UNIVERSITÀ DEGLI STUDI DI PALERMO

Dipartimento di Ingegneria Chimica, Gestionale, Informatica, Meccanica (DICGIM)

REAPower

Performance analysis of the first Reverse Electrodialysis prototype plant operating with natural brackish water and saltworks brine

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2nd International Conference on Salinity Gradient Energy
Leeuwarden, The Netherlands, 10-12 September 2014

Outline

1. **Introduction**
   - The use of natural solutions for RED process
   - The REAPower prototype plant

2. **Plant design and construction**
   - Process Flow Diagram
   - Piping layout
   - Equipment and Instrumentation
   - Pre-treatment of concentrate and dilute solutions

3. **Installation and start-up**
   - Installation of the first prototype and start-up
   - scale-up

4. **Results and Perspectives**
   - Power measurements with natural solutions
   - Power measurements with artificial solutions

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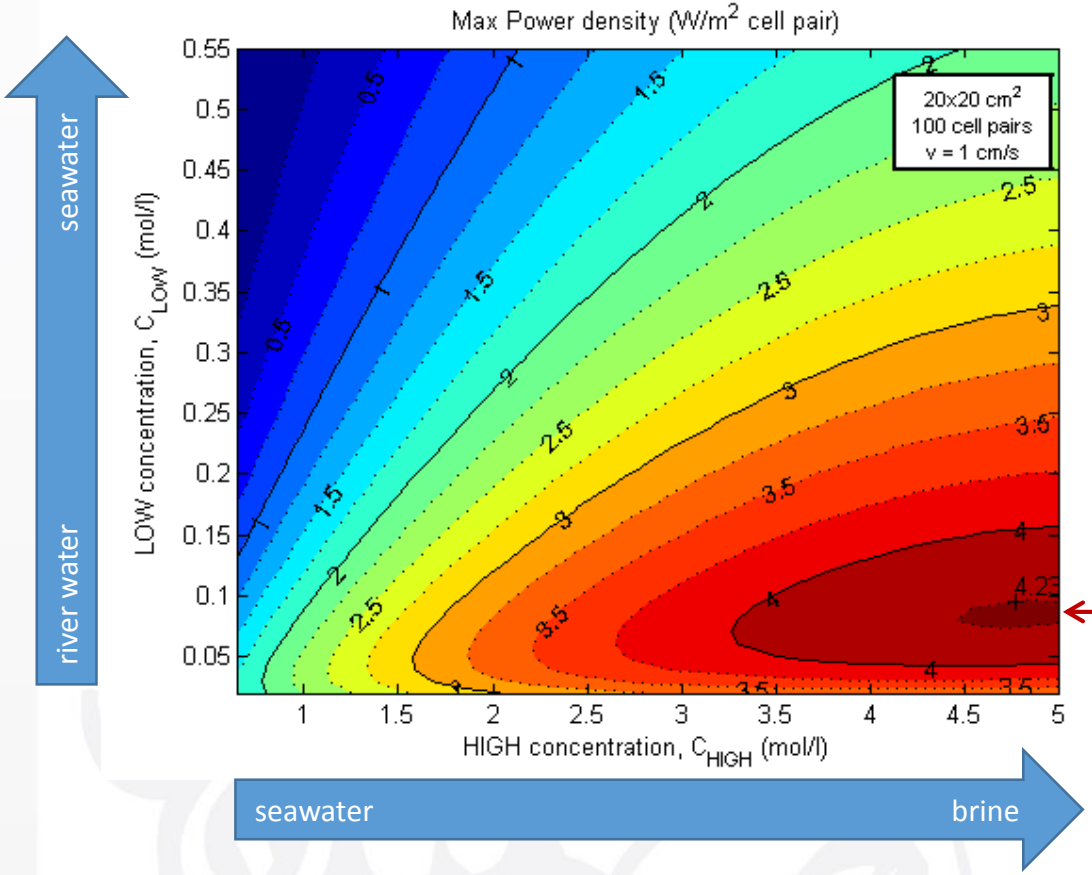
The use of natural solutions for RED process



BEST conditions:
brackish water (0.07 – 0.1 M)
+ brine (4.5 – 5 M)

Simulations of a **20x20 cm²** stack (**100-cells**) equipped with Fujifilm membranes, 270 µm spacers; feed flow velocity: 1 cm/s; T=20°C.

M. Tedesco *et al.* (2014), *Analysis and simulation of scale-up potentials in reverse electrodialysis*, Desalination and Water Treatment, *in press*, DOI: 10.1080/19443994.2014.947781

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The REAPower prototype plant

Facts and figures:

- ✓ **Saline solutions** available on site:
  - saturated brine (conductivity: 200 mS/cm, ≈ 250-300 g/l)
  - brackish water (conductivity: 3.4 mS/cm, ≈2 g/l)
  - seawater
- ✓ High **feed solution temperature** during summer (30°C)
- ✓ Use of **Iron Chloride** ($FeCl_2/FeCl_3$) as electrode rinse solution

Trapani saltworks (Sicily, South of Italy)

