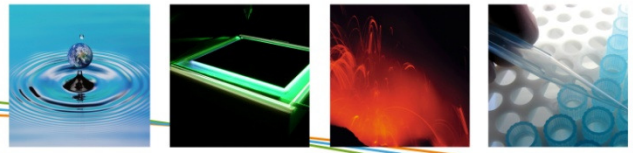
vito
vision on technology



REAPower

COOPERATION

Reverse Electrodialysis Alternative Power

Energy generation and desalination : The REAPower project

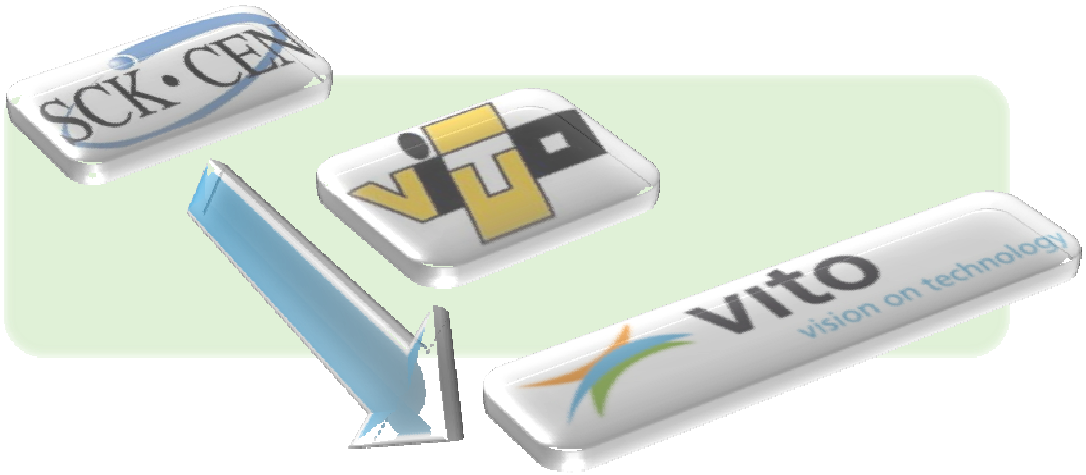
Inge Genné and Etienne Brauns

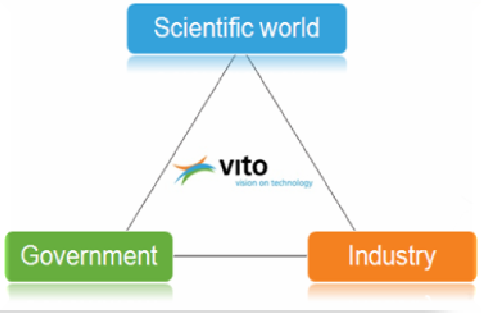
Salinity Gradient Power Generation
European Meeting
Brussels, April 13, 2011,

Topics in the presentation of today

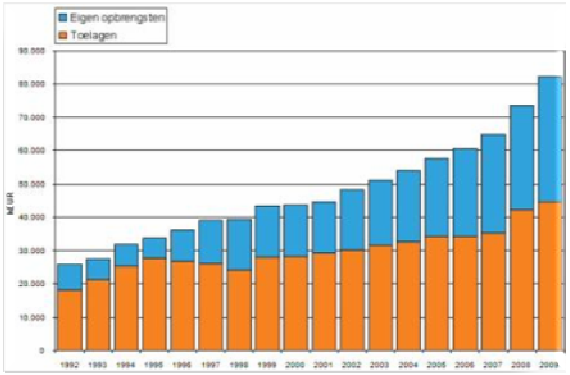
Energy generation and desalination : The REAPower project

- VITO introduction
- REAPower website
- REAPower objectives
- SGP-RE battery principle and advantage
- Theoretical effect of SGP-RE battery parameters, indications from
  - simple resistances in series point of view
  - Lacey model based calculations
- Hybrid concept and relation with REAPower
- REAPower consortium
- REAPower workplan explained
- Acknowledgments





Facts & Figures



- Founded in 1991
- Autonomous public research company
- Bridge between academia – government and industry
- 5-year framework contract
- Nearly 600 people, 10 nationalities
- Yearly budget of 70 MEUR

Research Fields

Energy

Quality of the environment

Industrial Innovation

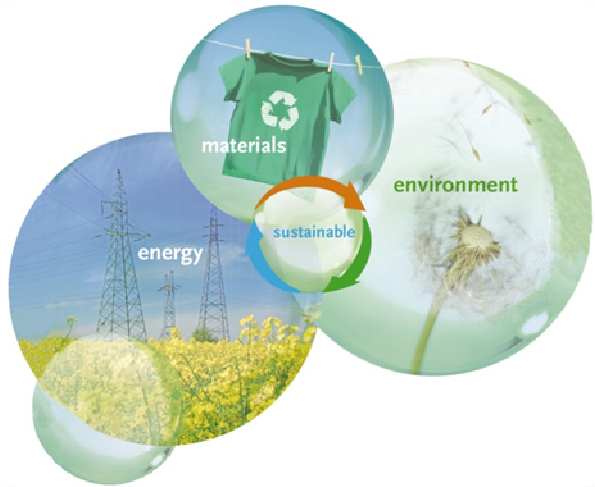
Industrial Innovation

Separation and conversion technologies
- Process streams
- Bioconversion
- Raw materials

