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16/09/2014

Salinity Gradient Energy by Reversed Electrodialysis - REAPower

International Symposium Innovative Desalination Technologies, Seoul

INES session, 03 September 2014

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VITO, VISION ON TECHNOLOGY

WHO IS VITO ?

» A LEADING EUROPEAN INDEPENDENT RESEARCH CENTRE, LOCATED IN FLANDERS/BELGIUM;

» 750 PEOPLE, ACTIVE IN THE AREAS OF CLEANTECH AND SUSTAINABLE DEVELOPMENT;

» ELABORATING SOLUTIONS FOR THE LARGE SOCIETAL CHALLENGES OF TODAY.

Reduce dependence on fossil fuels

More sustainable industry

Reorganisation of the environment

Separation and Conversion technologies (~100 people)

Our Technologies/ Expertise

SEPARATION TECHNOLOGY

CONVERSION TECHNOLOGY

MEMBRANES

ELECTRODES

Enabling competences

Markets

Chemical processing / PI
Biobased economy
Resource recovery

Our Stakeholders

Industry

Contract research

Open innovation

Spin-offs

Society

New value chains

- *Algae to products*
- *Bio-aromatics*
- *CO_2 to chemicals*

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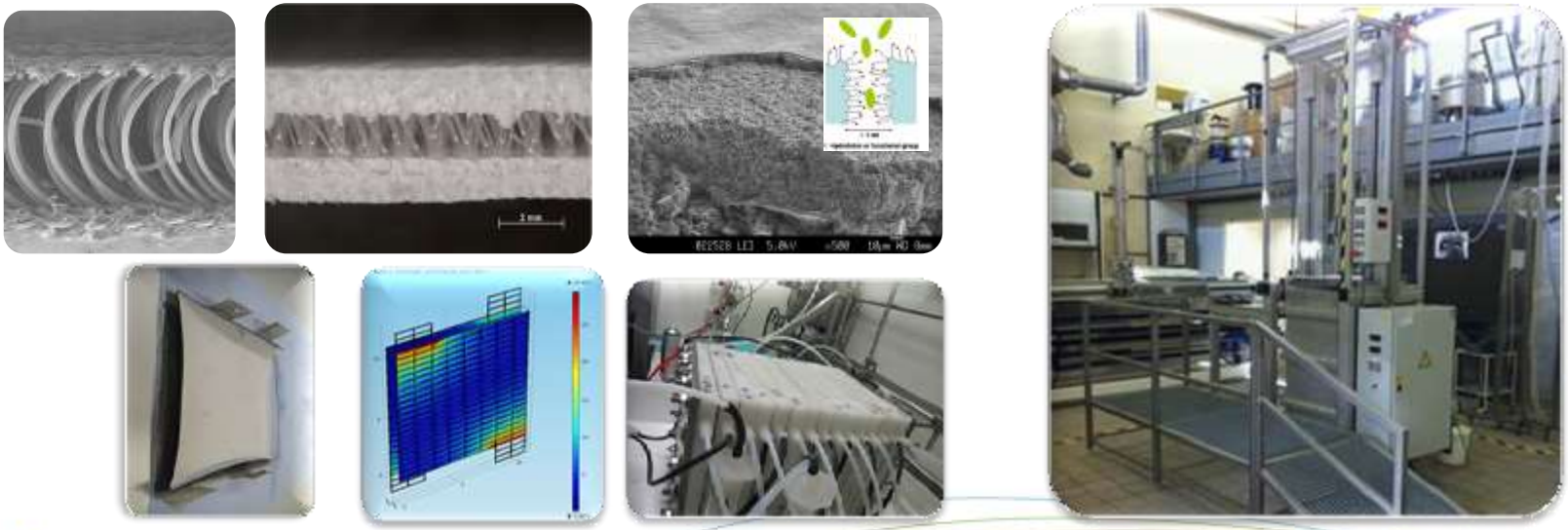
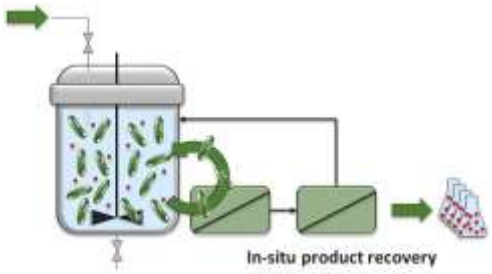
VITO as Product developer…

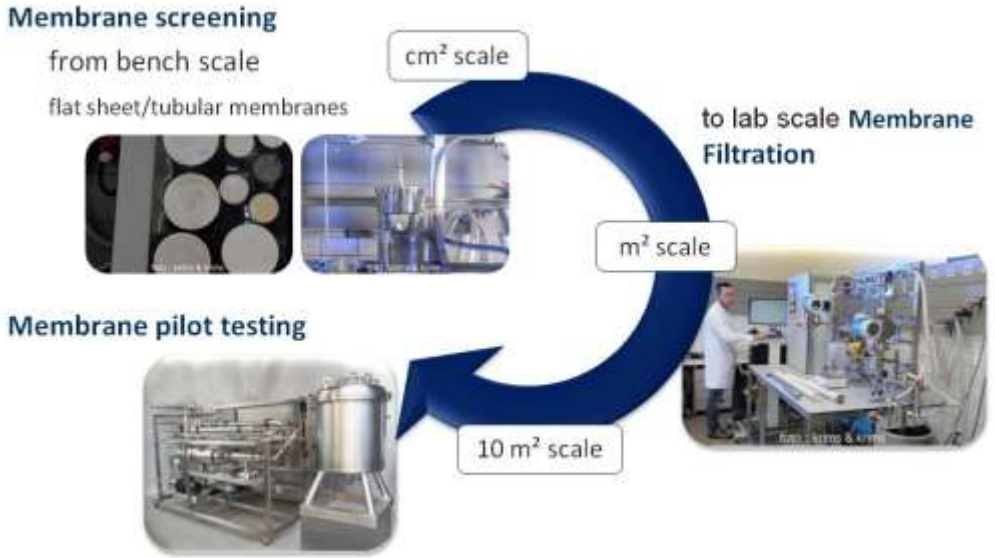
- **Membrane development** *(20 patents)*
  - Reinforced polymeric membranes (flat sheet-IPC, tubular, capillary)
  - Membrane contactors
  - Functionalised ceramic membranes
- **Electrodes and stacks** (carbon based)



VITO as Technology integrator…

- Membrane technology for water processing and resource recovery
  - *Equipment: MF/UF, NF, RO, MBR, ED, RED, MD, CDI*
- Integrating separation processes with conversion processes
- Setting-up demonstrators from lab to pilot scale
- Integrated approach: engineering, analysis, TEA…