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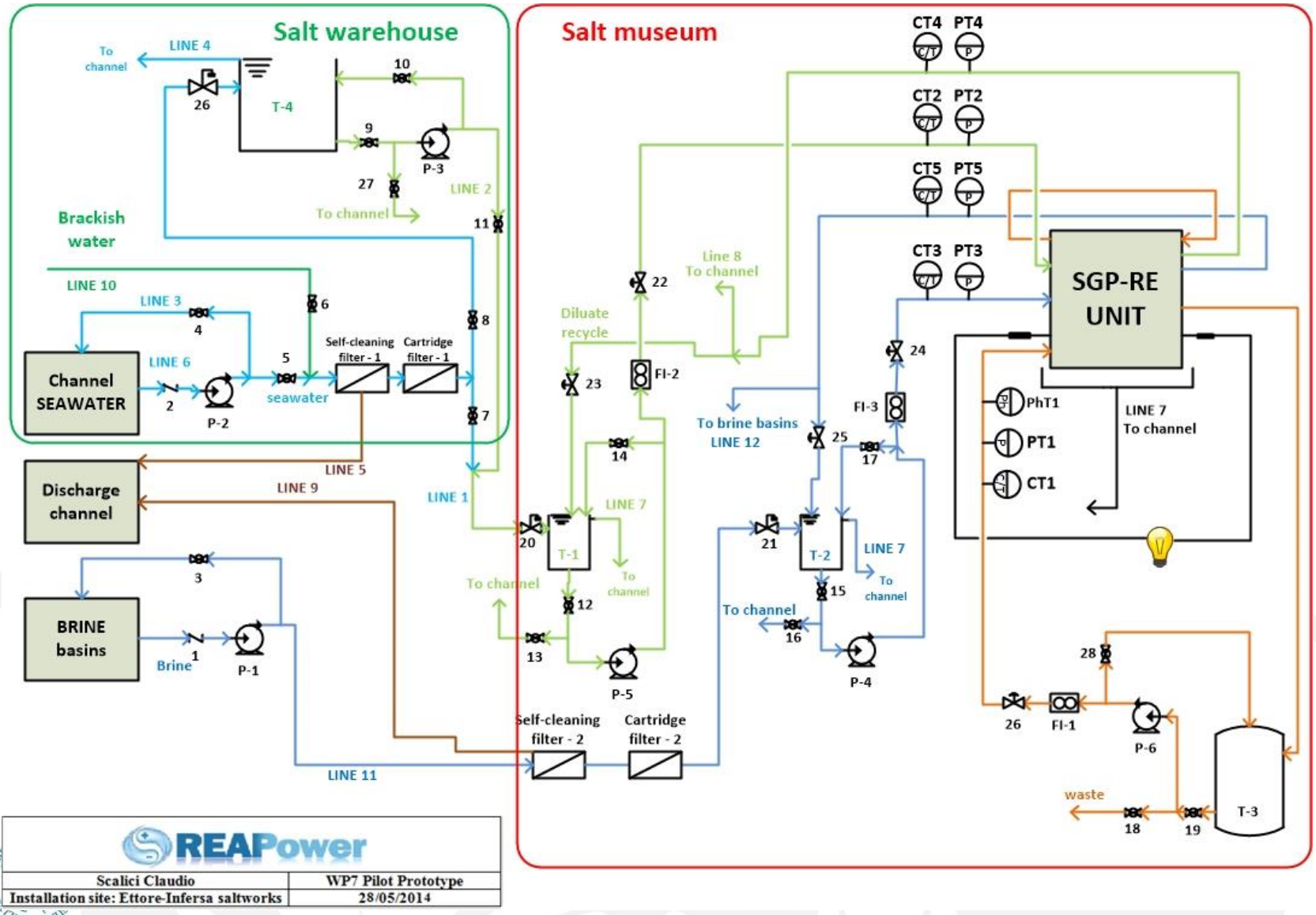
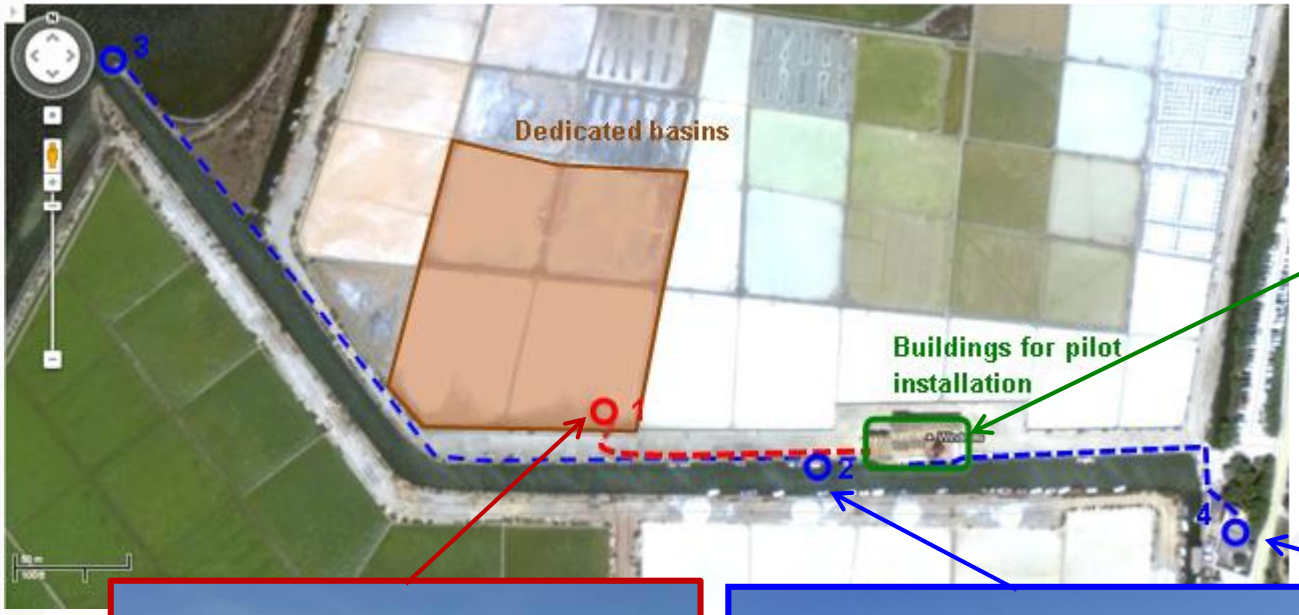
Process flow diagram



REAPower	
Scalici Claudio	WP7 Pilot Prototype
Installation site: Ettore-Infersa saltworks	28/05/2014