Materials technology
- Plasma technology
- Shaping of ceramics/powder technology
- Laser technology

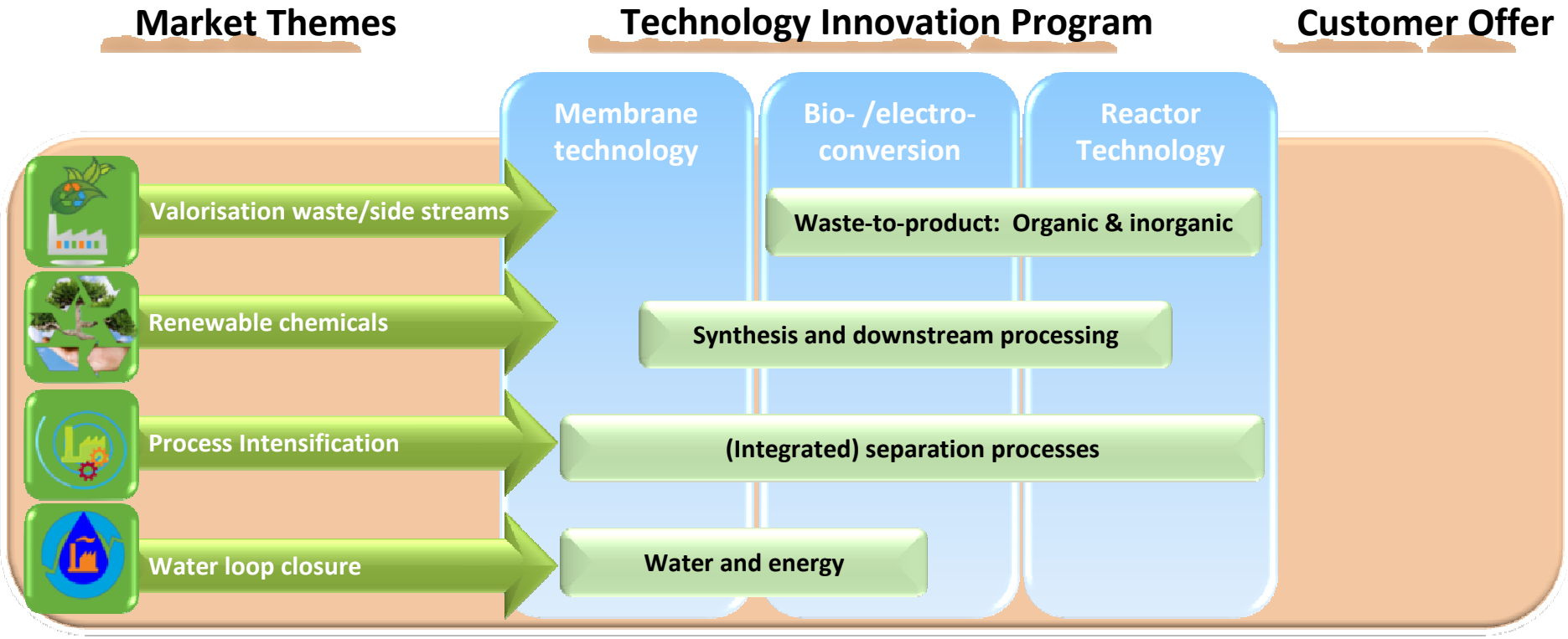
Environmental analyses and technologies
- Specialized organic and anorganic laboratory

- Top technological research in a number of topics relevant to environment, energy and materials
- Introduction and demonstration of innovative technologies
- Technological support to SME's



Strategic Focus on

Sustainable Chemistry



Membrane technology at VITO

1970
- Electrochemistry: alternatives for asbestos

1980
- Polymeric membranes – phase inversion process
- Separators

1990
- + Micro- and ultrafiltration, food applications
- + Tubular ceramic supports

2000
- + Application testing: MF/UF/NF/RO/ED/PV
- + Emphasis on membrane bioreactors

2005
- + Organic solvent nanofiltration
- + Tailor made polymeric + ceramic membranes

