 – Capacities – Research for the benefit of SME
- Duration: 1st August 2013 – 31st July 2015
- Total Budget: 1.495.520 €
- EU funding: 1.137.343
- Website: www.mfc4sludge.eu



INTRODUCTION: MFC4Sludge project

PROJECT DESCRIPTION

- Motivation: need of sustainable wastewater sludge valorization process
- Project concept: coupling of partial anaerobic digestion and MFC as a way to valorize the sludge and obtain energy



INTRODUCTION: MFC4Sludge project

PROJECT DESCRIPTION

- Objectives:

TECHNICAL AREA	OBJECTIVE
ANAEROBIC DIGESTION	Reduce HRT to maximum 7 days
	Keep operating temperature below 30°C
	Avoid methane production and maximise suitable substrates for the MFC (volatile fatty acids)
MFC	Obtain power output ratings of minimum 250W/m3
	Reduce impact in electricity generation to 0.3 kg CO2/kWh by optimising the MFC design
	Develop novel stack configurations and increase the ratio "electrodes surface area/volume" circa 20%

INTRODUCTION: MFC4Sludge project

PROJECT DESCRIPTION

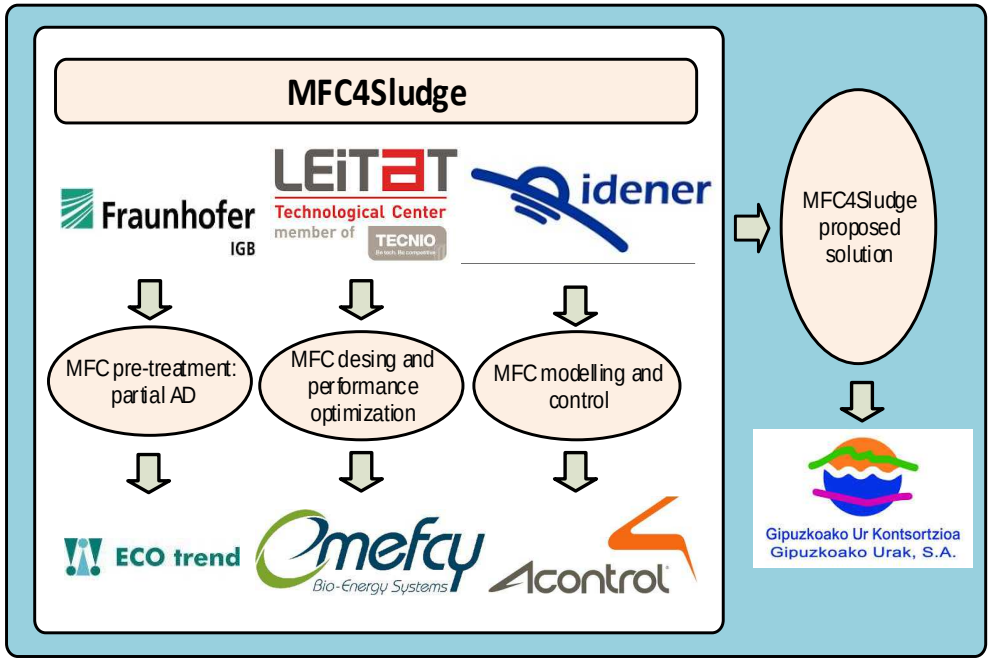
- Objectives:

TECHNICAL AREA	OBJECTIVE
CONTROL STRATEGIES	HA-AD and MFC mathematical models
	HA-AD-MFC combined model
	Advanced control strategies development
SCALE-UP	Lab scale and pilot scale prototypes to be developed
	90% COD degradation while reducing sludge volume at least 75%
	Net energy generation of minimum 140 W/m3

INTRODUCTION: MFC4Sludge project

CONSORTIUM DESCRIPTION

- 3 RTD performers: LEITAT, Fraunhofer IGB and IDENER
- 3 SMEs: ECOtrend, Emefcy and ACONTROL
- 1 End-User: Gipuzkoako Urak



PROCESS DEVELOPMENT

INTRODUCTION: MFC4Sludge project

PARTIAL ANAEROBIC DIGESTION

- Primary and secondary sludge where investigated
- Maximization of VFA content
- Minimization of biogas production
- pH-value $\leq$ 6.5