Piping layout



Brackish water well

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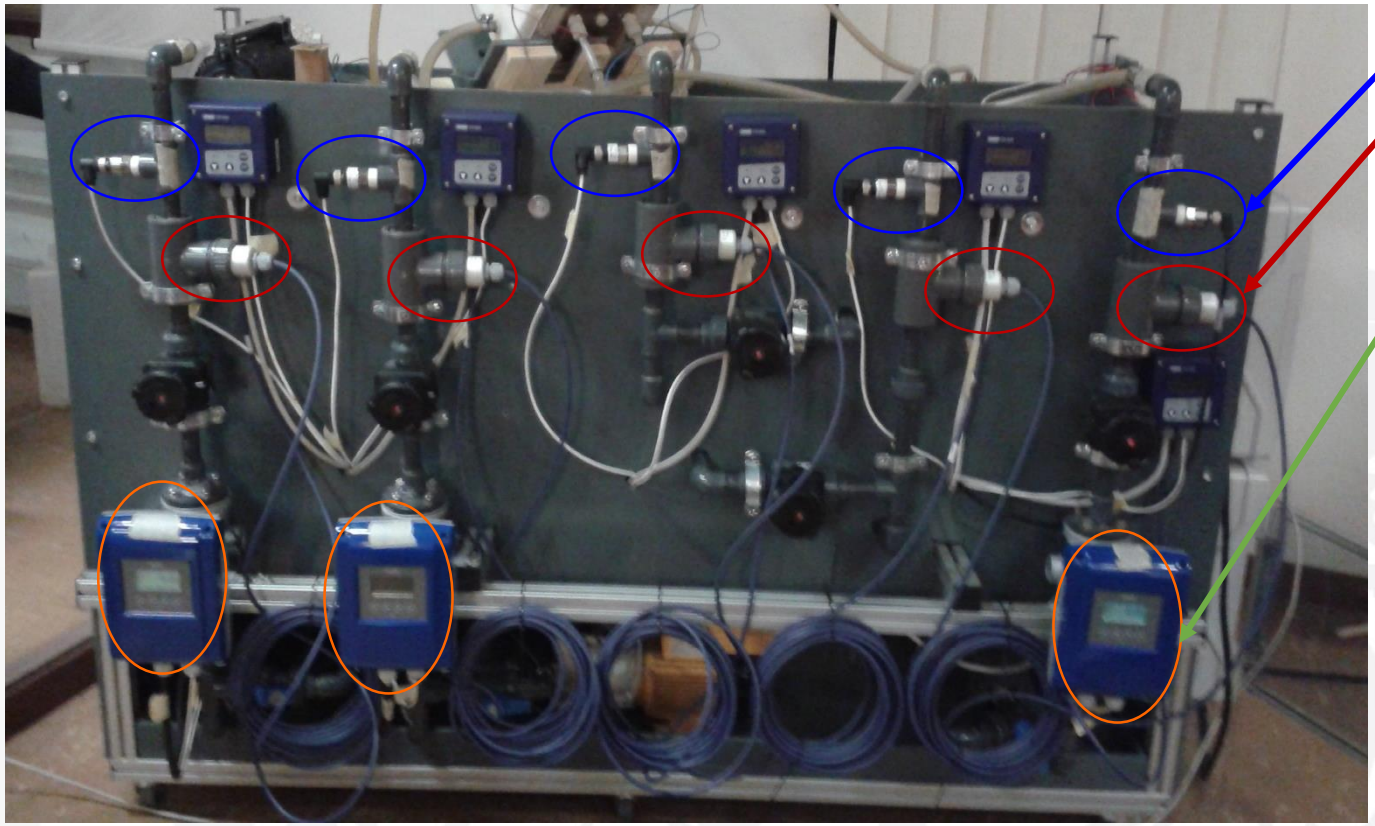
Equipment and Instrumentation

Measuring devices for:

- Pressure
- Conductivity/
  Temperature
- Flow rate



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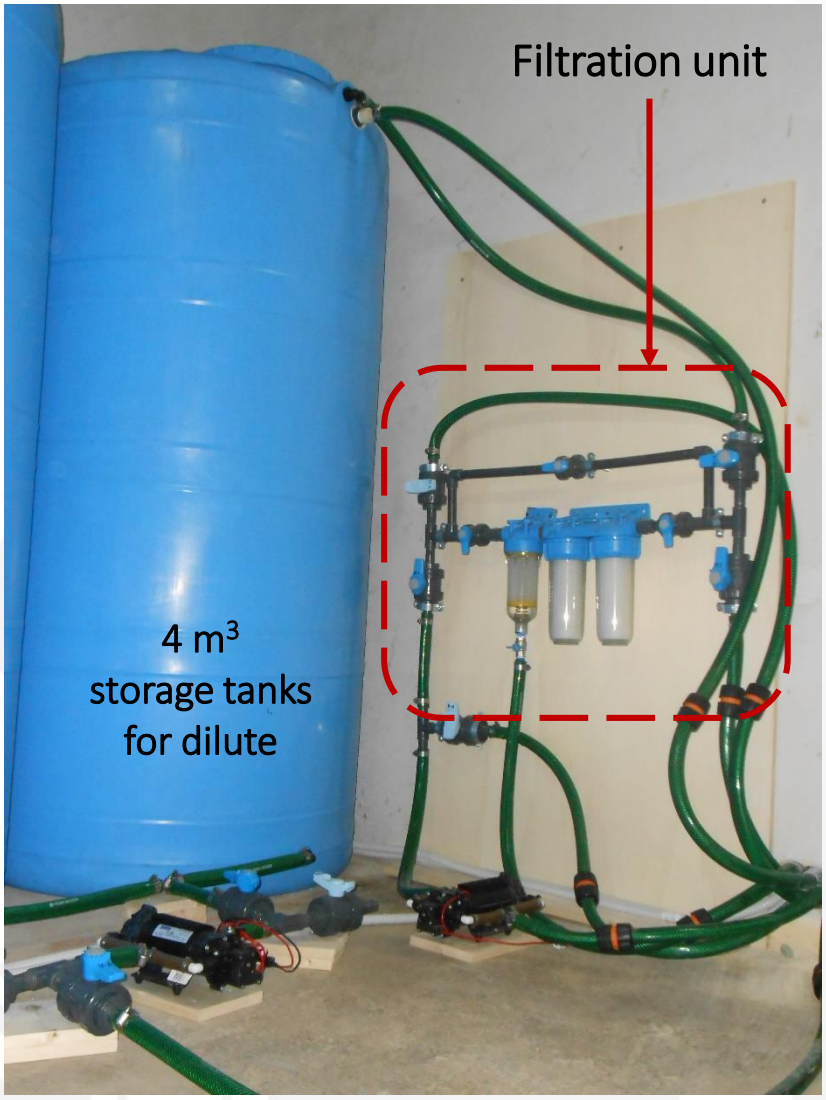
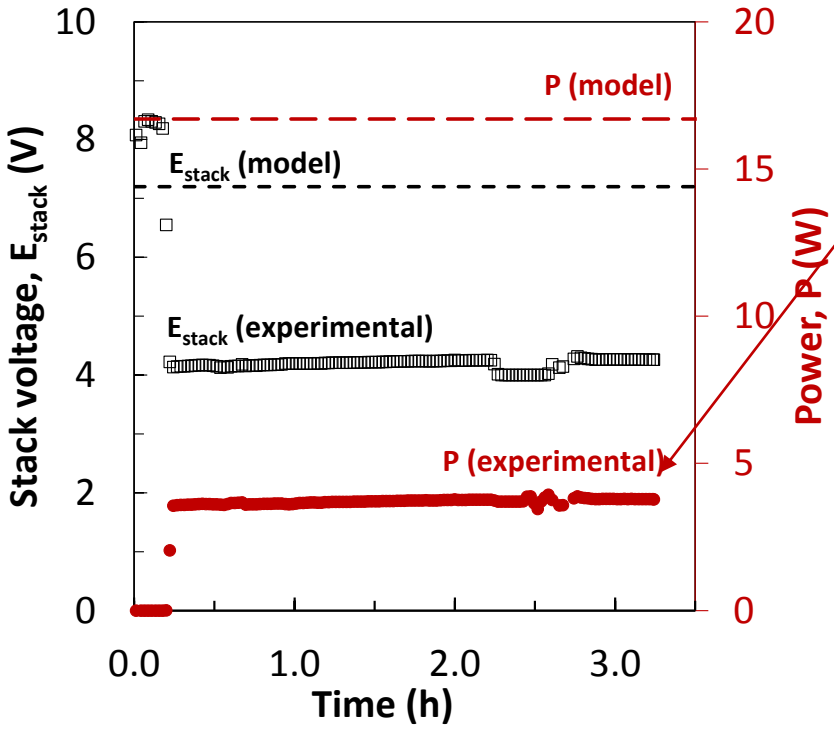
Pre-treatment of concentrate and dilute solutions

