UNIVERSITÀ DEGLI STUDI DI PALERMO

Facoltà di Ingegneria

Dipartimento di Ingegneria Chimica, Gestionale, Informatica, Meccanica

Integrated cycle for the production of fresh water, minerals and energy

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INTRODUCTION

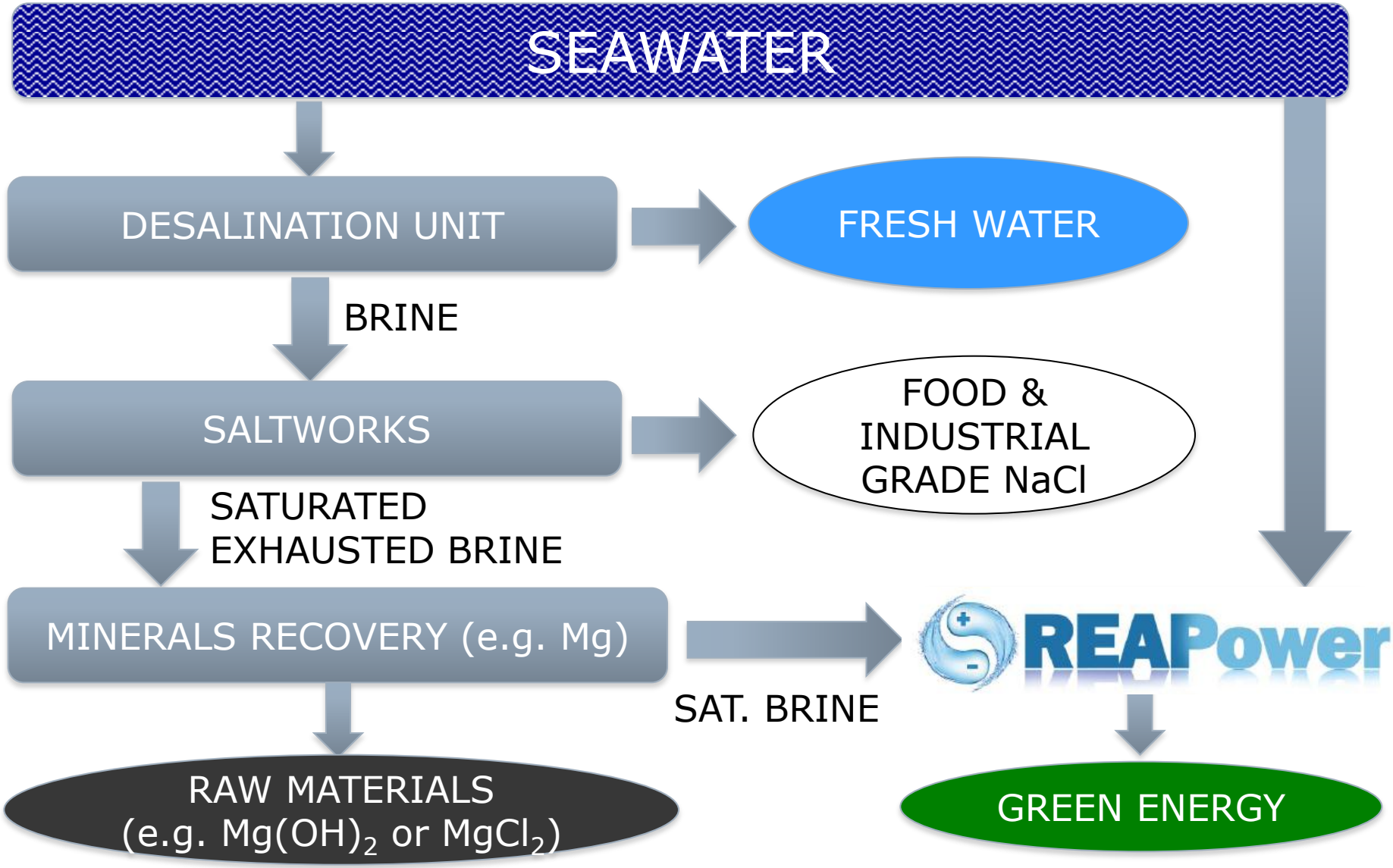
Environmental issues are more and more crucial in the design strategies of new desalination plants.

Two possible alternatives are proposed:

- Novel and low-impact brine disposal strategies to be implemented;

- Re-use and exploitation of brines as a non-conventional source of minerals and energy.