HA-AD process		
Hydraulic retention time	[d]	8; 6; 4.5
Temperature	[°C]	30
Solid content	[g L^{-1}]	15 - 18
Reactor volume	[L]	1.6
Inoculum		Outgassed sludge from anaerobic biogas process

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PARTIAL ANAEROBIC DIGESTION

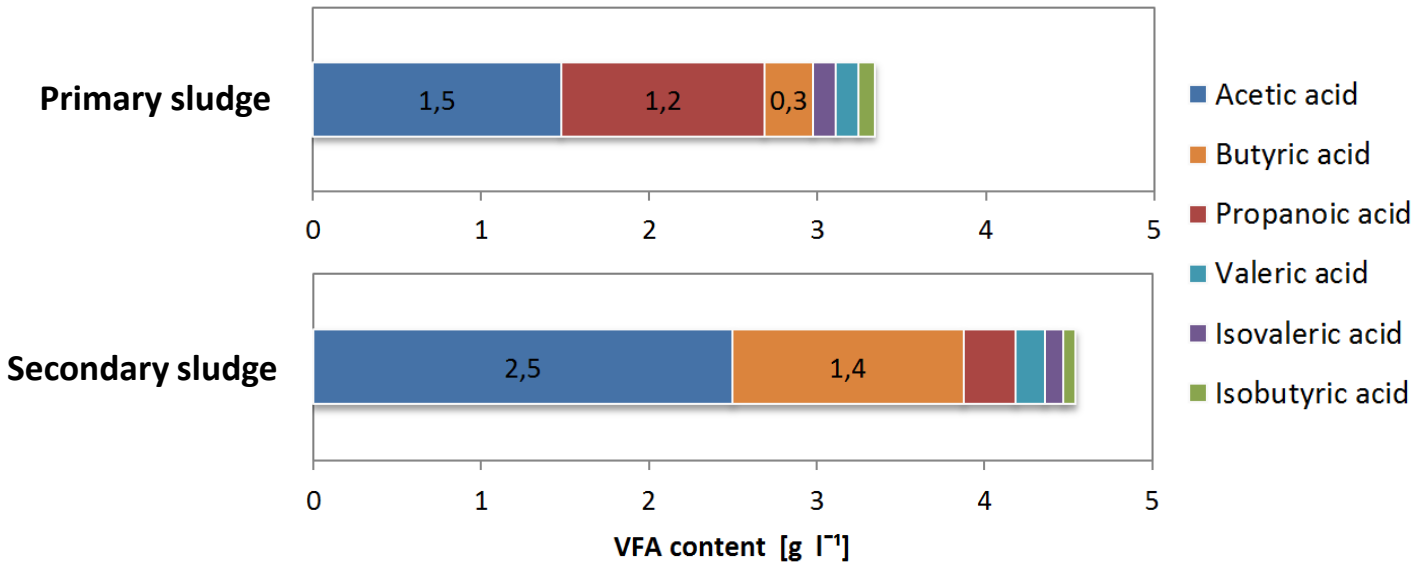
- Biogas production was reduced at HRT 4.5 to almost 0 NL d^{-1} in the primary sludge digestion
- COD was increased by almost 35% during HA-AD
- The conductivity in the HA-AD process was 4.2 mS
- Highest VFA-production at HRT of 4.5
- *Clostridium aceticum* and *Acetobacter wolfii* were added to reduce BG-production
- pH value stabilized at 5.2

INTRODUCTION: MFC4Sludge project

PARTIAL ANAEROBIC DIGESTION

- VFA content in the HA-AD process

The highest amount of VFA content was 4.6 g L^{-1} in SeSl and 3.4 g L^{-1} in PrSl digestion