SELF-CLEANING FILTER **50 micron** + FILTER **25 micron** + FILTER **5 micron**



Installation of the first prototype and start-up

(22x22 cm^2 stack, 109 cell pairs)



22x22 cm^2 109 cell pairs stack fed with **brackish water (3.4 mS/cm)** and **brine (137 mS/cm)**.
T = 17°C. Flow rate: 6 l/min (1 cm/s).

Low power production due to:

- non-optimal membranes (designed for river water/ seawater)
- diluted brine (≈ 2 M NaCl).

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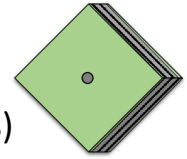
Plant scale-up

REDSTACK FUJIFILM

FEB 2014
- **lab stack**
(22 x 22 cm^2, 109 cell pairs)

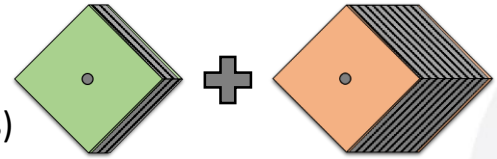
→ **5 m^2** cell pairs area installed

MAR 2014
- **small prototype**
(44 x 44 cm^2, 125 cell pairs)



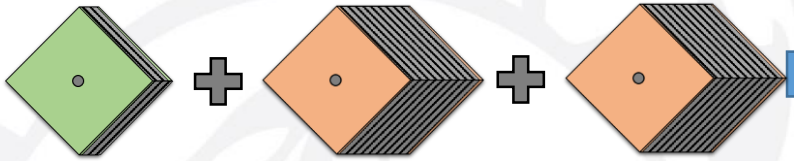
→ **24 m^2** cell pairs area installed

JUL 2014
- **1st large prototype**
(44 x 44 cm^2, 500 cell pairs)



→ **121 m^2** cell pairs area installed

AUG 2014
- **2nd large prototype**
(44 x 44 cm^2, 500 cell pairs)



→ **218 m^2** cell pairs area installed

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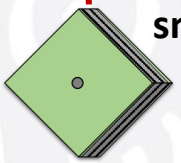
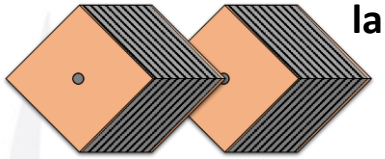
Plant scale-up: final configuration



small prototype
44 x 44 cm^2
125 cell pairs



large prototypes
44 x 44 cm^2
500 cell pairs

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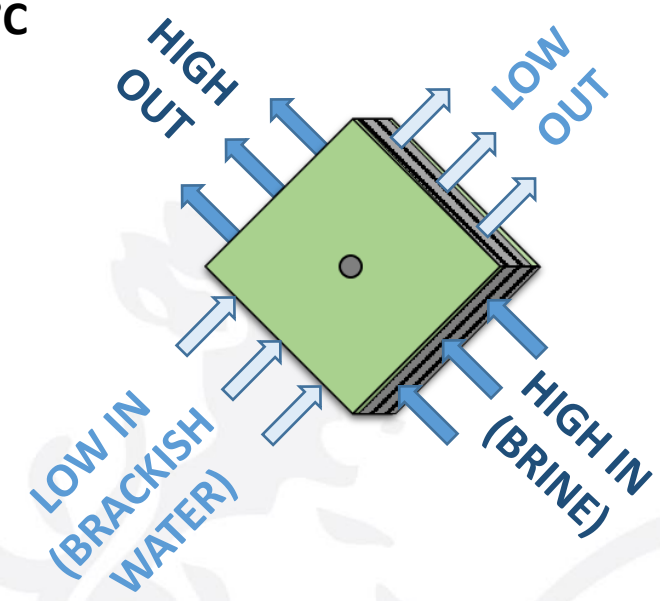
Power measurements with **natural** solutions (1/4)

Standard test conditions (1 cm/s velocity)

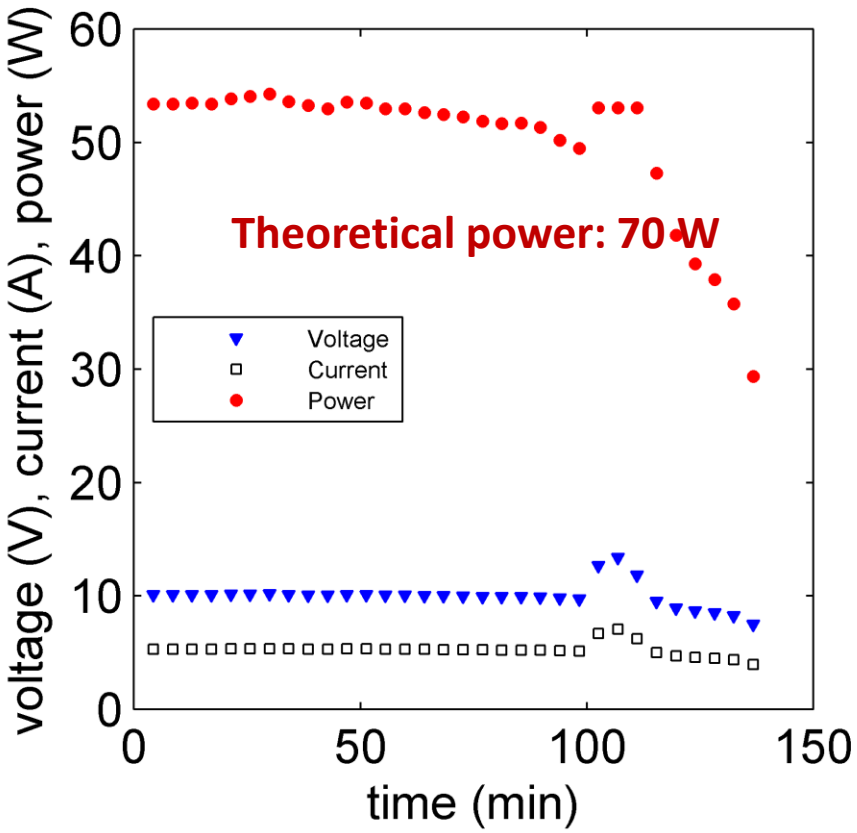
150 mS/cm
26°C

13 mS/cm
29°C



3.4 mS/cm
25°C

200 mS/cm
30°C



44x44 cm^2 125 cell pairs stack fed with brackish water and saturated brine. Feed flow rate: **8 l/min** (1 cm/s). R_{load} = **1.9 ohm**.