The idea of an integrated cycle



The experience of Trapani site

MED-TVC plant

- In 1995 **4 MED-TVC units** started-up with a nominal production of **9000 m^3/d each**;

- Each unit has got **12 effects** and a Vapor Ejector for the **Thermal Vapor Compression**;

- The first Stage Temperature is around 65° C and the **nominal Performance Ratio** of the unit is up to **16 kg of distillate/kg of vapor**;

MED-TVC plant

Plant operating and performance parameters

Energy consumption		**Brine blow-down parameters**			
Electricity (kWh/m^3)	Vapour (kg/m^3)	Conv. Ratio	**Flow rate (m^3/d)**	**Conc. (gr/lt)**	**Temp. (° C)**
2÷2.5	60÷80 (45bar)	≈30%	**≈80,000**	**≈53**	**≈35-38**

Chemicals used in the plant are:

- **Anti-foam: Nalco (few ppm in the feed);**
- **Anti-scaling: Belgard (few ppm in the feed);**
- **Disinfection: Sodium hypochlorite, produced *in situ* and injected with "shock frequency" (disinfection procedures stopped in the last 2 years)**

Saltworks “Mariastella”

Salt pond

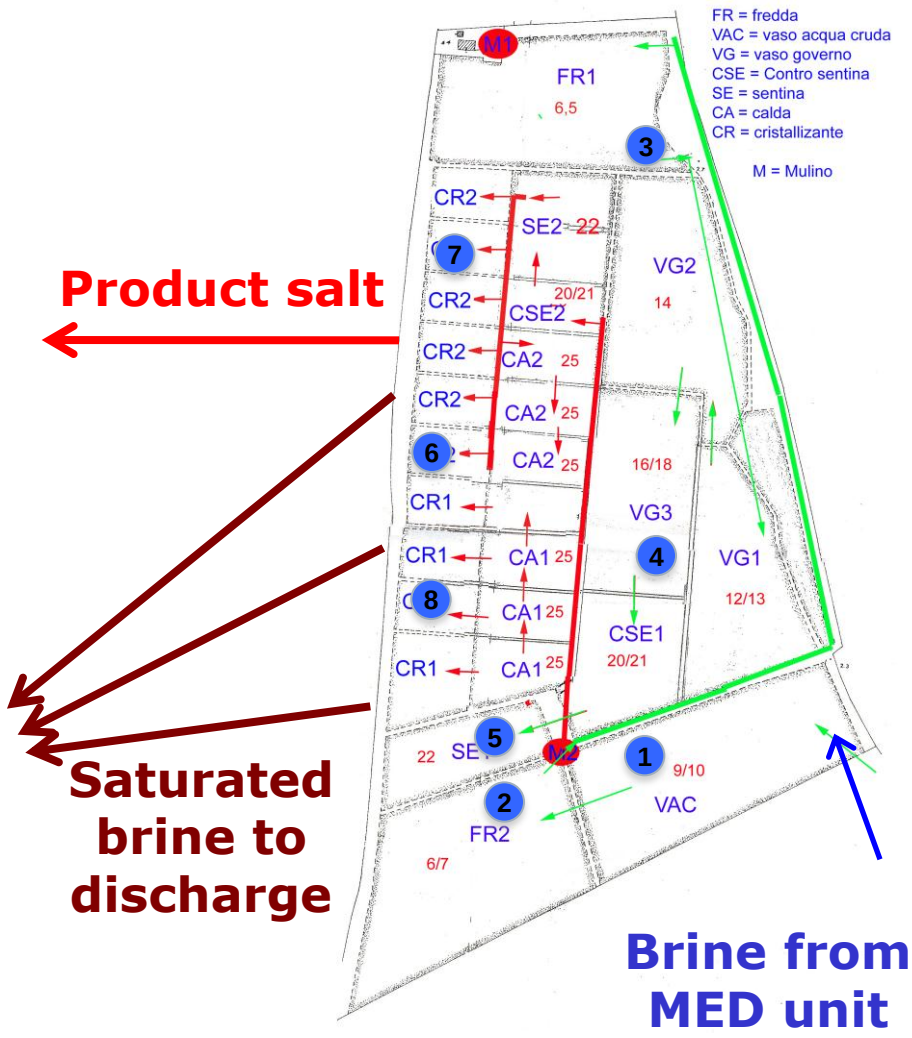
≈ 150,000 m²

MED-TVC plant

Saltworks “Mariastella”

NOVEL EXPERIMENTAL SALTWORKS FLOW CHART (from 2008):

- Brine from the MED unit enters the first pond (VAC) at 5° Be and 35° C;
- It continues evaporating/ concentrating, with a slight variation in the basins sequence;
- NaCl crystallisation stage is anticipated in time and basin sequence;
- A double/triple collection step may be required to avoid crystallisation basins overflow



Saltworks "Mariastella"

BENEFITS OF THE NOVEL SALTWORKS CONFIGURATION:

CONVENTIONAL OPERATIONS:

Production historical data										
Year	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
Prod. (ton)	2370	0	1941	1934	1694	1630	1765	1686	2000	2000

NOVEL CONFIGURATION:
Brine in ≈ 600 m^3/d

2008 ↓ **2900 tonn***

2009-2010 ↓ **???**

2011 ↓ **2500 tonn***

A production increase by 20-30% can be estimated!!!