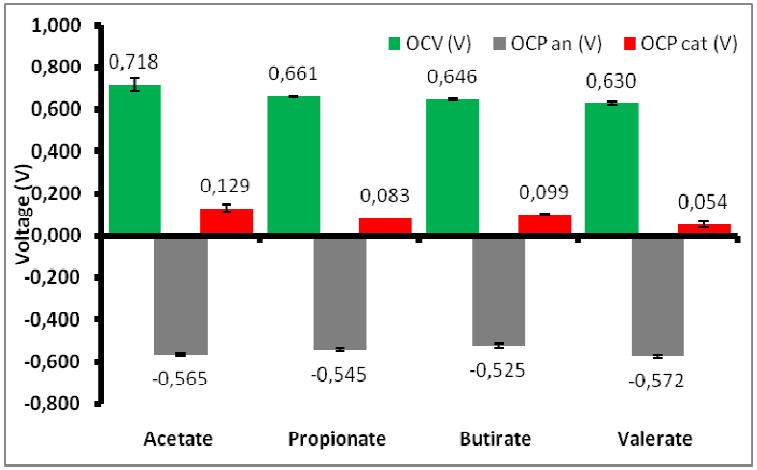


INTRODUCTION: MFC4Sludge project

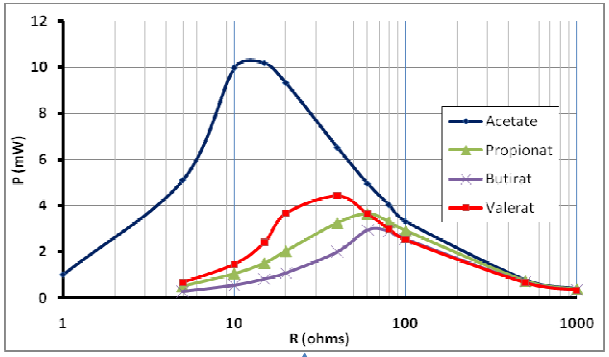
MFC DEVELOPMENT

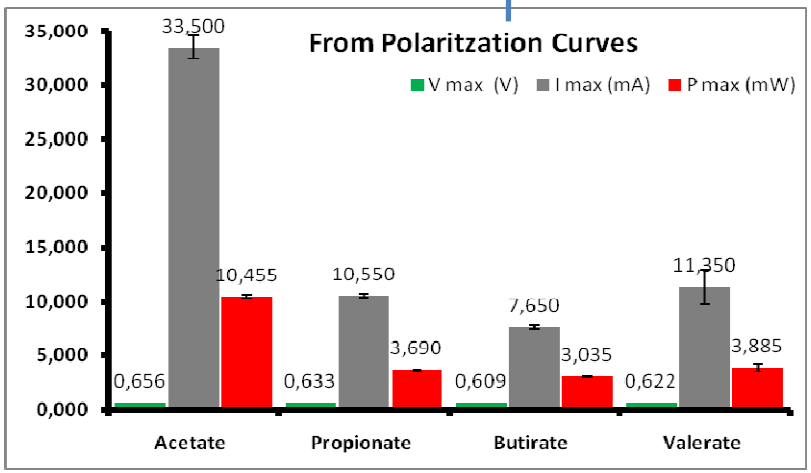
➢ MFCs Characterisation

Electrochemical techniques: polarization curves, Constant Load Discharge (CLD), constant voltage operation, Electrochemical Impedance Spectroscopy (EIS) and Cyclic Voltamperometry (CV).