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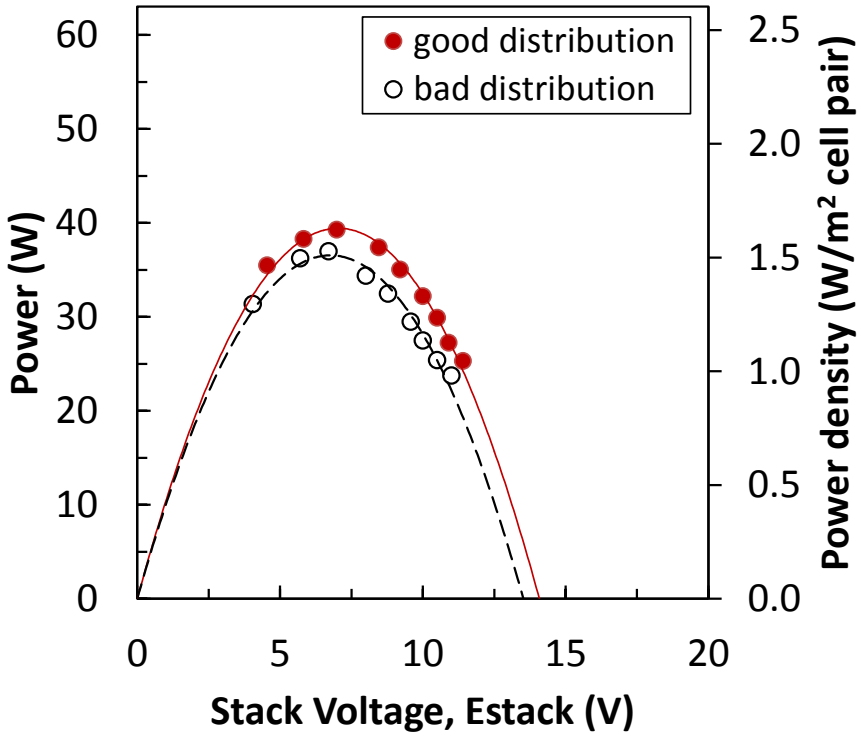
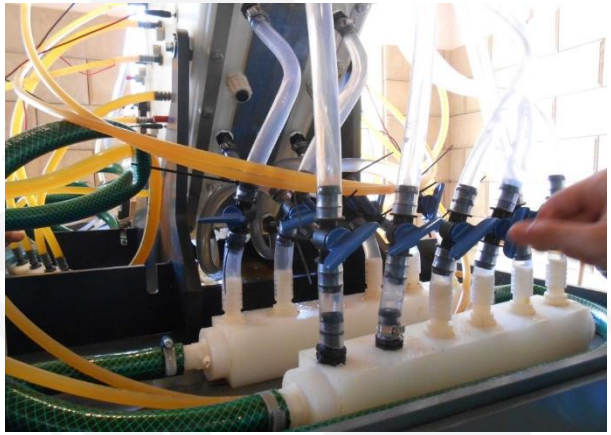
Power measurements with **natural** solutions (2/4)

Influence of flow distribution on power output





First test (○): standard conditions (flow rates: 8 l/min).
Second test (●): improving the flow rate distribution by the inlet-outlet plugs. 44x44 cm^2 125 cell pairs stack fed with brackish water (3.4 mS/cm) and brine (**170 mS/cm**).

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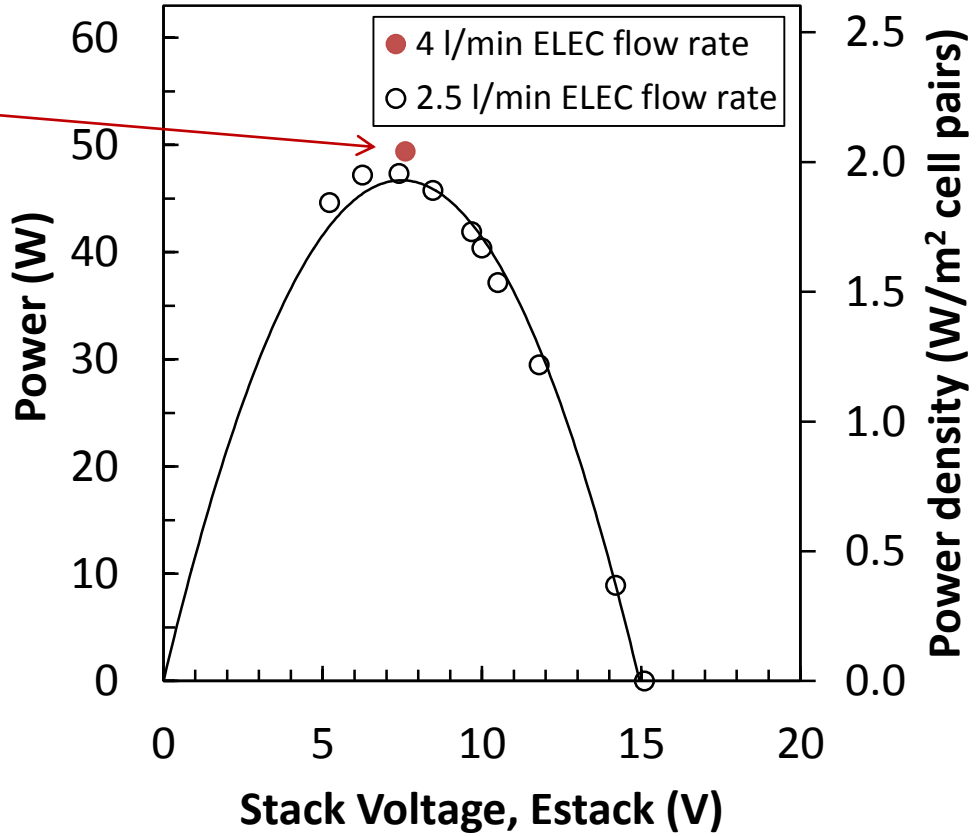
Power measurements with **natural** solutions (3/4)