*An average production increase of 17% was registered in all Trapani saltworks in these years

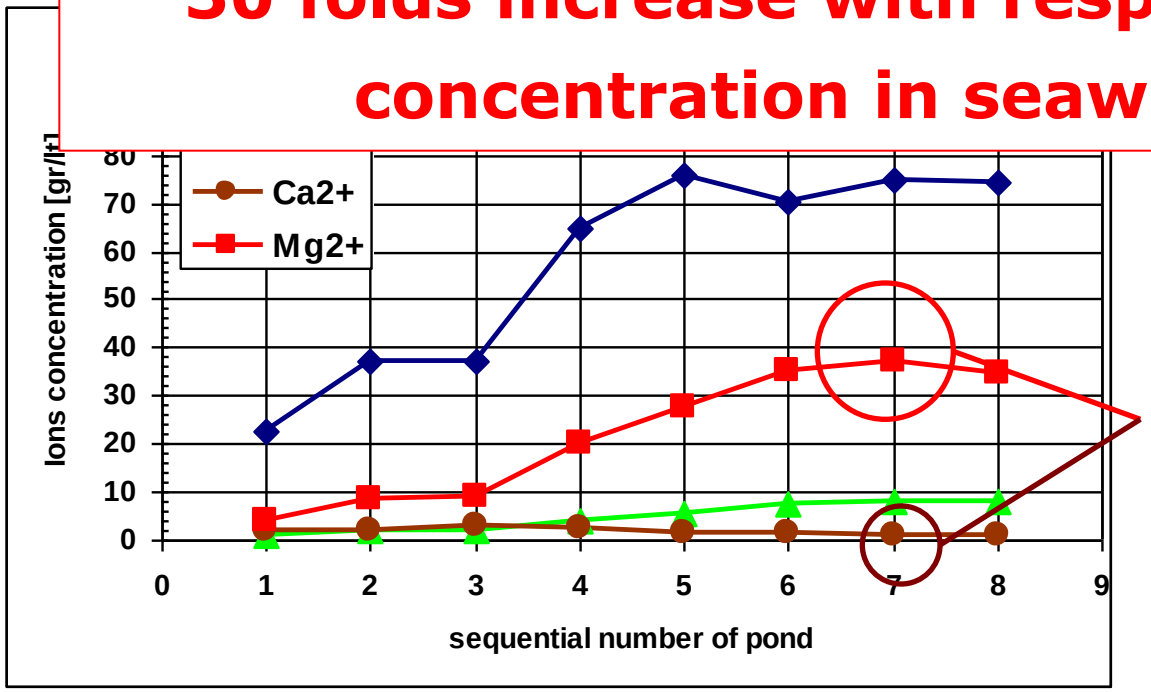
No variation in salt quality has been observed;

Biological life within saltworks basins still continue, not affected by the variation in feed stream

Saltworks "Mariastella"

Ions concentration along the basins of the experimental saltworks (samples collected on the 27th of May 2008)

30 folds increase with respect to Mg concentration in seawater!