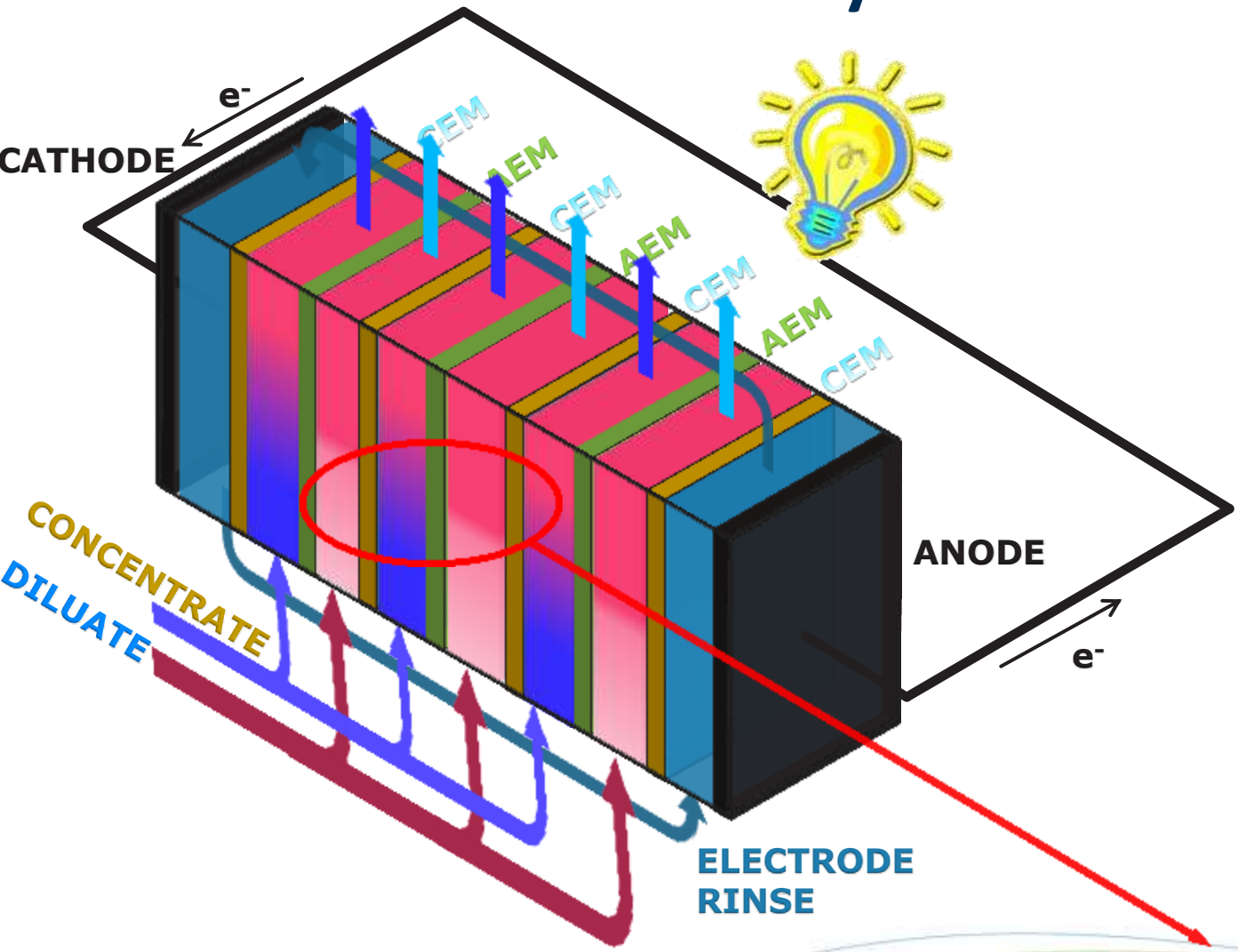
The REAPower Project

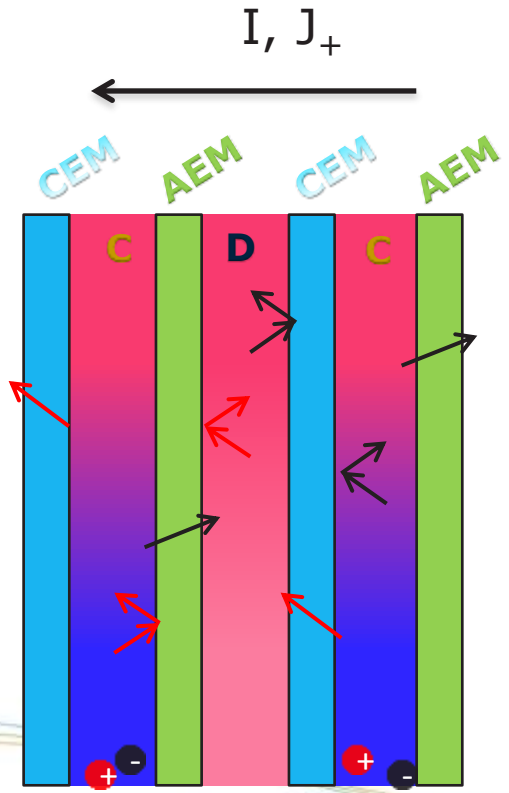
Main facts:

- Project title: *Reverse Electrodialysis Alternative Power Production*
- Call identifier: FP7-ENERGY-2010-FET (Future Emerging Technologies for Energy Applications)
- Starting date: 1 October 2010
- Closing date: 30 September 2014

The objective of REAPower is to prove the concept of electricity production through SGP-RE using **brine** and **sea (/brackish) water** and to develop the necessary materials, components and processes.