OCV, OCP(an) and OCP(cat) for each VFA



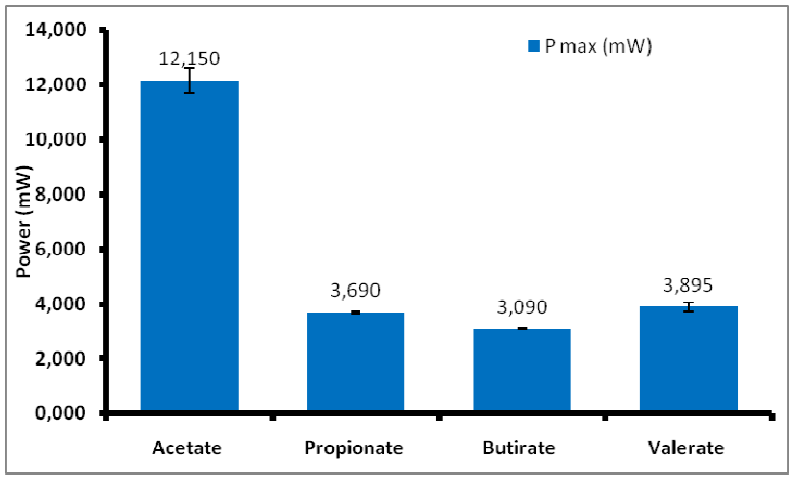


Electrical parameters of Polarization Curves (PC) for each VFA

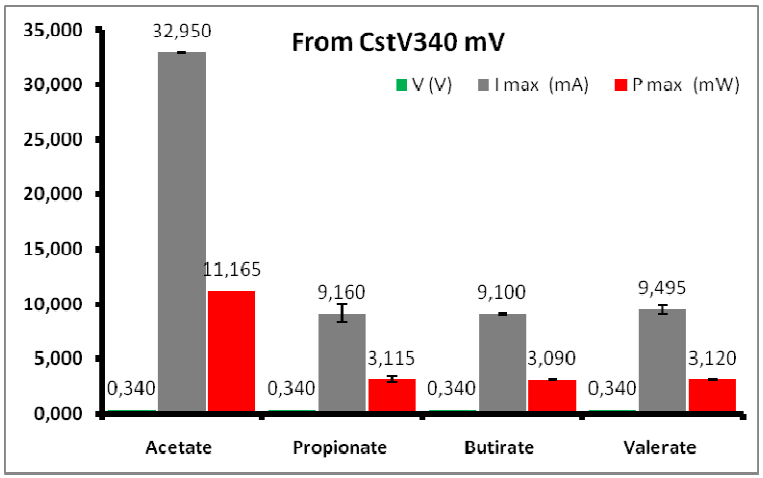
INTRODUCTION: MFC4Sludge project

MFC DEVELOPMENT

- **VFAs performance**



Power output for constant Load Discharge (CLD) measurement for each VFA. An average of two MFC



Electrical parameters from constant voltatge working conditions of four VFAs. An average of two cells

VFA	ΔDQO (%)	ϵ_{CB} (%)
Acetate	71,840	38,317
Propionate	58,330	8,228
Butirate	30,470	14,211
Valerate	18,920	28,460

INTRODUCTION: MFC4Sludge project

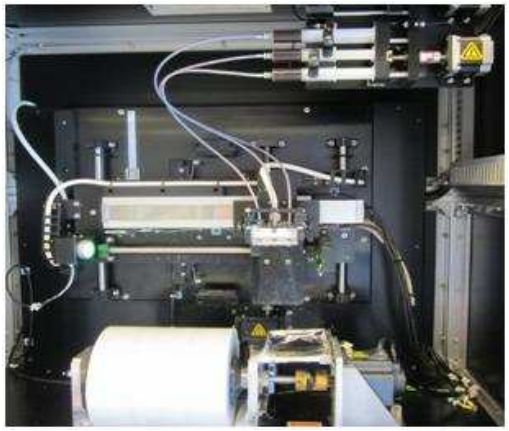
MFC DEVELOPMENT

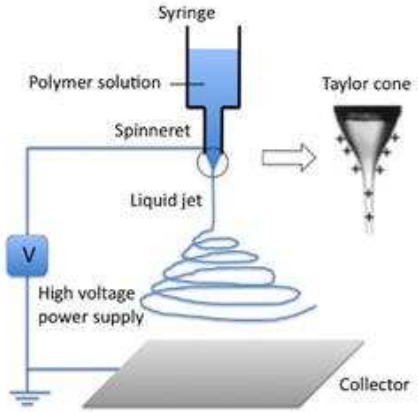
➢ Novel Air-cathode development

DEVELOPMENT OF NOVEL FREE-STANDING AIR-CATHODE

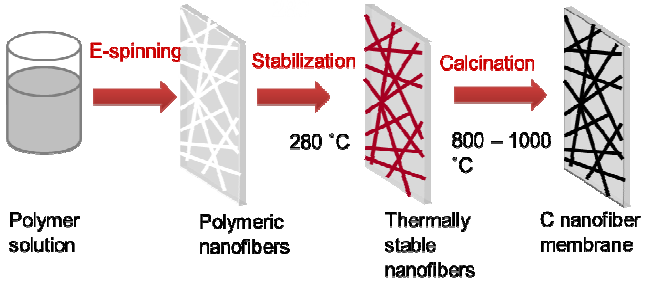
Use of free-standing metal-doped carbon nanofibers as direct cathode for the MFCs

a) Electrospinning of a solution of polyacrylonitrile and a precursor salt (Co, Ni, Fe acetate) in DMF