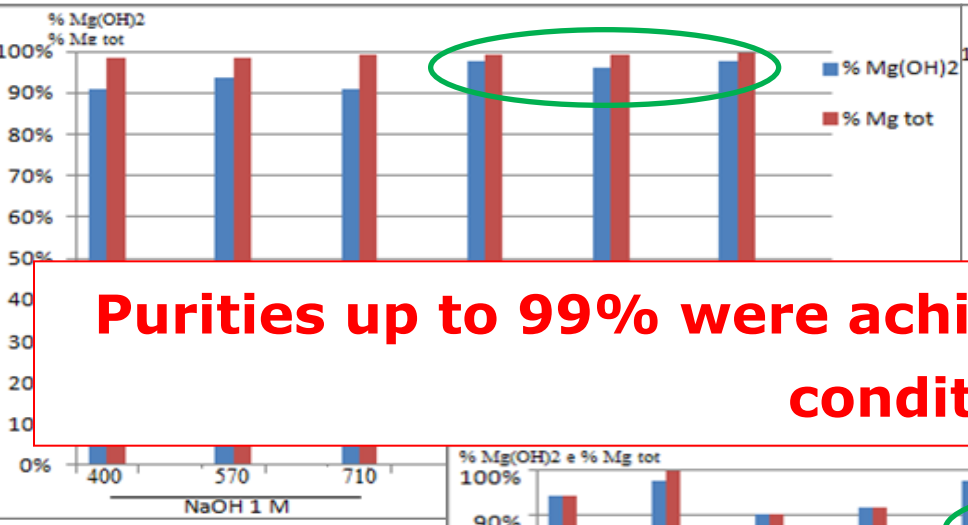


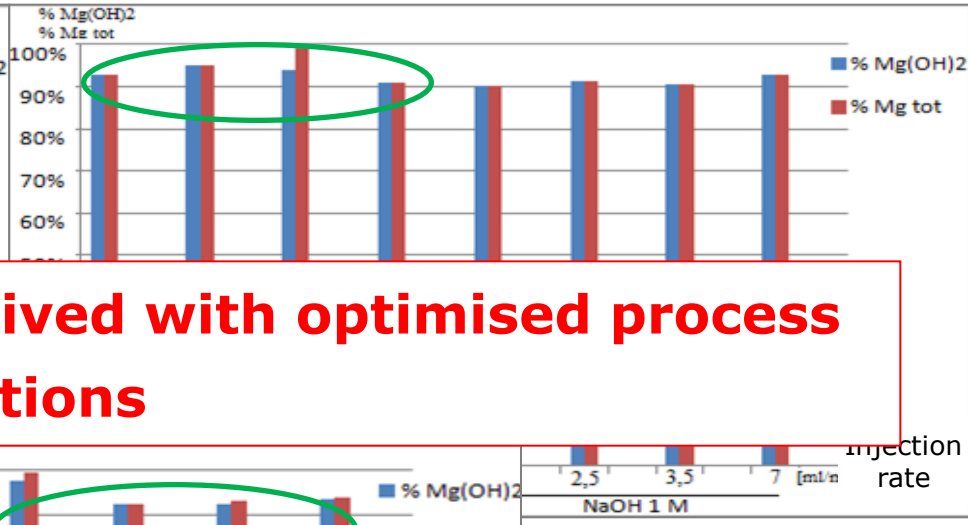
More than **35 gr/lt** of **Mg^{2+}** (free of Ca^{2+}) available for recovery

Mg recovery from exhausted brine

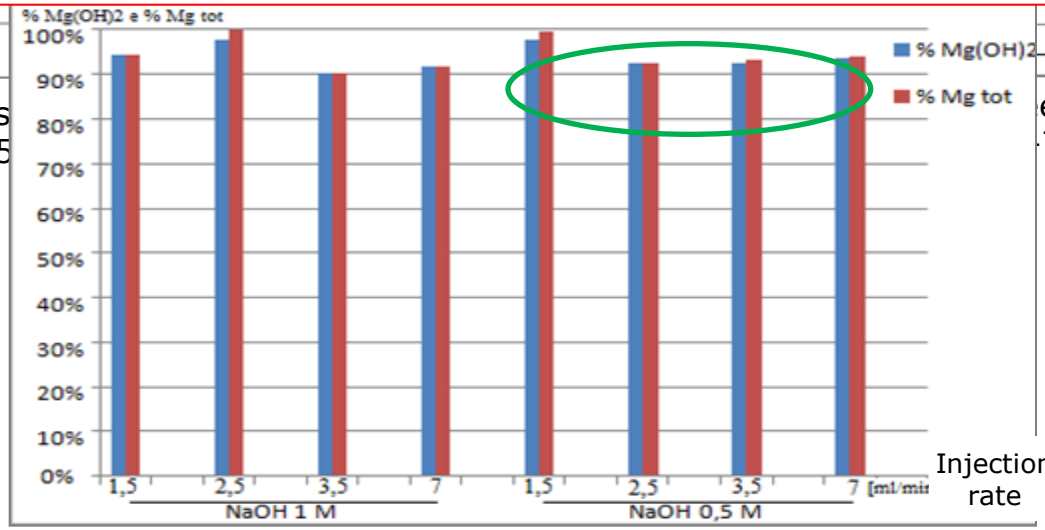
Laboratory tests results: magnesium purities

Purities up to 99% were achived with optimised process conditions





T= 25° C; impeller s … ed: 570 RPM; NaOH NaOH injection rate: 3,5 … 7 ml/min



T= 40° C; impeller speed: 570 RPM; NaOH injection rate: 1,5-2,5-3,5-7 ml/min

Mg recovery from exhausted brine

Laboratory tests results: precipitation efficiency

In all tests the efficiency of Mg removal has been between 99 and 100%

Ca^{2+}- & Mg^{2+}-free brine is obtained, perfectly suitable for feeding a Salinity Gradient Power - Reverse Electrodialysis (SGP-RE) unit

REAPower

Final considerations on the Mg production potential

MAGNESIUM: ESTIMATED PRIMARY WORLD PRODUCTION, BY COUNTRY

(Metric tons)

Country	2005	2006	2007	2008	2009
Brazil	6,000	6,000	18,000	15,000	16,000
Canada	50,000	65,000	16,300	2,000	--
China	470,000	520,000	625,000	559,000	501,000
Israel	27,853	24,581	29,618	32,051	29,000
Kazakhstan	20,000	21,000	21,000	21,000	21,000
Russia	45,000	35,000	37,000	37,000	37,000
Serbia	1,500	1,500	2,000	1,500	1,500
Ukraine	2,000	2,200	2,500	2,000	2,000
United States	W	W	W	W	W
Total	622,000	675,000	751,000	670,000	608,000