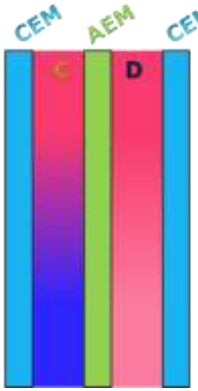
The Reverse Electrodialysis technology





SGP-RE applications

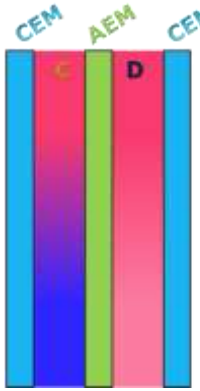
Blue Energy



Concentrate
=
Sea water

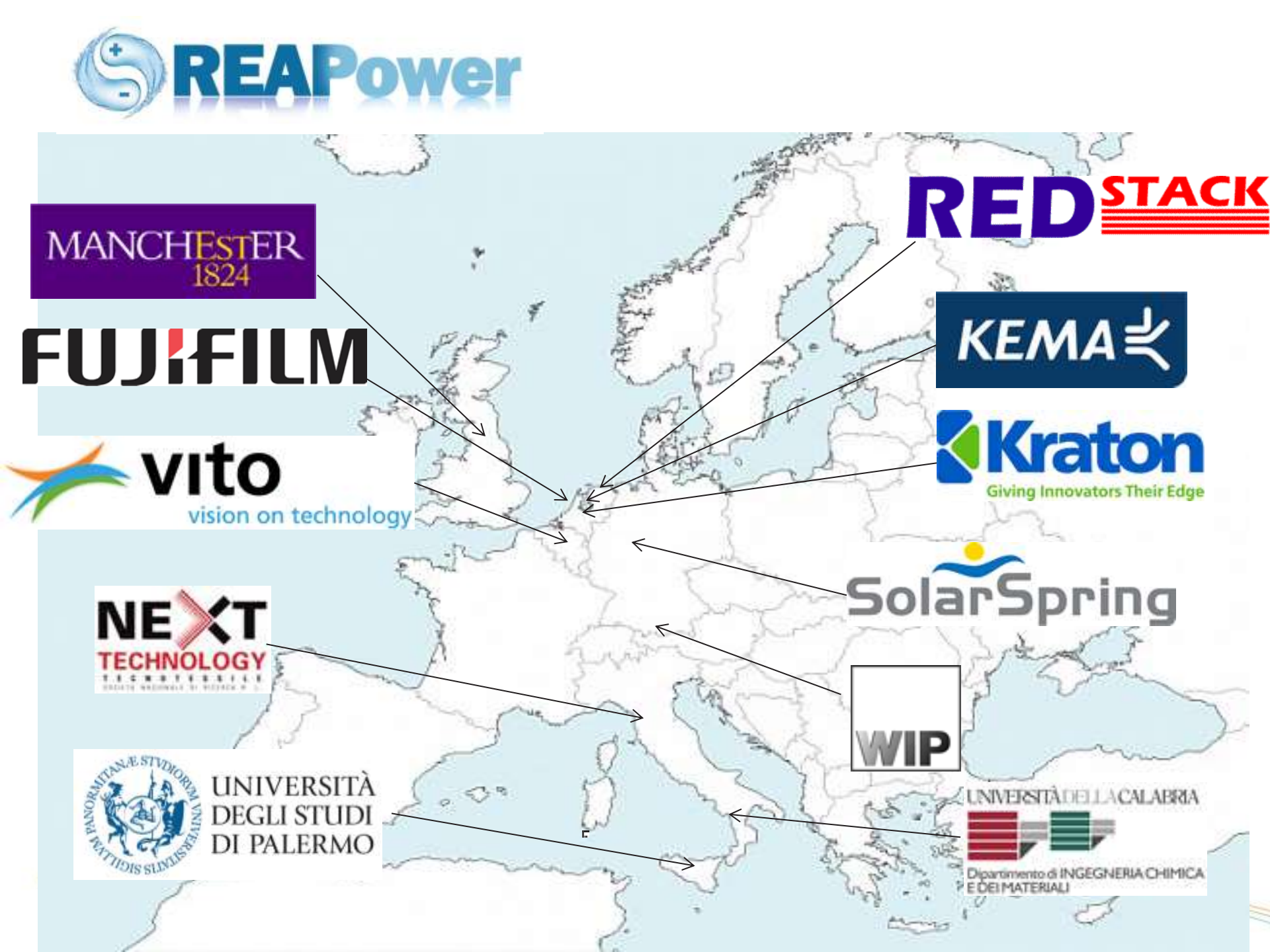
Diluate
=
river water

REAPower



Concentrate
=
Brine

Diluate
=
Brackish or
sea water


REAPower
MANCHESTER 1824
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NEXT TECHNOLOGY
UNIVERSITÀ DEGLI STUDI DI PALERMO
RED STACK
KEMA
Kraton
Giving Innovators Their Edge
SolarSpring
WIP
UNIVERSITÀ DELLA CALABRIA
Dipartimento di INGEGNERIA CHIMICA E DEI MATERIALI

The REAPower Project

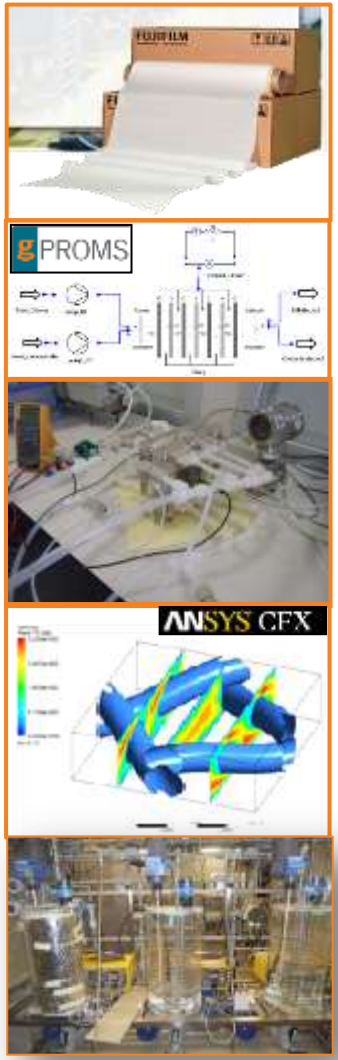
The idea

to produce energy from salinity gradients generated by

sea/brackish water and ultra-concentrated brines

R&D strategy

- ✓ Development of new **Ion Exchange Membranes** for highly concentrated solutions
- ✓ Selection of best conditions for **redox couple/spacers/stack design**
- ✓ Wide **experimental investigation** on lab-scale stack
- ✓ Development/validation of a **predictive modelling tool**
- ✓ **Economic analysis** and process sustainability on large scale *(ongoing)*



Improvements in membranes development

Increased **permselectivity**

✓ Permselectivity has achieved values of **65% for AEM** and **up to 90% for CEM** when **in contact with** almost saturated **brine**

Reduced **membrane resistance**

✓ Membrane specific resistance reduced to **1.5-2.5 Ω·cm²** (possibly lower in the near future – thinner membranes)

Electrochemical aspects and stack design

Redox couples selection

Investigated redox couples under different conditions:

- ✓ **$FeCl_3/FeCl_2$**
- ✓ **$K_3Fe(CN)_6/K_4Fe(CN)_6$**
- ✓ Fe(III)-EDTA/Fe(II)-EDTA

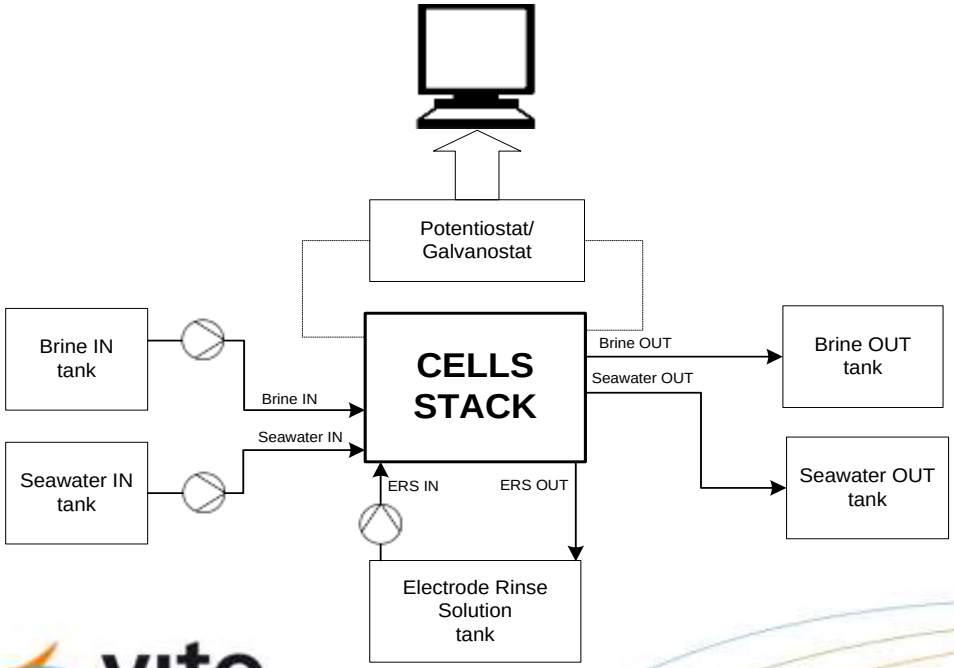
New **stack design**

- ✓ Two optimized **stack geometries** designed, constructed and tested
- ✓ Currently available for pilot testing