b) Thermal treatment



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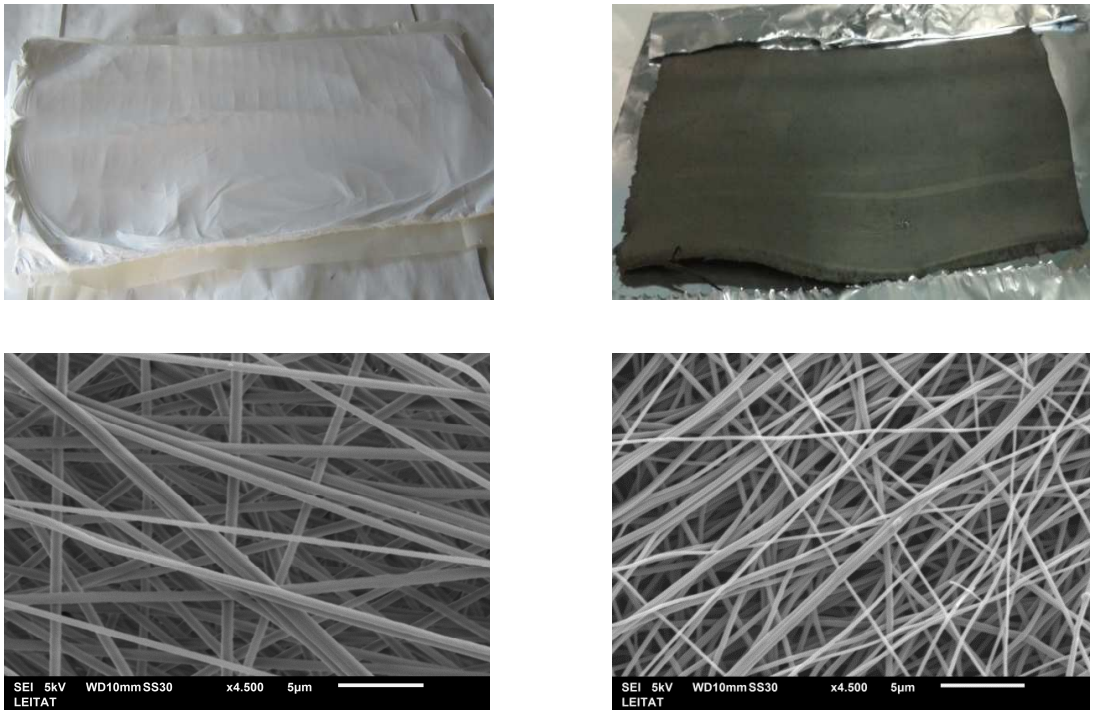
MFC DEVELOPMENT

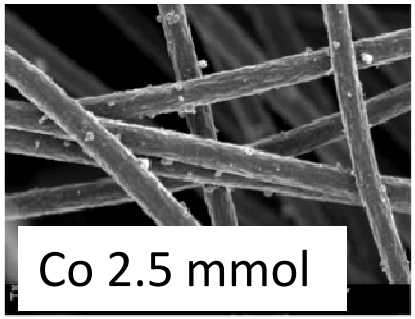
Produced PAN Nanofibers

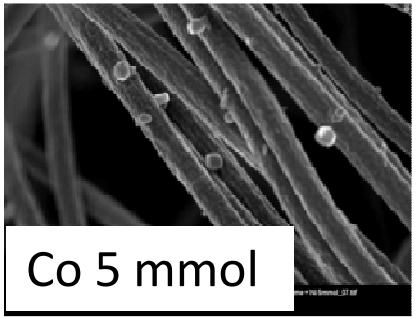


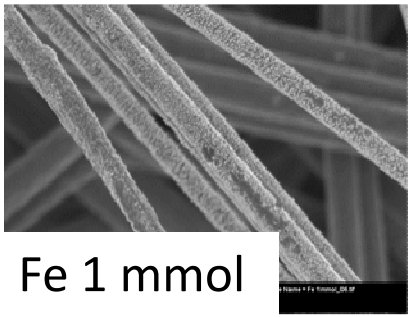
Photos (above) and SEM images (below) of the electrospun (left) and carbonized (right) nanofibers