Main world producers of ***metallic Magnesium***

www.indexmundi.com/en/commodities/minerals/magnesium/magnesium_t8.html

Salt production capacity in Trapani ~ 90000 ton/year → with ~ 360000 m^3/year of exhaust brine

Assuming a Mg^{2+} concentration in brines ~ 30 g/l and a 100% Mg recovery: total $Mg(OH)_2$ production potential is:

→ 27000 ton/year **$Mg(OH)_2$**

or 10800 ton/year **metallic Mg**

~2% of world production

~30% Russian production

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REAPower

The REAPower project: power production by Reverse Electrodialysis with seawater and brines

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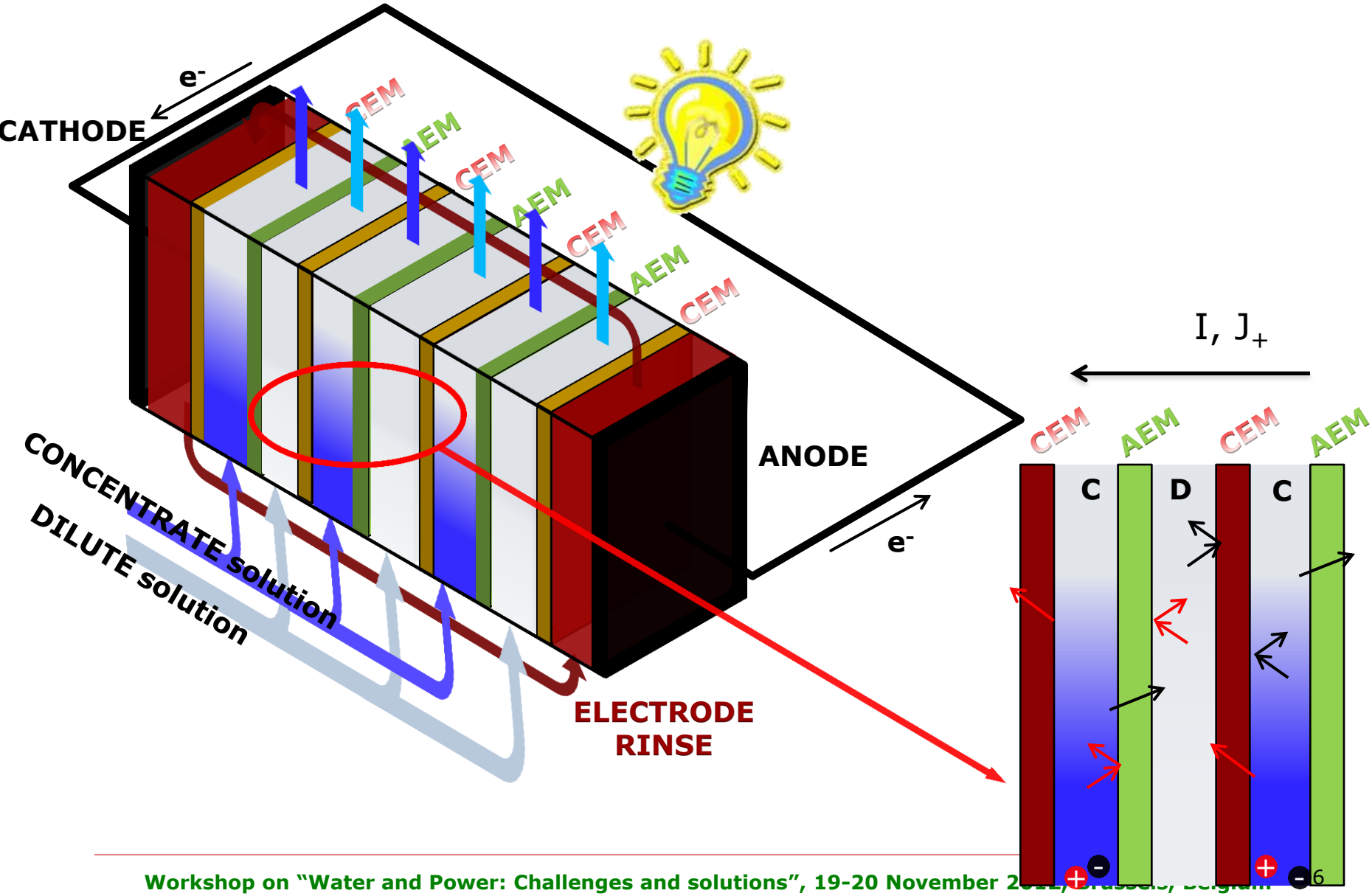
The REAPower project

Main facts

- Project acronym: ***Reverse Electrodialysis for Alternative Power production***
- Cooperative project financed through the FP7 programme
- *Starting date:* 1 October 2010
- *Closing date:* 30 September 2014

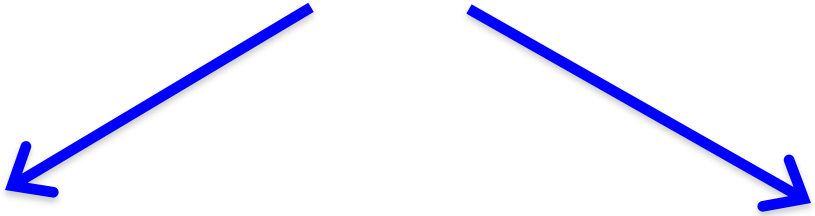
The Reverse Electrodialysis technology



The REAPower project

The idea . . .