Influence of electrode solution flow rate

Increasing electrode solution flow rate (4 l/min)



ELECTRODE SOLUTION:

- 0.1 M $FeCl_2$
- 0.1 M $FeCl_3$
- 2.5 M NaCl

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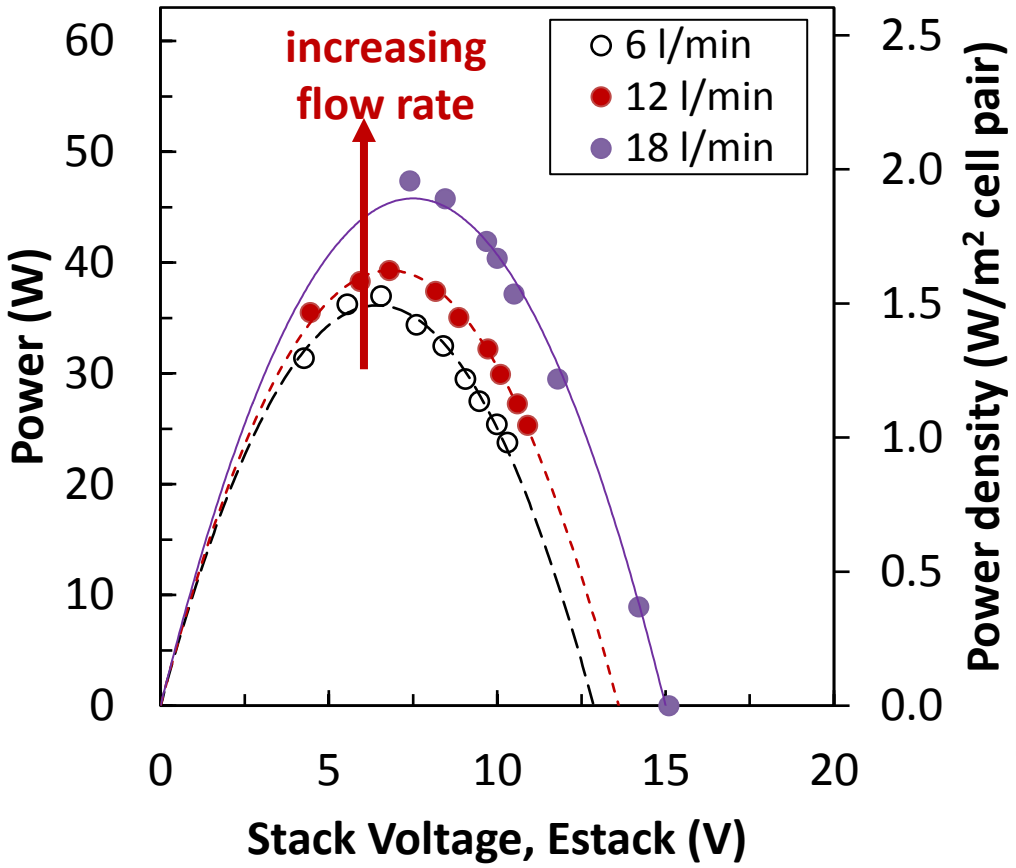
44x44 cm^2 125 cell pairs stack fed with brackish water (3.4 mS/cm) and brine (200 mS/cm).

Power measurements with **natural** solutions (4/4)

Influence of dilute flow rate



44x44 cm^2 125 cell pairs stack fed with brackish water (3.4 mS/cm) and brine (200 mS/cm).

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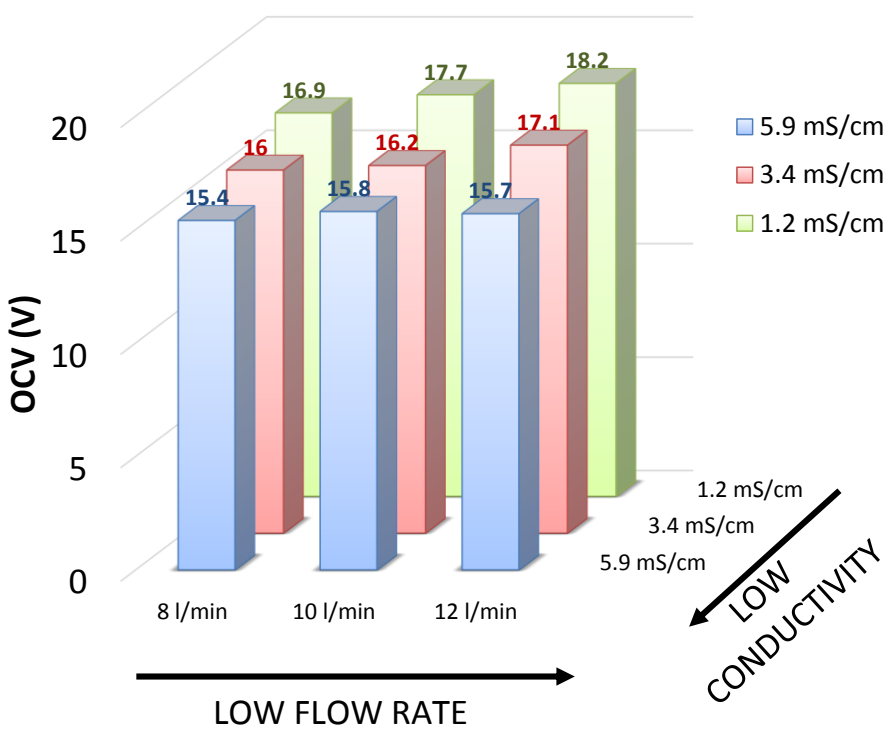
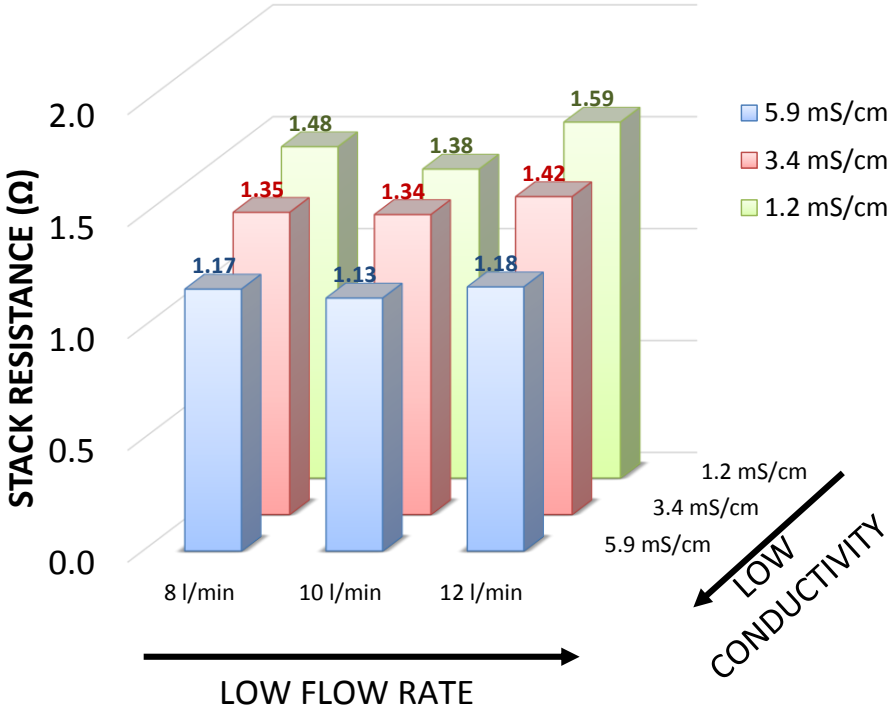
Power measurements with **artificial** solutions (1/3)