Experimental investigation at lab-scale

Experimental conditions investigated:

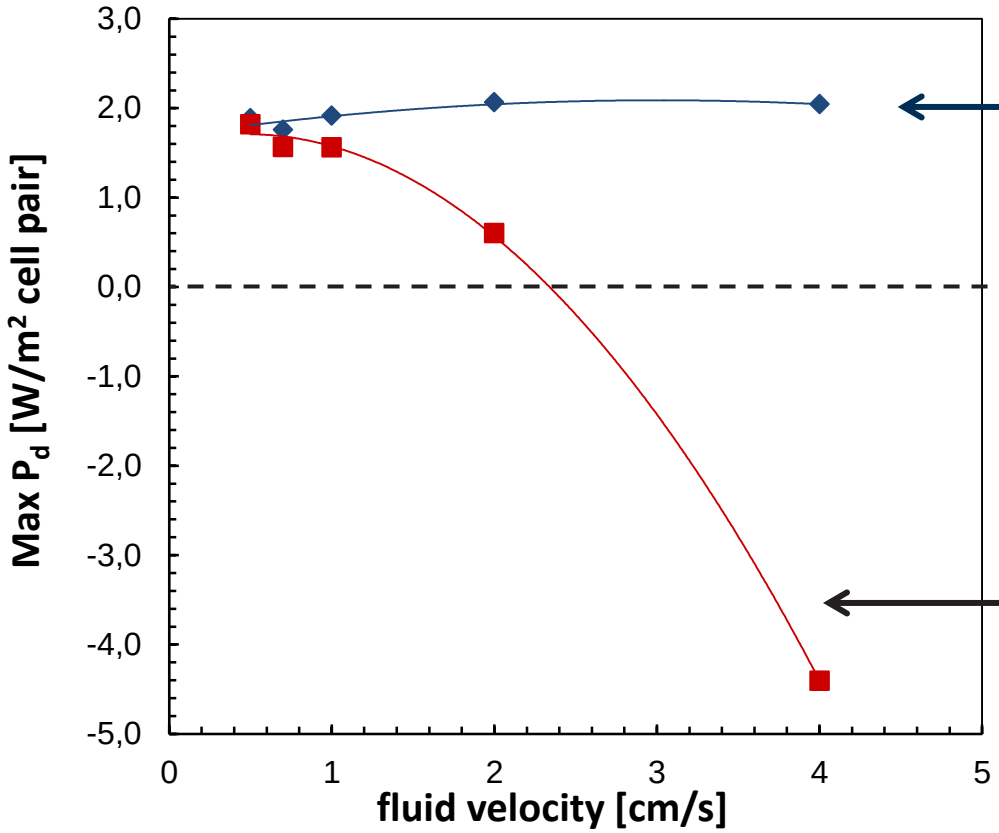
- ✓ fluid velocity (0.1 – 4 cm/s)
- ✓ feed temperature (20 – 40 °C)
- ✓ number of cell pairs (5 – 50)
- ✓ concentration of redox couple (0.1 – 0.3 M of $K_3Fe(CN)_6/K_4Fe(CN)_6$)
- ✓ salt concentration of both solutions.
- ✓ Membrane thickness



Showing that the SGP-RE installation works…

Experimental investigation on a lab-scale unit

e.g. Effect of fluid velocity on power output



Max power density (gross)

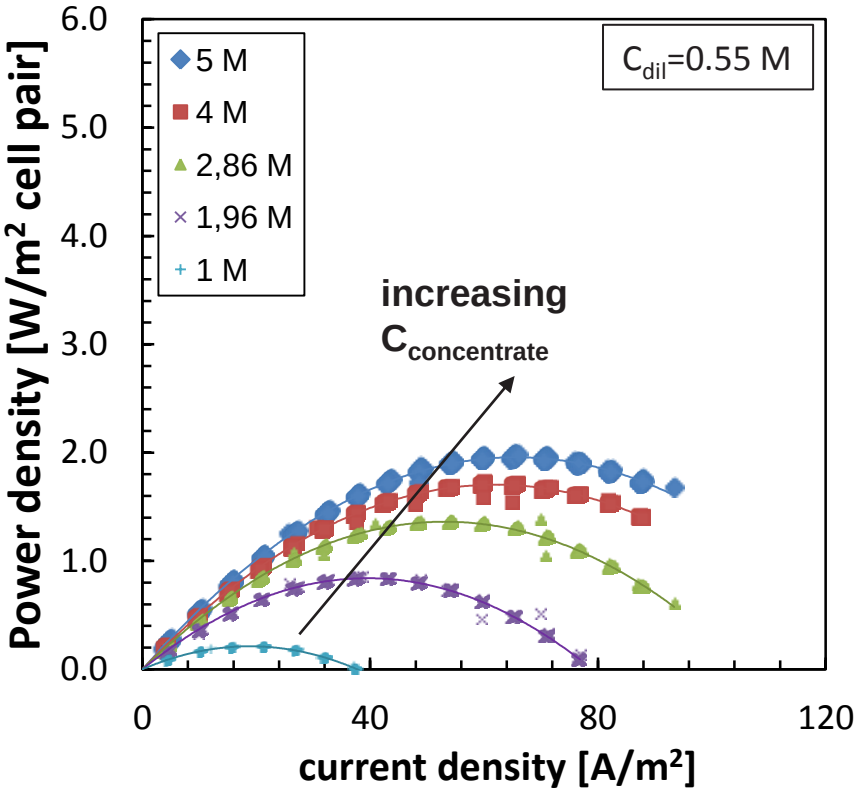
Max power density (net): Power density – Hydraulic losses

Stack equipped with 50 cell pairs, Fujifilm membranes, Deukum 270 µm spacers .Brine solution: 5 M NaCl, seawater: 0.5 M NaCl. T=20°C. Electrode rinse solution: 0.1 M $K_3Fe(CN)_6$ / $K_4Fe(CN)_6 \cdot 3H_2O$ + 2.5 M NaCl.