To produce energy from salinity gradients generated by ultra-concentrated brines and sea- or brackish-water



Technological benefits for the SGP-RE process

New potentials for the exploitation of brines

The REAPower project

Technological basic concepts . . .

i) Seawater (≈30-35 g/lt) in the LOW conc. compartment and concentrated brine (≈ 300 g/lt) in the HIGH conc. compartment dramatically reduce the electrical resistance in all battery compartments

ii) As a result: an ultra-low overall internal resistance within the SGP-RE battery cell-pairs can be achieved . . . especially with the introduction of thinner membranes

iii) Thus, the ultra-low internal resistance will significantly promote a higher power density of the SGP-RE battery.

The REAPower project

Technological barriers . . .

Effect of salinity on permselectivity	Solution strategy	Improve IEMs formulation/preparation
High fouling and scaling potentials	Solution strategy	Adequate pre-treatments for seawater and brine
Still low power density	Solution strategy	Thin IEMs & Membrane Integrated Spacer
Limited quantity of brine	Solution strategy	Increase "fuel efficiency" and regeneration strategies

Which brines for the SGP-RE process?

Environmental issues related to brine discharge have become more and more crucial in a number of different situations such as:

Desalination plants

Mining activities

Salt industry

Solutions so far proposed can be:

- Novel and low-impact brine disposal strategies to be implemented;
- Re-use and exploitation of brines as a non-conventional source of minerals and energy.

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Which brines for the SGP-RE process?

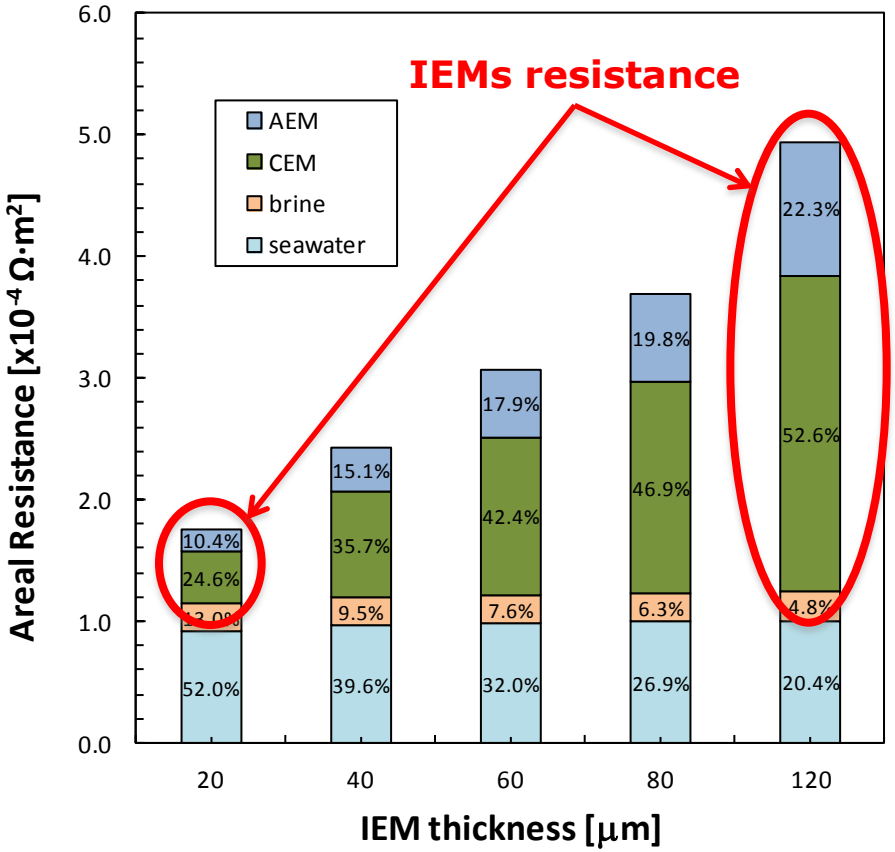
Prototype installation site: Trapani saltworks (Sicily, Italy)