Membrane technology at VITO

2011

Membrane/module development

- Polymeric membranes
- Ceramic membranes
- Electrodes/separators

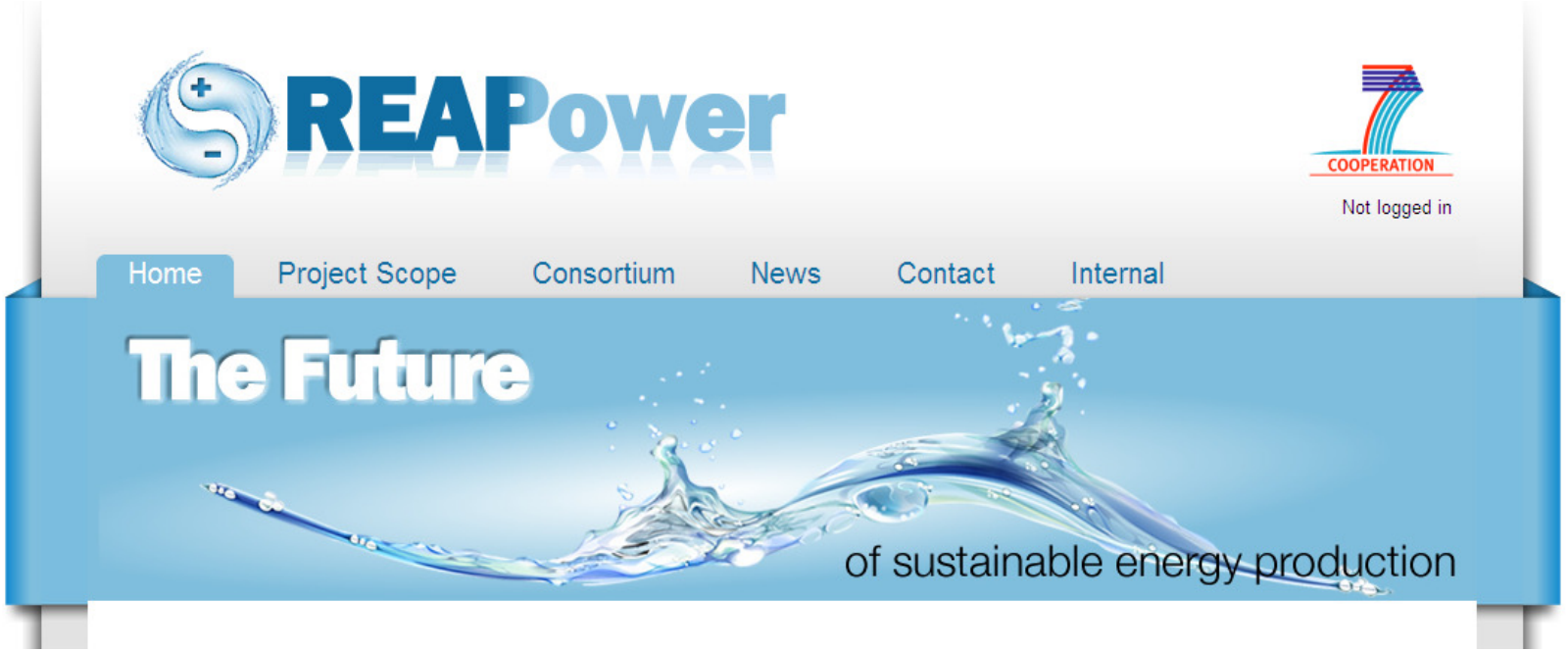
Membrane processes

- MF/UF/NF/RO/MBR/PV/ED, membrane distillation, reverse electrodialysis

Membrane applications

- Water treatment
- Solvent filtration/affinity separation
- Biomass filtration (downstream processing)
- Enzymatic membrane reactors (enzyme immobilisation)
- In situ product recovery from fermentation broths
- Electrochemical cells / microbial fuel cells (MFCs)

Salinity Gradient Power : REAPower (website)



http://www.reapower.eu/

FP7, Theme Energy.2010.10.2-1
Future Emerging Technologies for Energy Applications (FET)