INTRODUCTION: MFC4Sludge project

MFC DEVELOPMENT

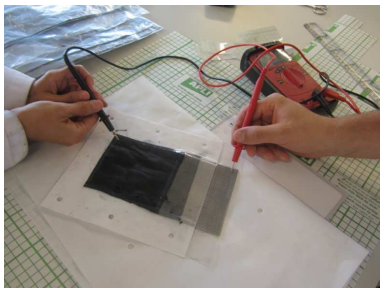




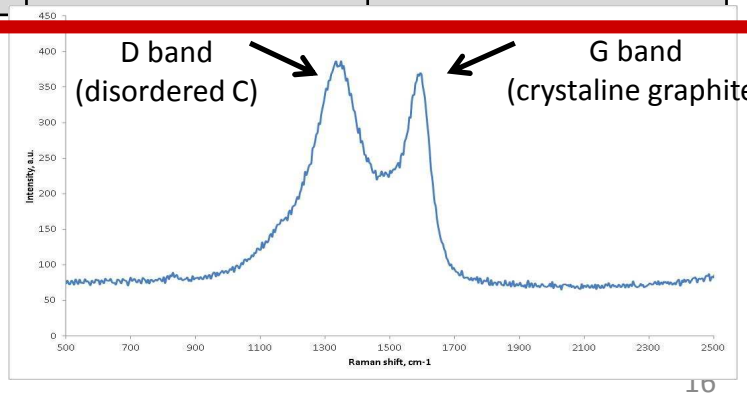


Characterization

CNFs	%wt. M	Conductivity (S/cm)	Surface Area (m^2/g)
Co 5 mmol	10.1	5.4	572.6
Co 2,5 mmol	4.50	8.3	447.5
Co 1mmol	1.53	3.0	296.5
Ni 5 mmol	8.68	2.9	109.9
Ni 2,5 mmol	4.7	3.2	281.0
Ni 1mmol	1.47	4.1	42.7
Fe 1mmol	1.72	5.9	365.7



Air-cathode testing



Raman Spectrum

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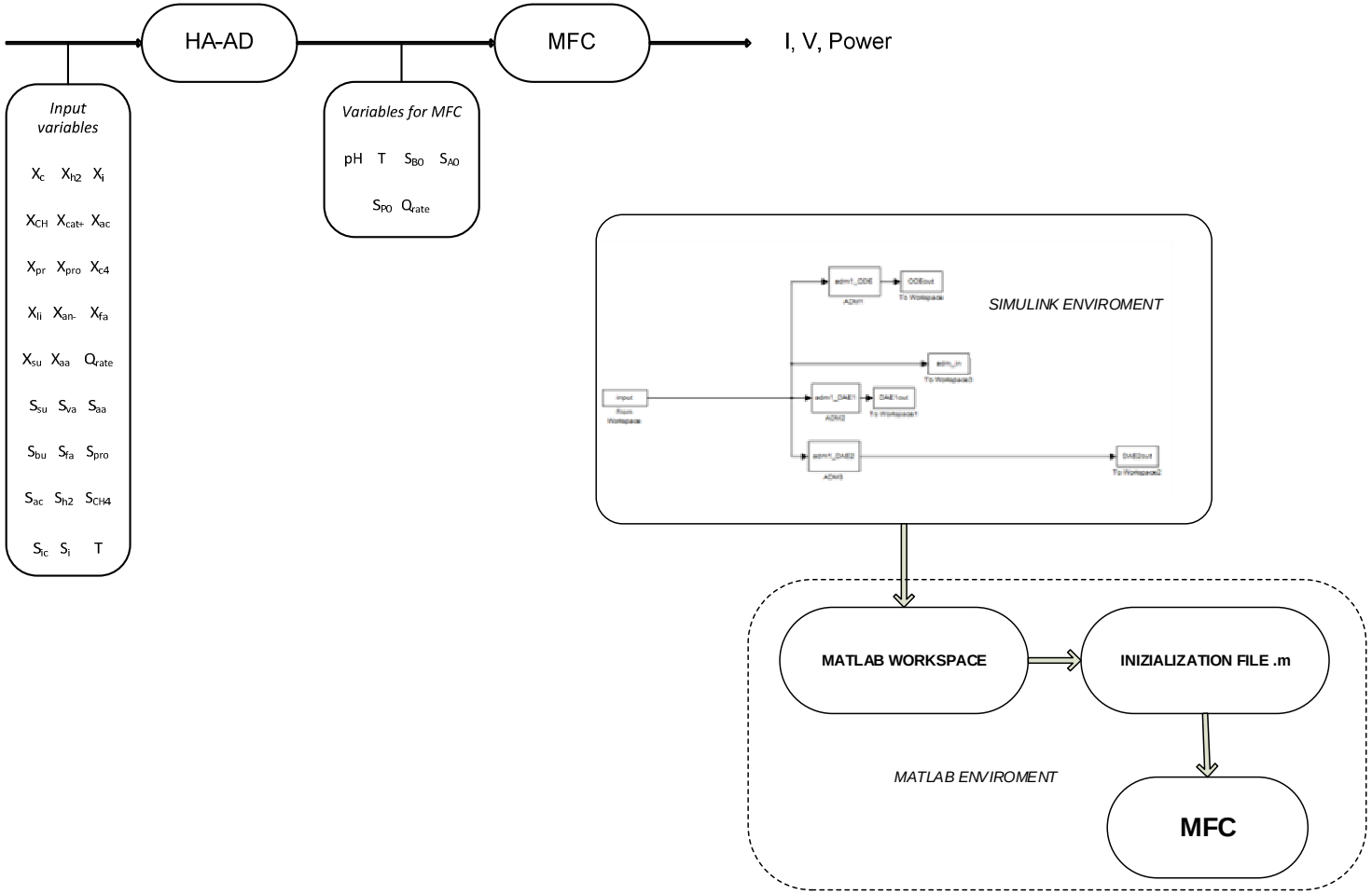
CONTROL STRATEGIES DEVELOPMENT