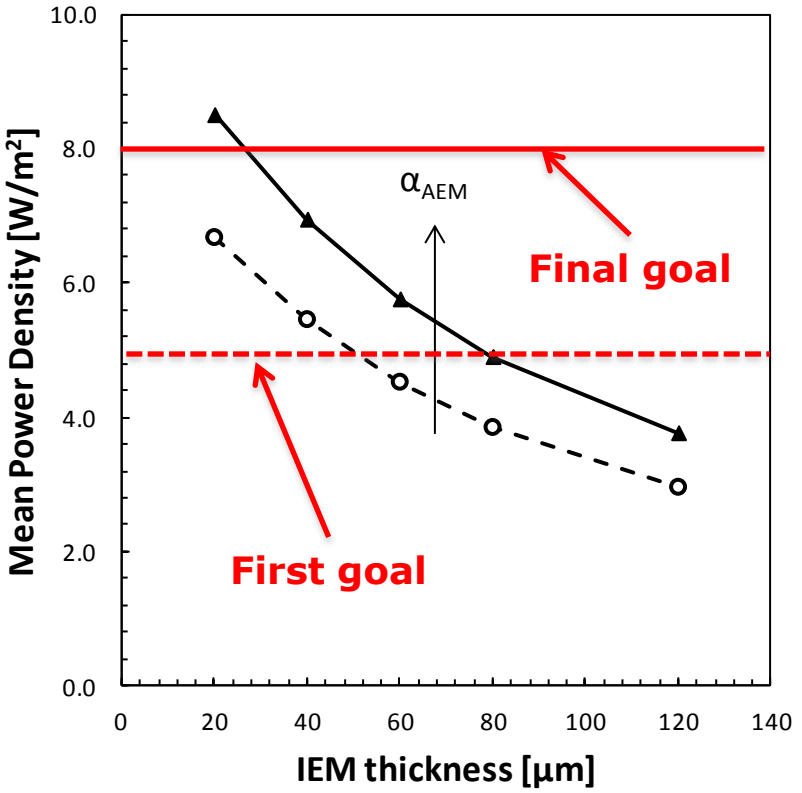
Direct access to both saturated brine and seawater from open channels