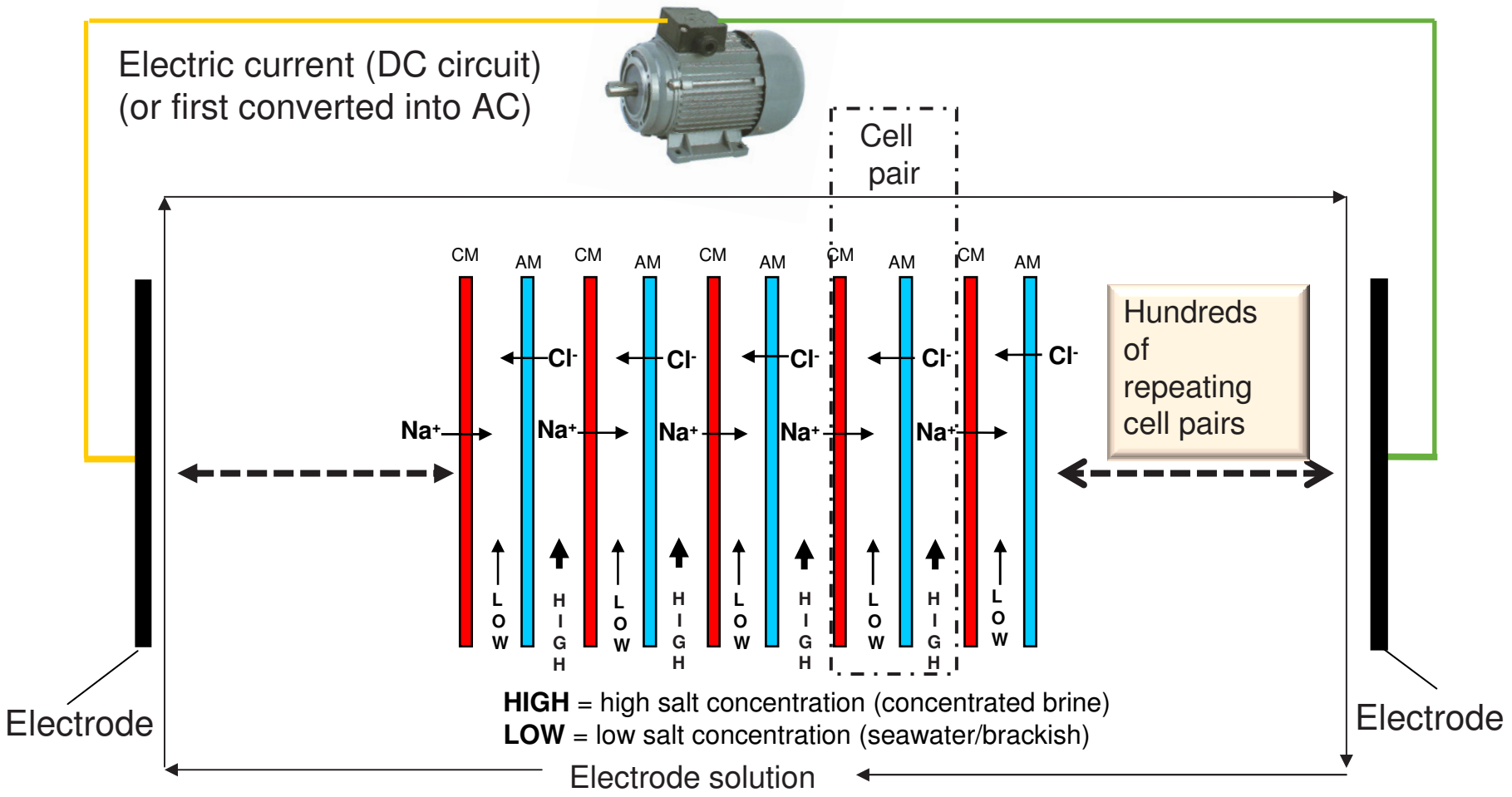
REAPower objectives

- REAPower targets an innovative concept based on the reverse electrodialysis technology. This technology consists of the extraction of the “osmotic energy” from two salt solutions showing a large difference in salt concentration, what is called salinity gradient power (SGP).

- 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.

- Time frame : 4 years ; October 2010 – October 2014

REAPower SGP-RE battery



Electrode solution redox-reactions at the electrodes induce the transport of electrons in the DC circuit

REAPower advantage

The use of

- highly conductive seawater (e.g. 35 kg/m³) in the LOW compartment
- even more conductive concentrated brine (e.g. 300 kg/m³) in the HIGH compartment

creates a low resistance in both the HIGH and LOW battery compartments

As a result:

opportunity to target a low total internal resistance within the SGP-RE battery cell-pairs through the introduction of thinner membranes

In principle, a lower battery internal resistance should significantly promote a higher power density of the SGP-RE battery.

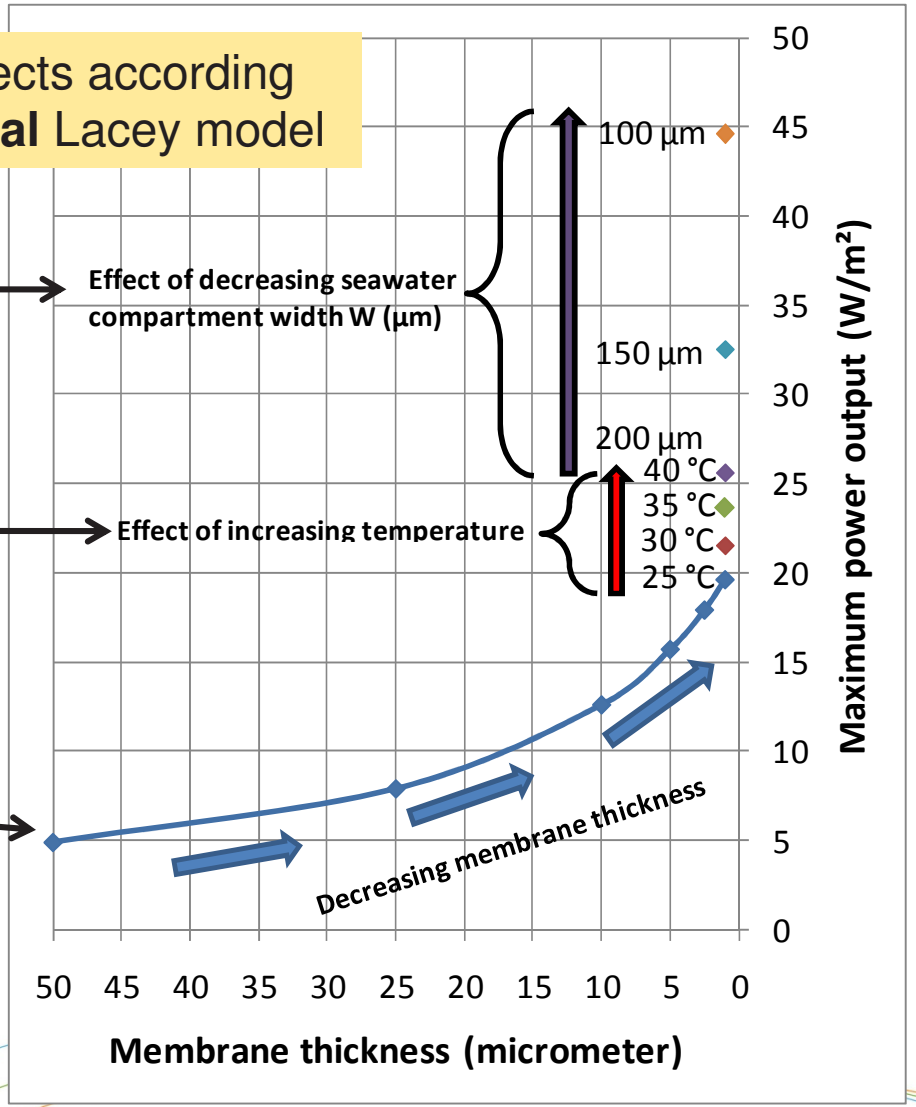
REAPower : theoretical effect of parameters