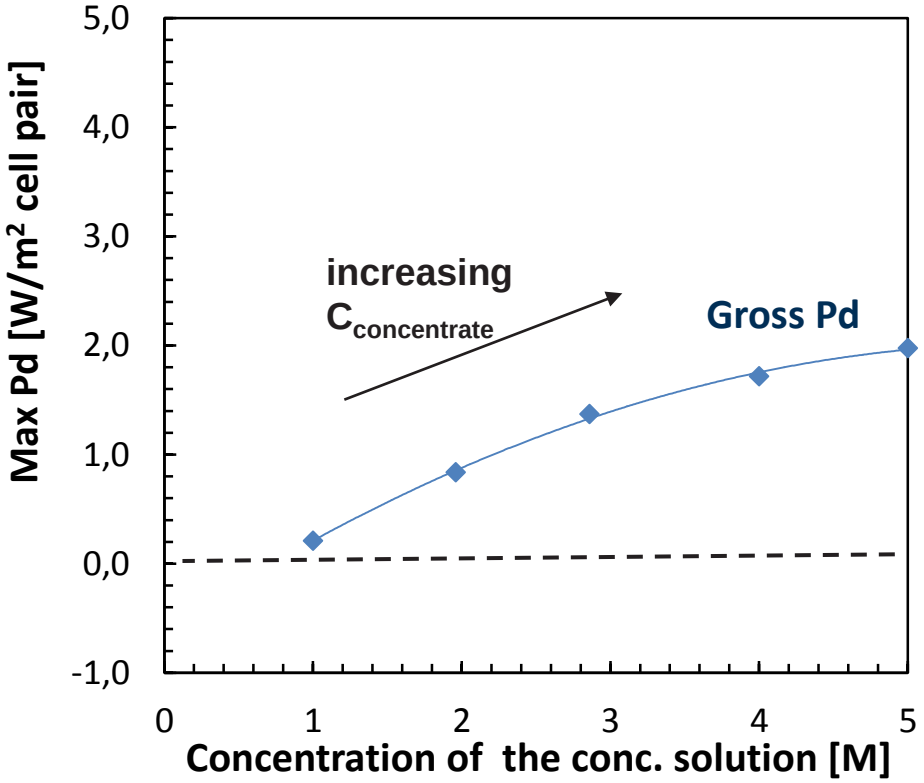
Experimental investigation on a lab-scale unit

e.g. Effect of the conc. of the concentrated solution (1 - 5 M)

Power density vs. current density



Maximum power density vs. C_{conc}

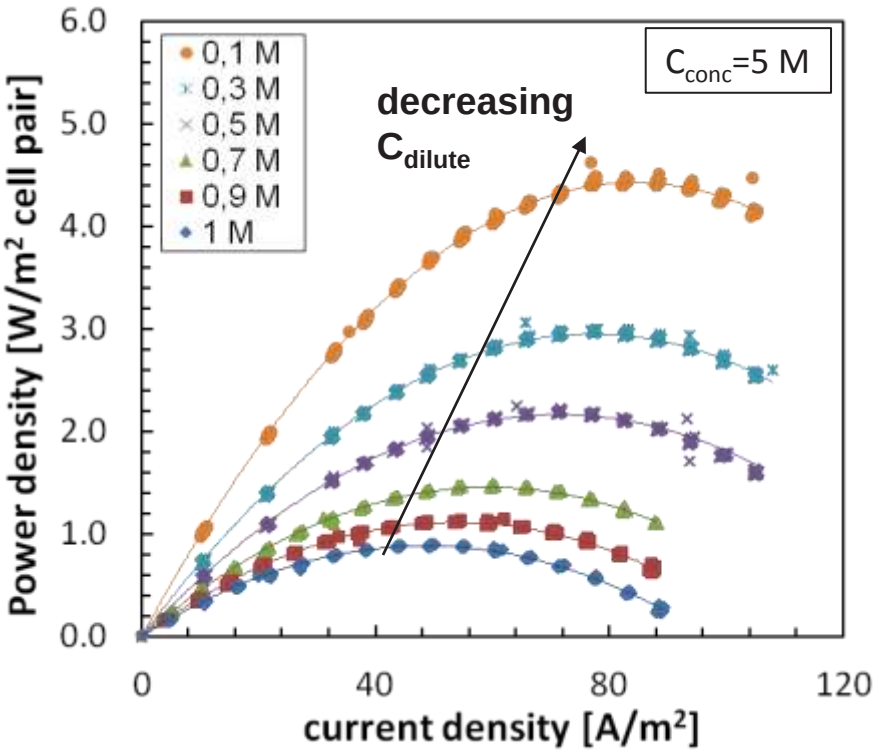


Stack equipped with 50 cell pairs, Fujifilm membranes, Deukum 270 µm spacers . Seawater: 0.55 M NaCl. T=20°C. Fluid velocity: 1 cm/s. Electrode rinse solution: 0.1 M $K_3Fe(CN)_6$ / $K_4Fe(CN)_6 \cdot 3H_2O$ + 2.5 M NaCl.

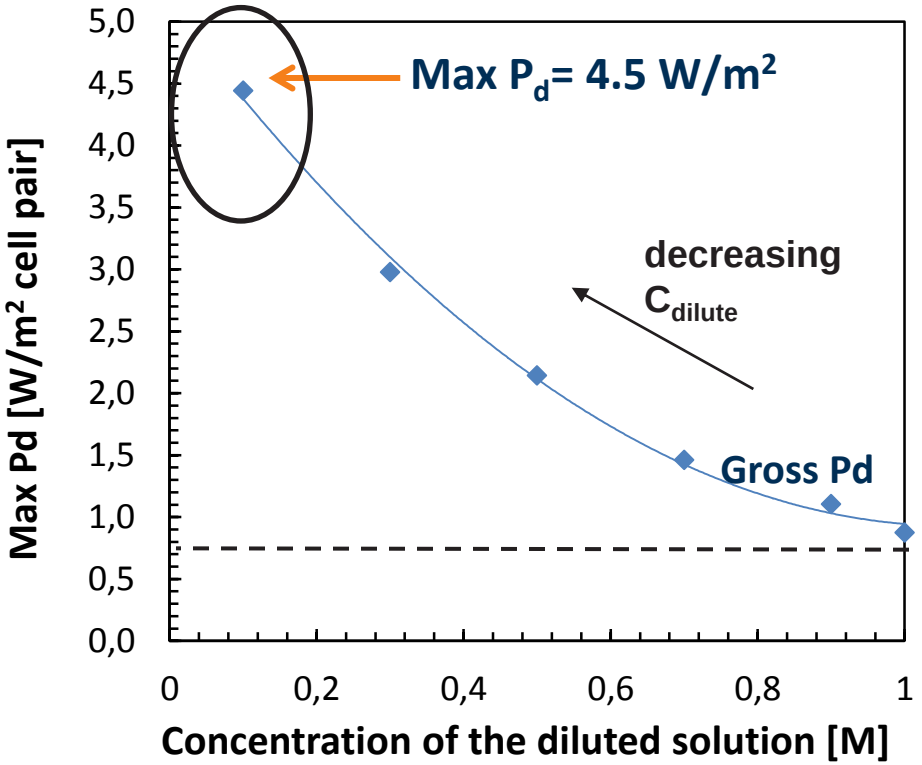
Experimental investigation on a lab-scale unit

e.g. Effect of the concentration of the diluted solution (0.1 - 1 M)