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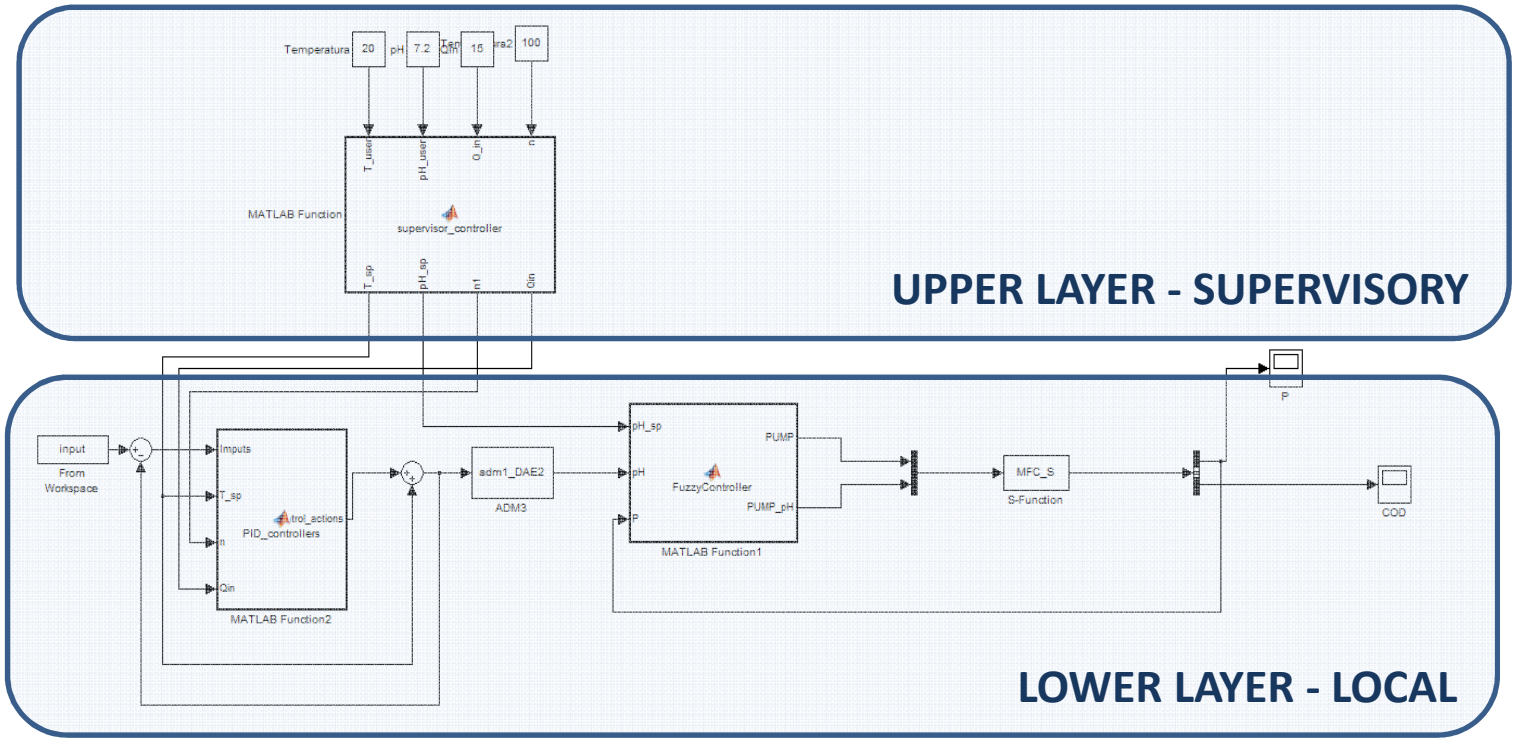
CONTROL STRATEGIES DEVELOPMENT