Parameter effects according to the **theoretical** Lacey model

3) Additional effect of lowering the compartment width

2) Additional temperature effect of thinner membranes

1) Effect of thinner membranes



E. Brauns, Desalination 237 (2009) 378–391

REAPower : lowering the internal battery resistance

To give a rough idea and in theory, when assuming :

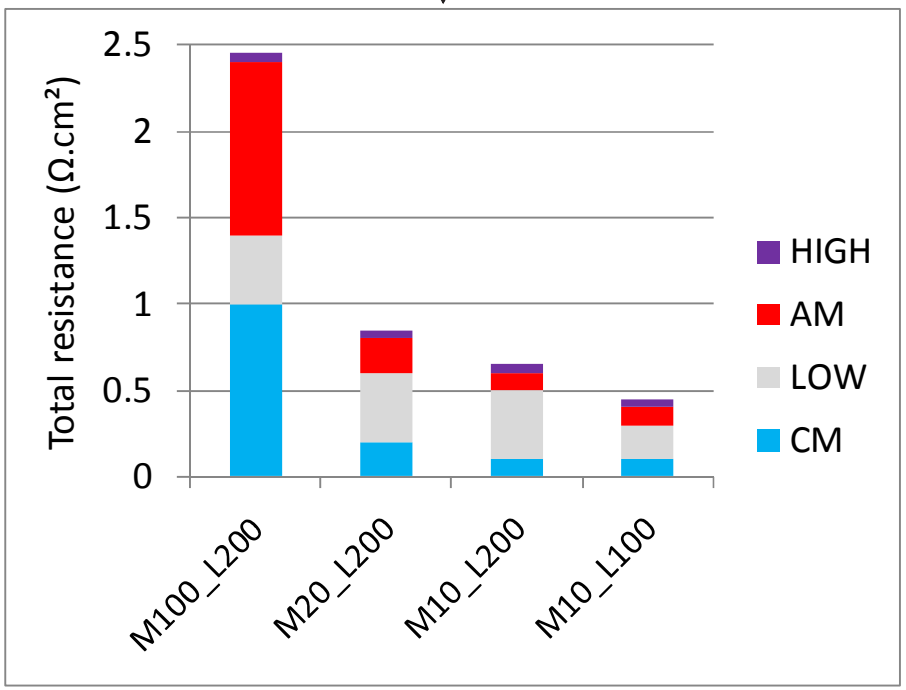
- simplified series of resistances
- AM and CM : specific membrane resistance of 100 Ω.cm
- seawater : 20 Ω.cm (*about 50 times lower than fresh water !*)
- brine : 2.5 Ω.cm

Theoretical indication of the internal cell pair resistance optimization window

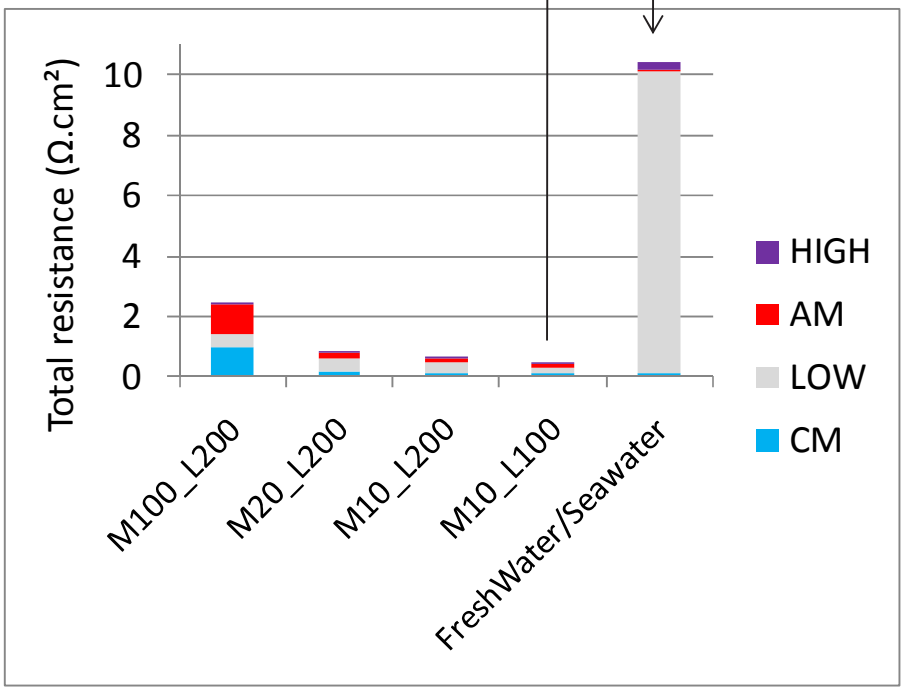
CM membrane		LOW compartment		AM membrane		HIGH compartment		Total resistance	
(µm)	(Ω.cm²)	(µm)	(Ω.cm²)	(µm)	(Ω.cm²)	(µm)	(Ω.cm²)	(Ω.cm²)	(%)
100	1	200	0.4	**100**	1	200	0.05	***2.45***	***100***
20	0.2	200	0.4	**20**	0.2	200	0.05	0.85	35
10	0.1	200	0.4	**10**	0.1	200	0.05	0.65	26
100	1	**100**	0.2	**100**	1	200	0.05	2.25	92
50	0.5	**100**	0.2	**50**	0.5	200	0.05	1.25	51
20	0.2	**100**	0.2	**20**	0.2	200	0.05	0.65	26
10	0.1	**100**	0.2	**10**	0.1	200	0.05	0.45	18