Power density vs. current density



Maximum power density vs. C_{dilute}



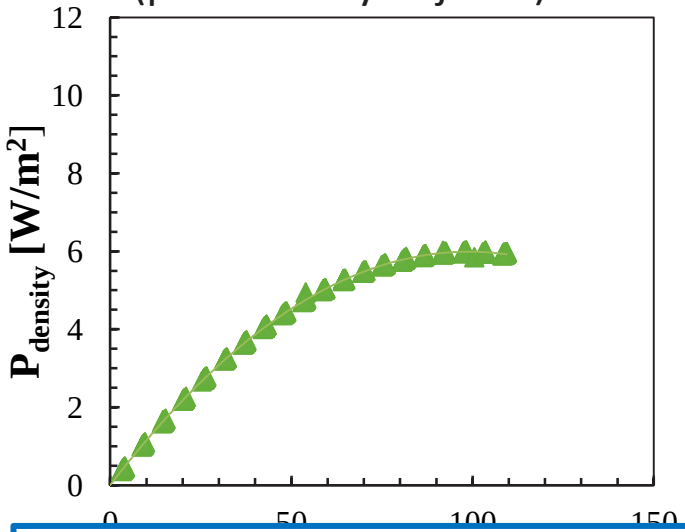
Stack equipped with 50 cell pairs, Fujifilm membranes, Deukum 270 µm spacers . Brine: 5 M NaCl. T=20°C. Fluid velocity: 1 cm/s. Electrode rinse solution: 0.1 M $K_3Fe(CN)_6$ / $K_4Fe(CN)_6 \cdot 3H_2O$ + 2.5 M NaCl.

Experimental investigation on a lab-scale unit

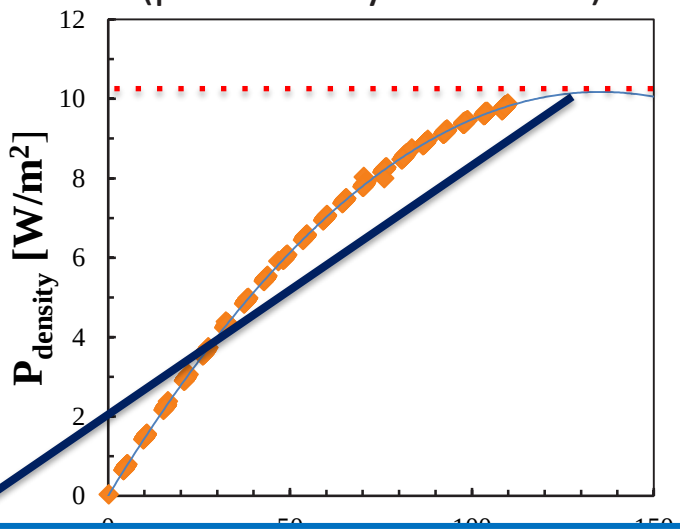
MAX power output conditions: T = 40°C & 0.1M (d) and 5M (c)

➔ Membrane thickness

Thick membranes
(provided by Fujifilm)



Thin membranes
(provided by Fumatech)

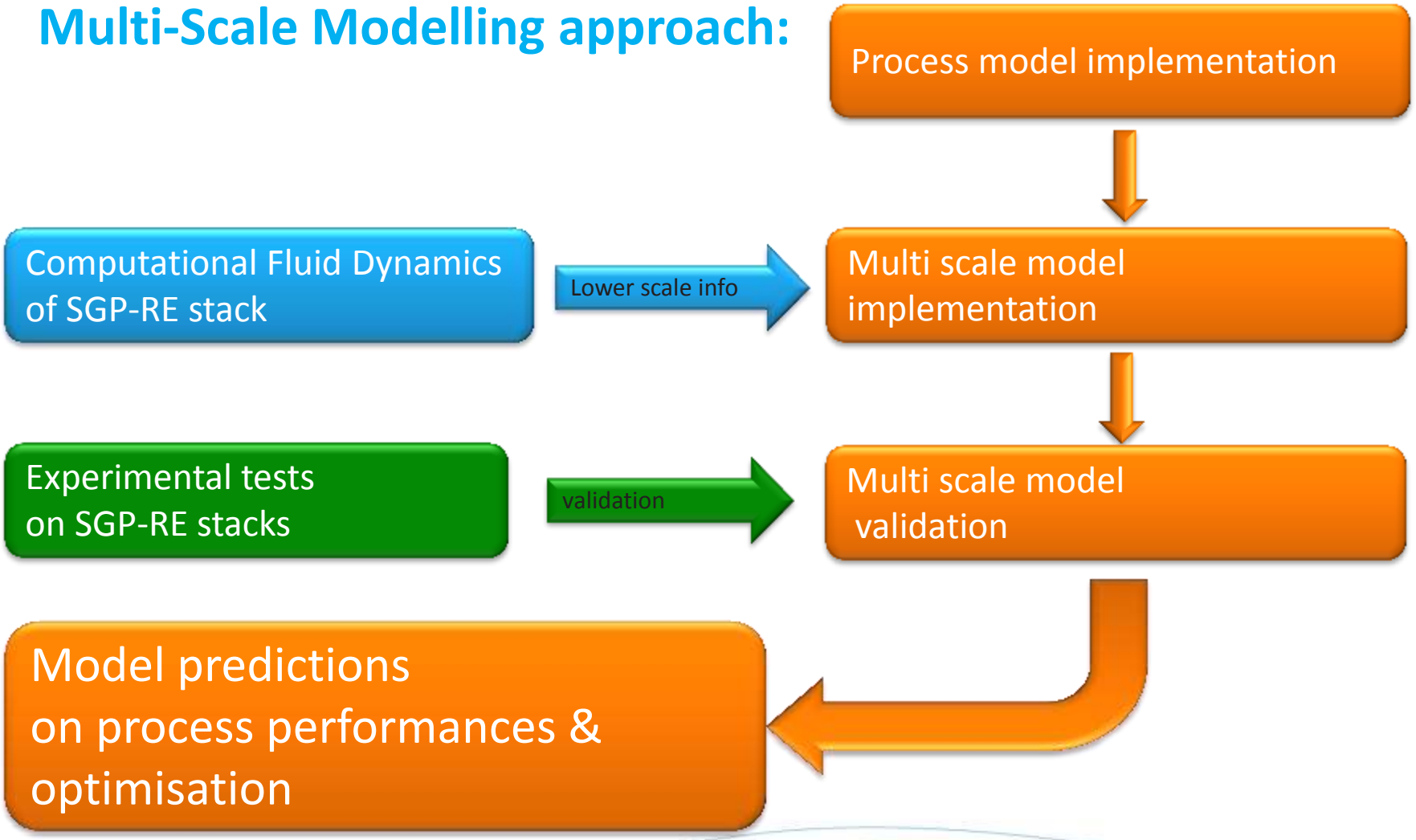


Power density between **15 and 20 W/m²** can be expected with larger number of cell pairs, i.e. reducing the effect of **blank resistance (with model solutes!)**