Installation place within an old, restructured WINDMILL

Achievements and perspectives

Power density output: effect of IEMs properties



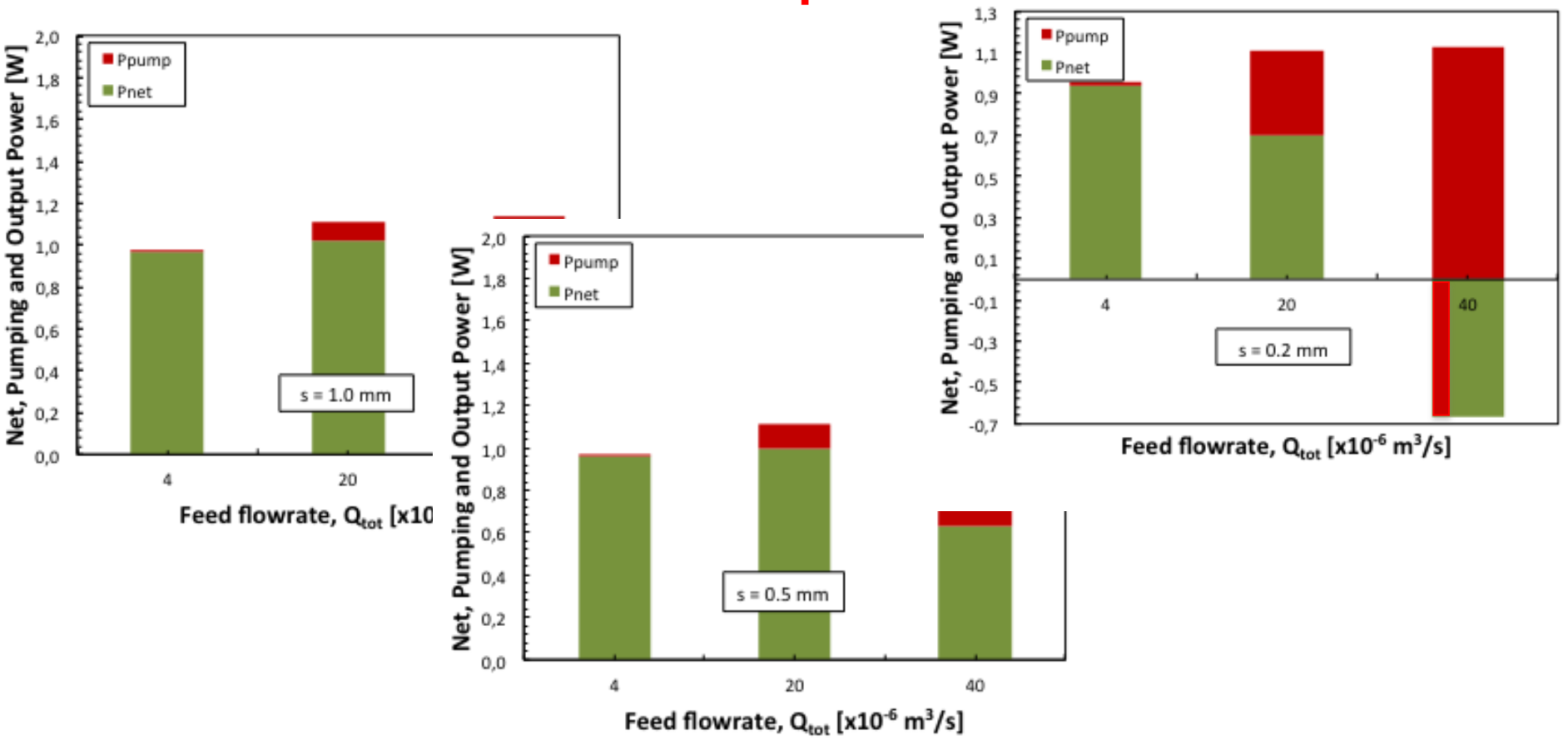


Simulation of a 1000 cells stack assuming a linear decreasing of IEMs resistance with IEMs thickness. α_{AEM} = 0.65, α_{CEM} = 0.90. Spacer thickness of seawater/brine compartments $\delta = 200\ \mu m$.

Achievements and perspectives

Power density output: effect of stack geometry

Gross and Net power output



Simulation of a **50-cells stack** with **200 μm** spacers; rectangular distributor/collector with thickness s= 0.2 – 0.5 – 1.0 mm; external load is assumed equal to stack resistance

Achievements and perspectives

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

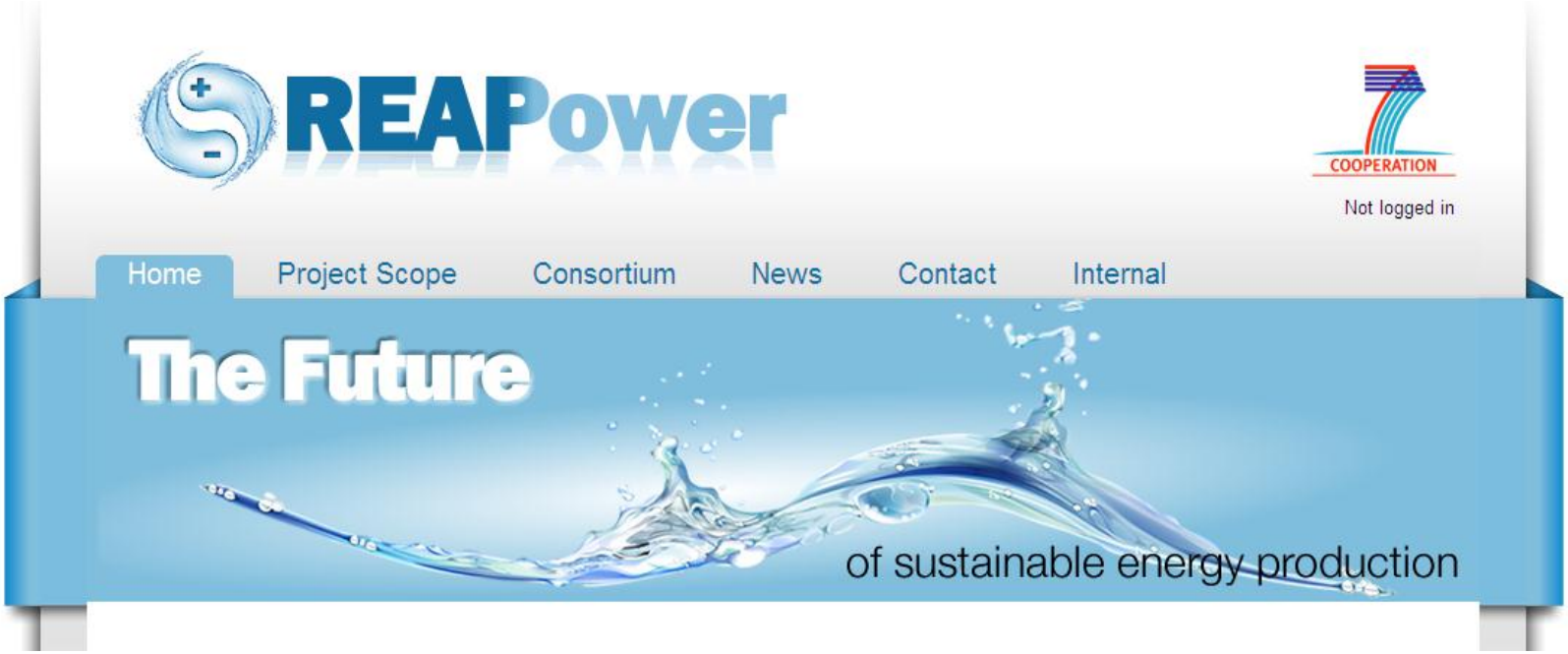
-Total cell pair surface: ≈ 60 m^2;

-Expected power density: > 5 W/m^2;

-Expected power output: > 300W

REAPower website

http://www.reapower.eu/



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Thanks for your kind attention

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