Influence of dilute conditions on OCV and stack resistance





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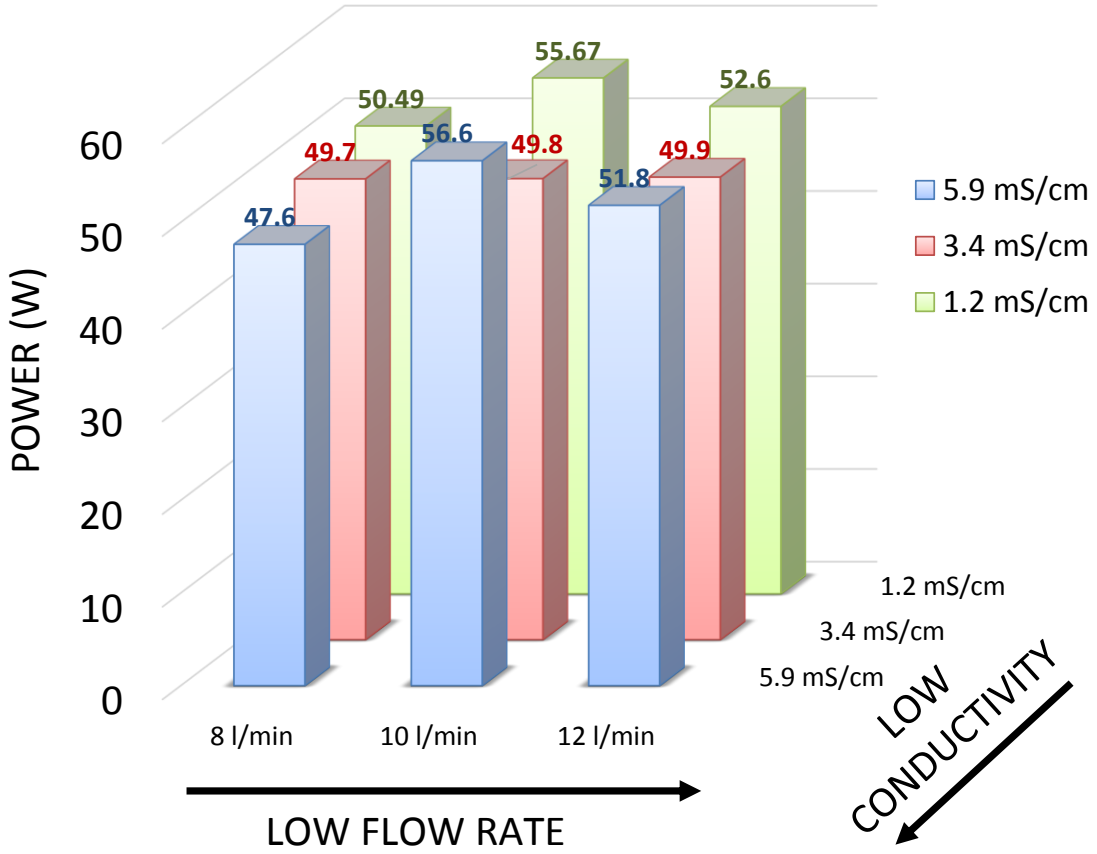
44x44 cm^2 125 cell pairs stack fed with **artificial brine (215 mS/cm)** and **artificial brackish water (1.2 – 5.9 mS/cm)**.

Power measurements with **artificial** solutions (2/3)

Influence of dilute conditions on power output



44x44 cm^2 125 cell pairs stack fed with **artificial brine (215 mS/cm)** and **artificial brackish water (1.2 – 5.9 mS/cm)**.

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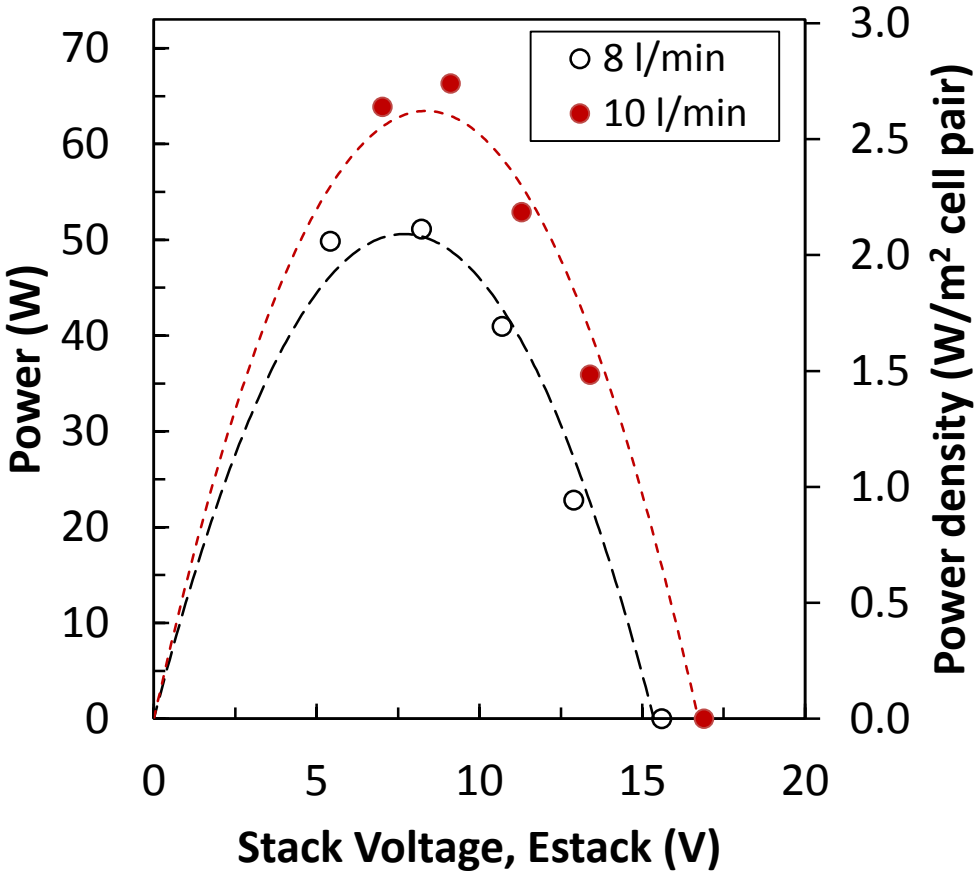
Power measurements with **artificial** solutions (3/3)