REAPower : lowering the internal battery resistance

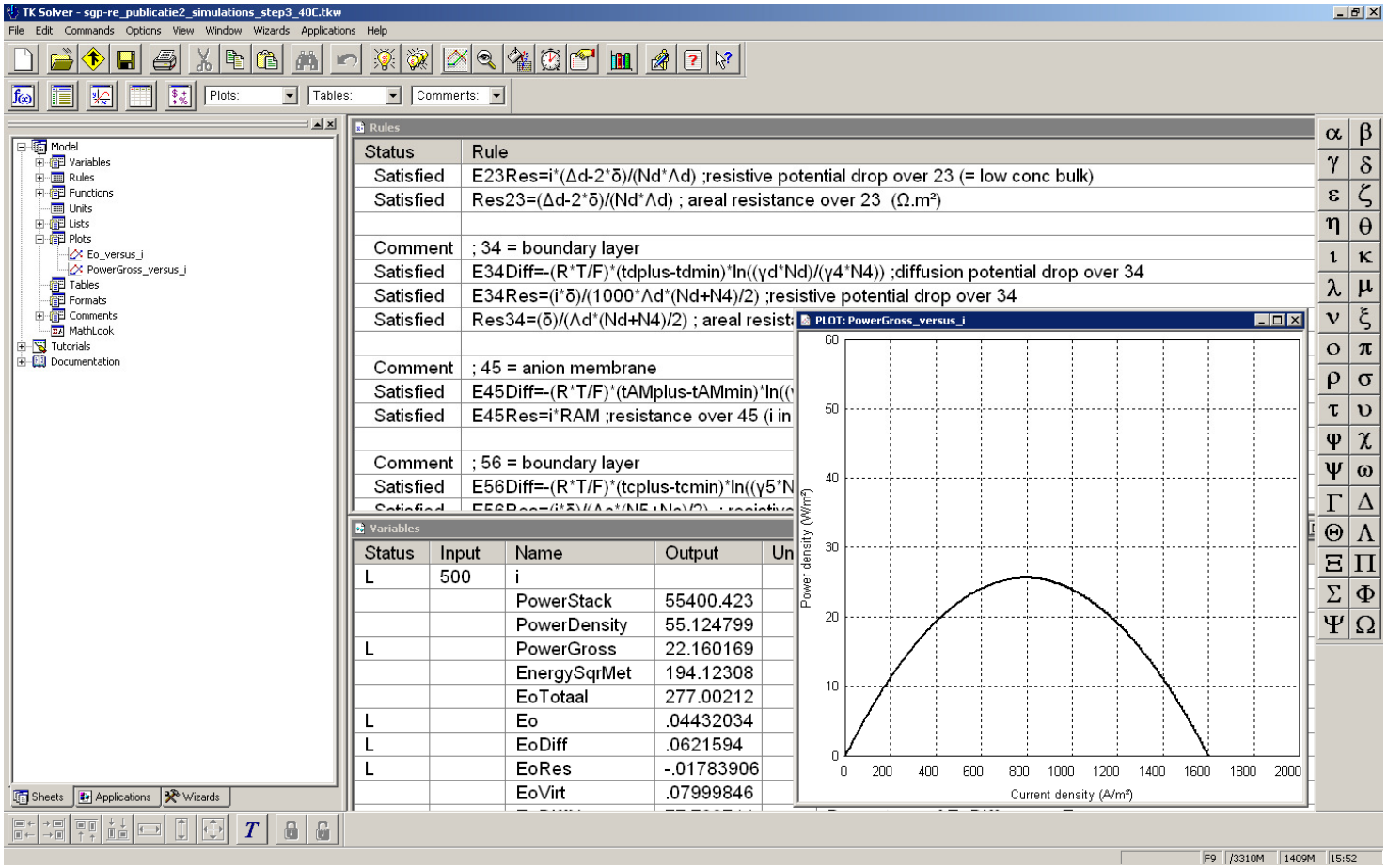
Brine and seawater



The effect of putting fresh water in the LOW compartment and seawater in the HIGH compartment in the case M10_L100