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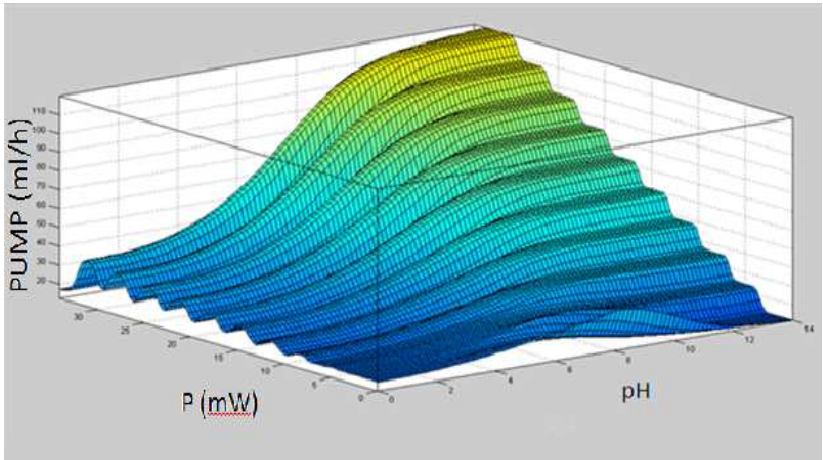
CONTROL STRATEGIES DEVELOPMENT

- MFC local controller development
  - Use of Fuzzy logic approach as advanced control strategy
  - No need of mathematical model, only knowledge about system dynamics
  - Target: pH control and power maximisation
  - Creation of inference rules -> 3D Surface for each pH setpoint



CONCLUSIONS

INTRODUCTION: MFC4Sludge project

CURRENT TASKS

- Lab scale prototype implementation including:
  - ✓ Anaerobic digester
  - ✓ MFC: air-cathode type
  - ✓ Recirculation loops
  - ✓ Control system: Labview based (providing User interface for setpoints definition and prototype testing-operation)

INTRODUCTION: MFC4Sludge project

FUTURE STEPS

- Pilot scale prototype design
- Pilot scale prototype construction
- Prototype implementation in a real wastewater treatment plant, i.e. end-user Gipuzkoako Urak facilities
- Prototype operation and overall process optimization
- Dissemination and exploitation of project results

INTRODUCTION: MFC4Sludge project

SUMMARY – MAIN CONCLUSIONS

- Partial anaerobic digestion as great pre-treatment for MFC influent (increases carbon-content in substrate) when using 30ºC and 4,5 days as HRT

- Acetate as VFA providing best MFC performance. New air-cathode design (poster PO-37, METs and water treatment (II): removal of organic pollutants)

INTRODUCTION: MFC4Sludge project

SUMMARY – MAIN CONCLUSIONS

- Fuzzy logic control as an advance and innovative control strategy for MFC. MFC 2D mathematical model produced and under validation (poster PO-63, System and architecture in MET)

- Current status: real wastewater test and whole system integration and testing. Pilot deployment in upcoming months

Thanks for your attention!

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