50 cell pairs; D

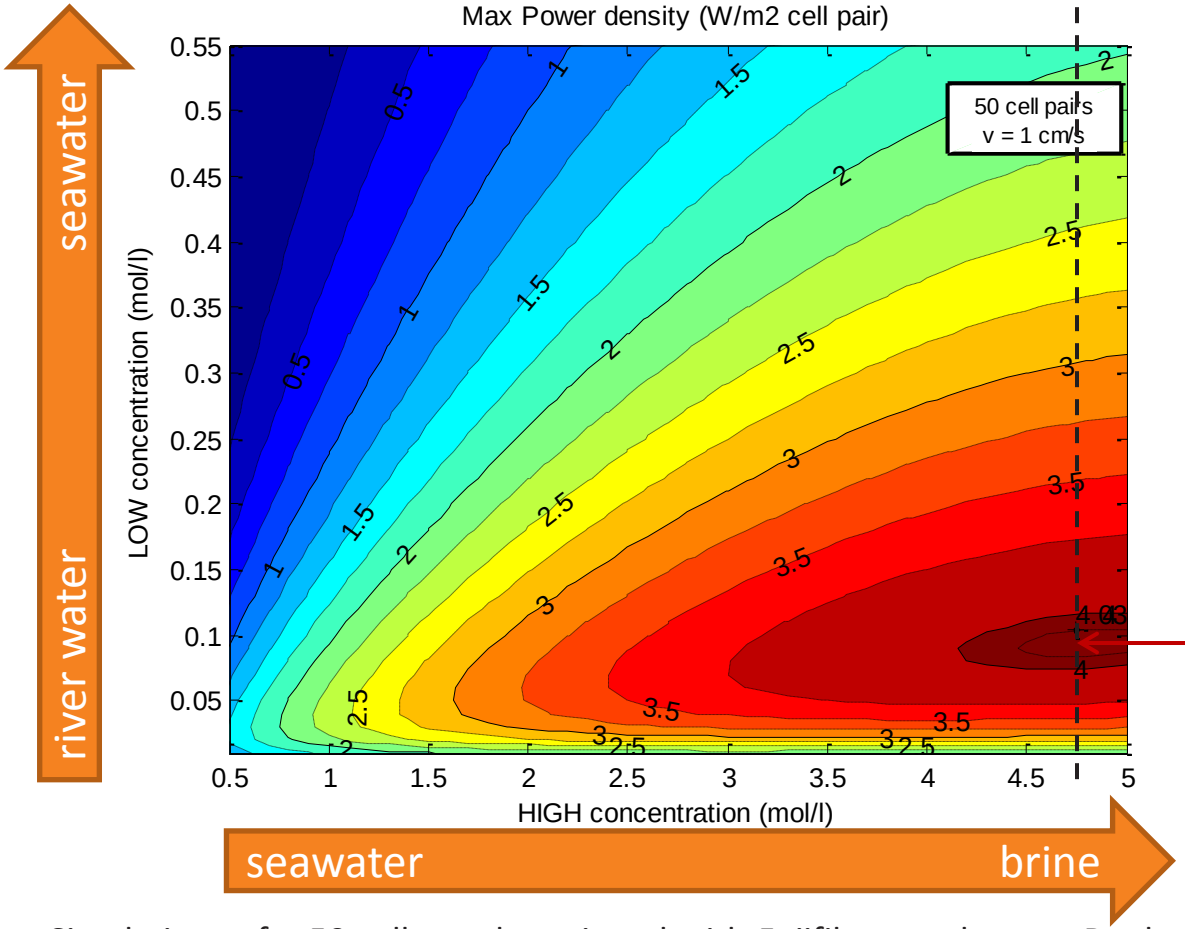
CFD modelling and process simulation

Multi-Scale Modelling approach:

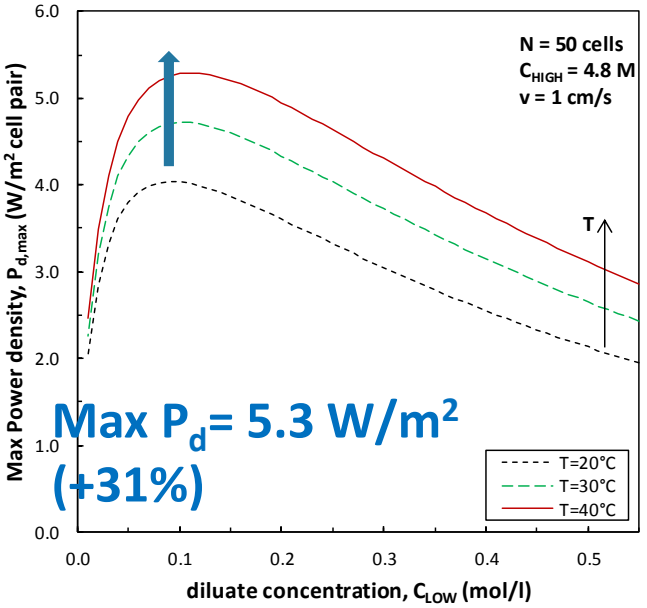


Model used to predict parameter dependences

e.g. Influence of inlet concentrations



Influence of T



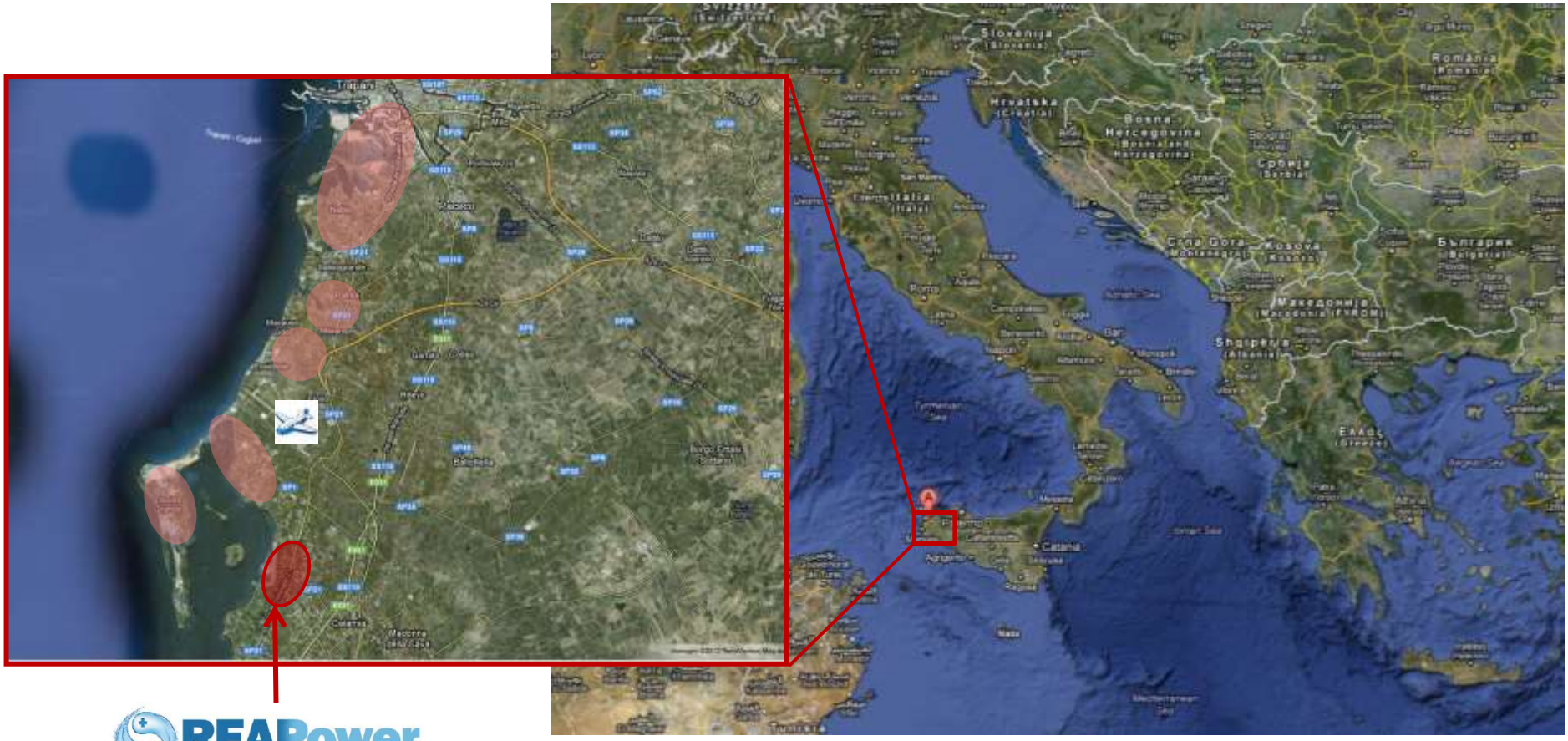
Max P_d= 5.3 W/m²
(+31%)

BEST conditions:
brackish water (0.05 – 0.1 M)
+ brine (4.5 – 5 M)

Simulations of a 50-cells stack equipped with Fujifilm membranes, Deukum spacers; fluid velocity inside channels: 1 cm/s; T=20°C. Blank resistance: 0.4 Ω.

The REAPower prototype installation site

The singular framework of Trapani saltworks



The REAPower prototype installation site

The "*Ettore-Infersa*" saltworks

Direct access to both saturated brine and seawater from open channels

Installation place within an old, restructured WINDMILL

Prototype installation: plant specifications

Site features

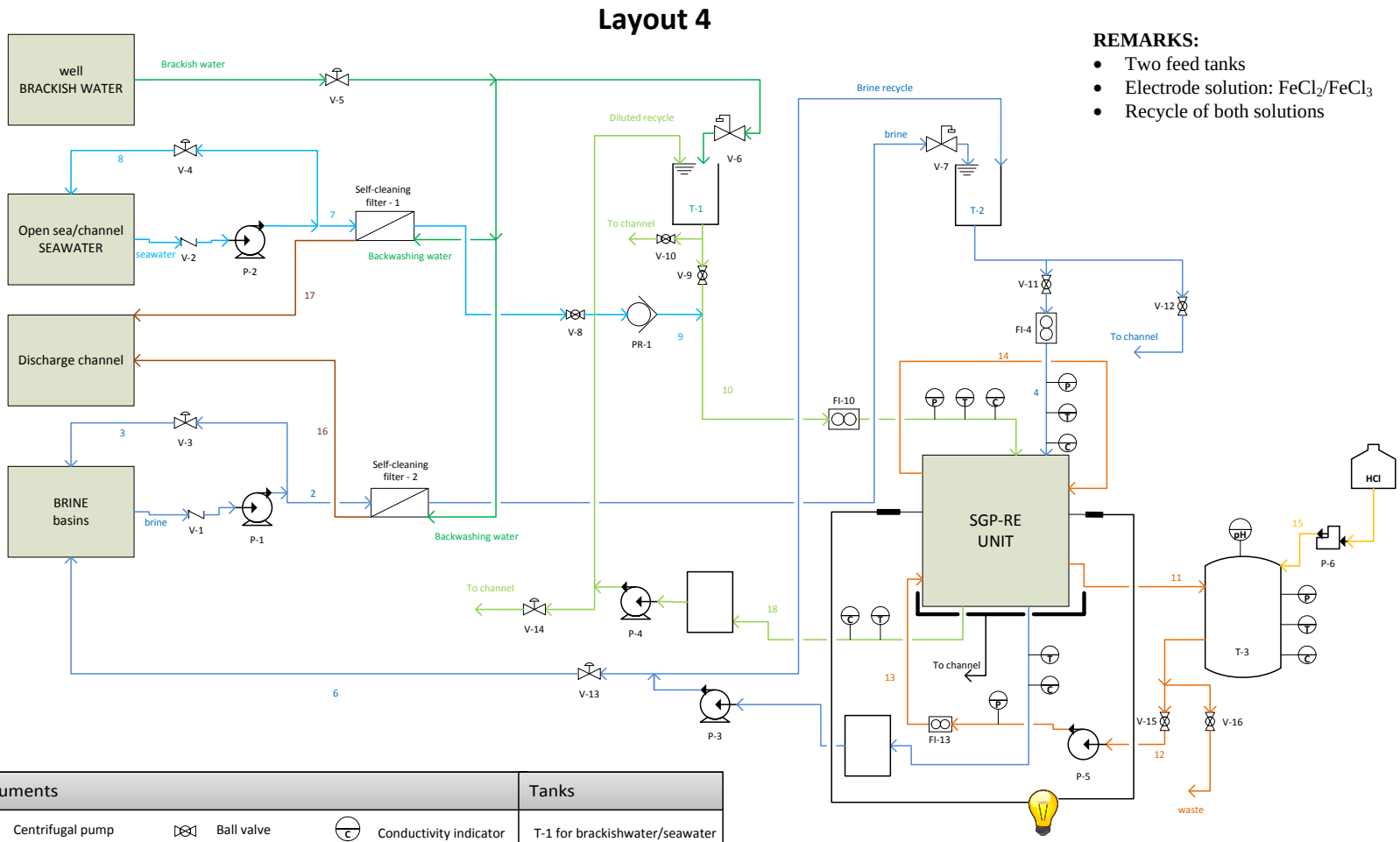
- Seawater availability: unlimited;
- Brine availability: 10-15 m^3/h (much larger with feed-recycle);
- Brine concentration: variable between 250 and 320 gr/lt.

Prototype features

- RED stack dimensions: 44x44 cm
- 500 cell pairs;

➔ *Expected power density: > 5 W/m^2*

Process Flow Diagram & recycle option



Status:

- Optimisation of pilot on-going
- Technico-economical evaluation for different applications on-going

More information:

www.reapower.eu *(Movie shortly available)*