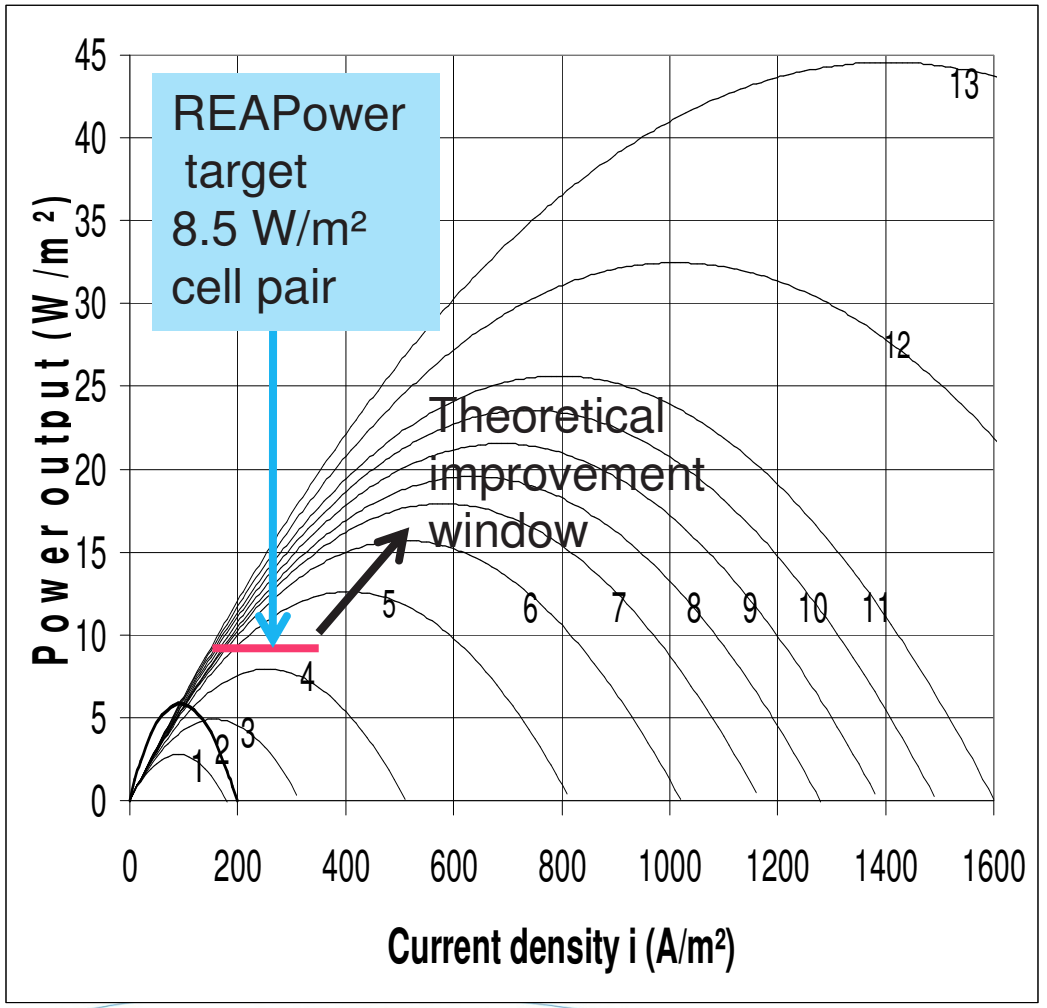
Simulations according to SGP-RE Lacey model



E. Brauns, Desalination 237 (2009) 378–391

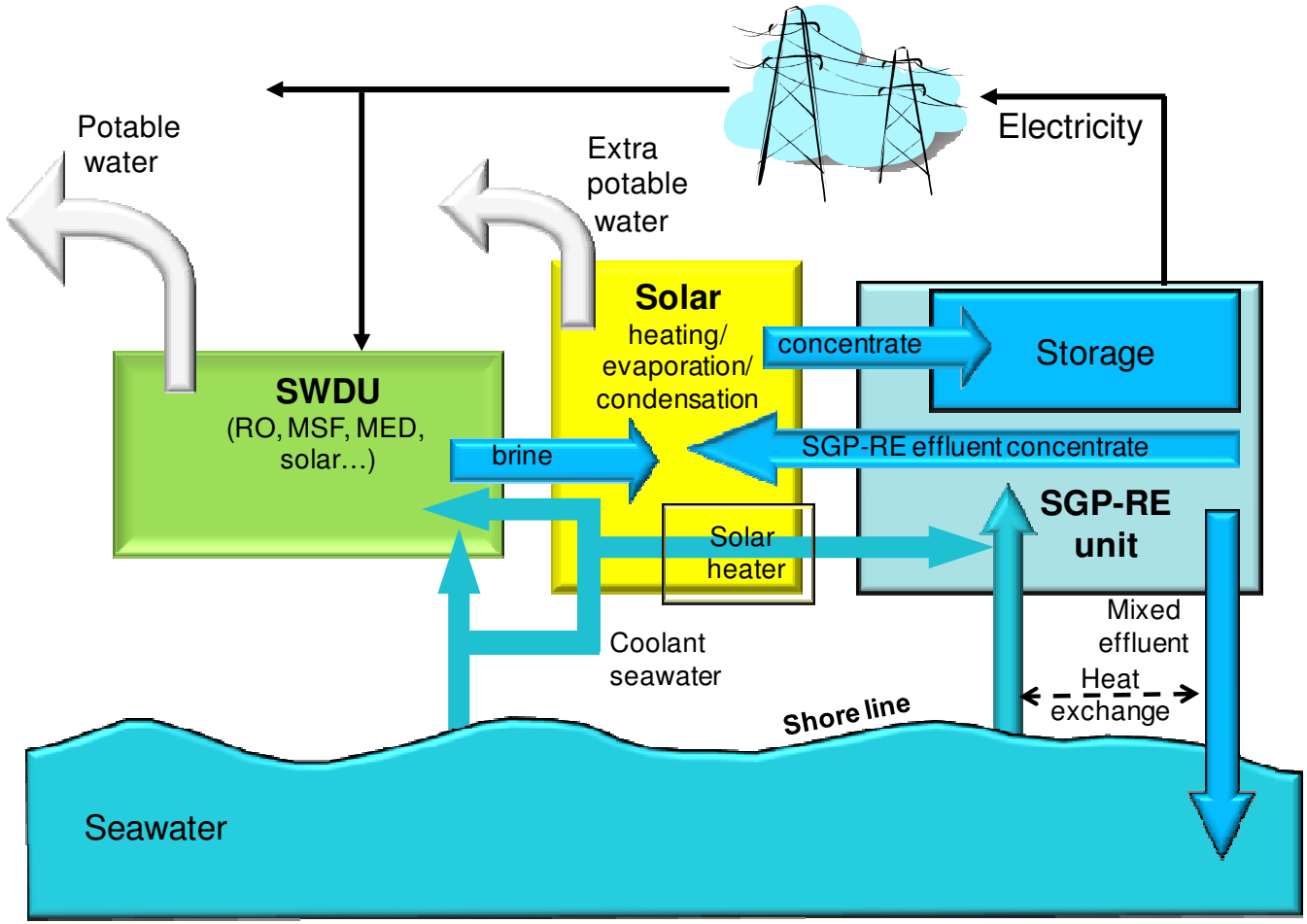
Power output indications from Lacey model