Influence of dilute flow rate

artificial solutions
(99.5% NaCl + water)



44x44 cm² 125 cell pairs stack fed with **artificial brine (220 mS/cm)** and **artificial brackish water (1.2 mS/cm)**.

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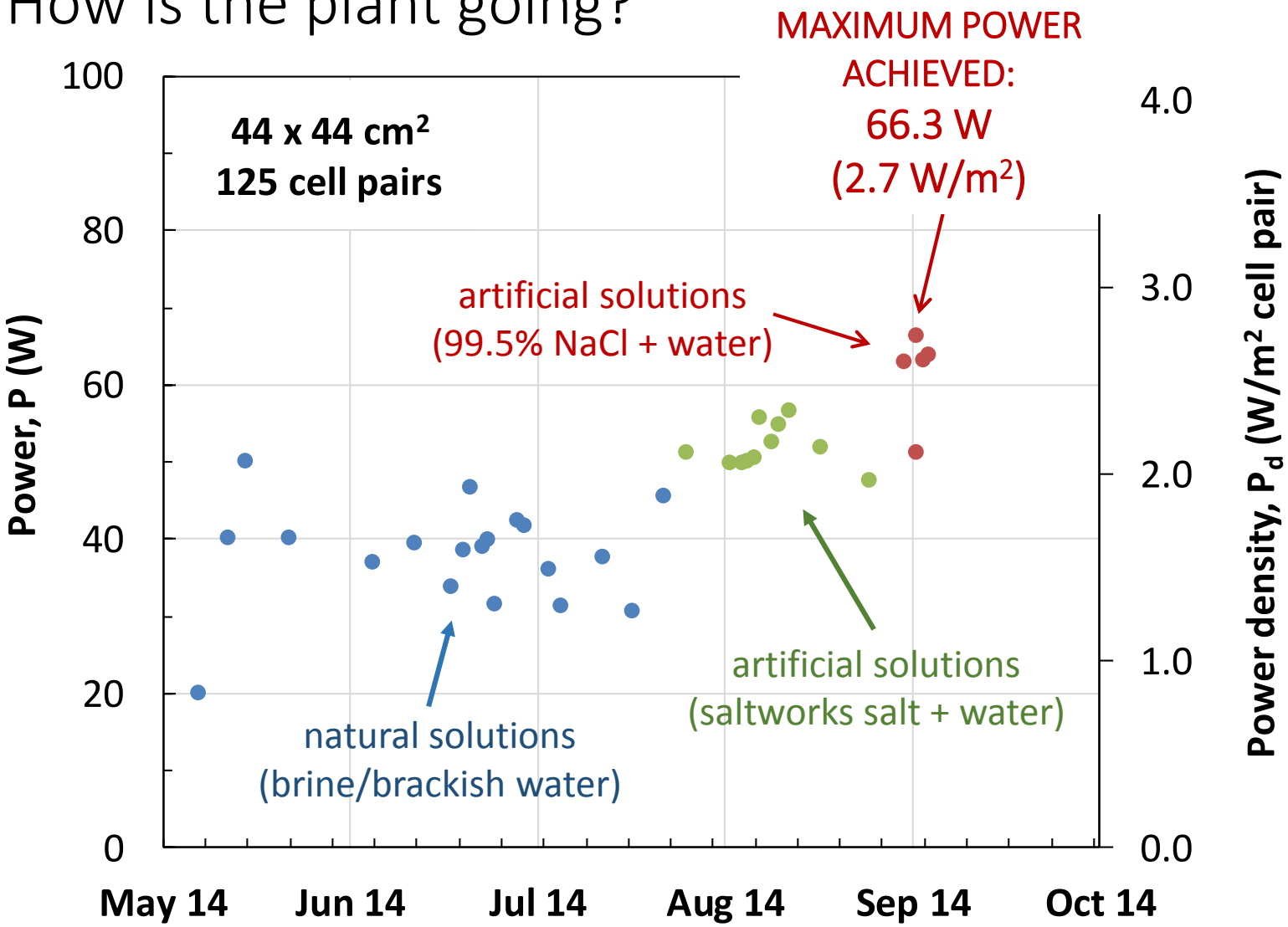
How is the plant going?



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Range of variable conditions: brine conductivity: **137 - 230 mS/cm**, dilute conductivity: **0.7 - 7 mS/cm**, temperature: **25-30°C**, flow rates: **8 – 16 l/min**.

What's next?

- testing with **large prototypes** (44 x 44 cm^2, 500 cell pairs)
- **Performance analysis** of the two large prototypes
- Operation with **full plant capacity** (1 module 125 cell pairs + 2 modules 500 cell pairs) using different **plant layouts** (serial/parallel arrangement)
- Investigating the influence of **natural solutions** on long-term performance

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Conclusions

- ✓ A **RED plant with 3 modules** (218 m^2 total cell pairs area) has been **successfully installed** and is currently **under investigation**
- ✓ **No performance loss** after 4 months testing
- ✓ Main achievements so far:
  - using **natural** solutions: **55 W** power output, **2.3 W/m^2** power density
  - using **artificial** solutions: **66 W** power output, **2.7 W/m^2** power density
- ✓ **300 W** already measured with each large prototype, with further testing ongoing…

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Acknowledgments

Claudio Scalici

Carmelo Cirino

Maurizio Bevacqua

Luigi Gurreri

Davide Vaccari

RED STACK

FUJIFILM

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Thank you
for your attention

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