CURVE	Membrane thickness (µm)	LOW compartment thickness (µm)	Temp. (°C)	Max Power Output (W/m²)
1	100	200	25	2.8
2		(Lacey)		6
3	50	200	25	4.9
4	25	200	25	7.9
5	10	200	25	12.6
6	5	200	25	15.7



E. Brauns, Desalination 237 (2009) 378–391

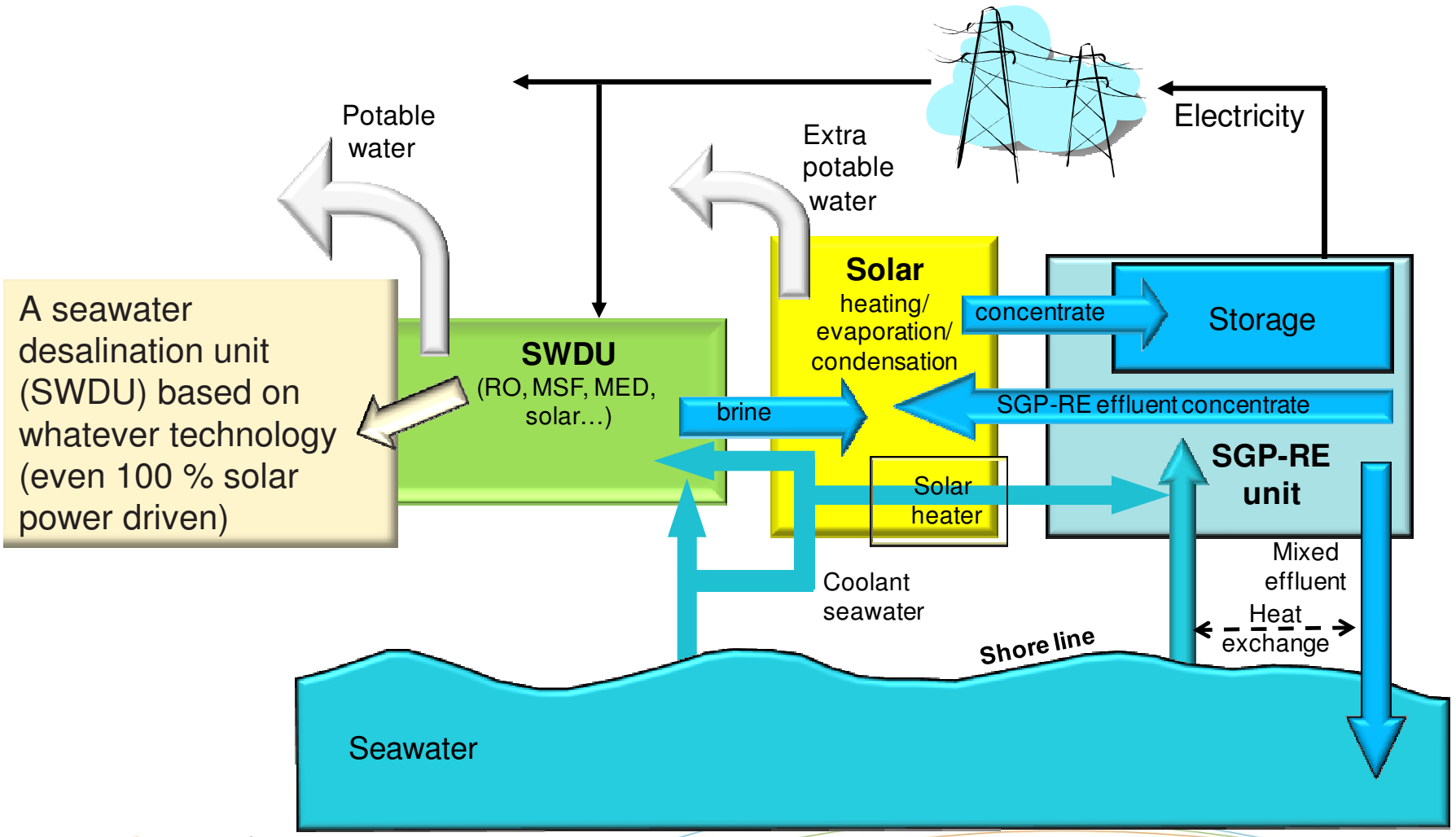
Hybrid system to produce energy and fresh water



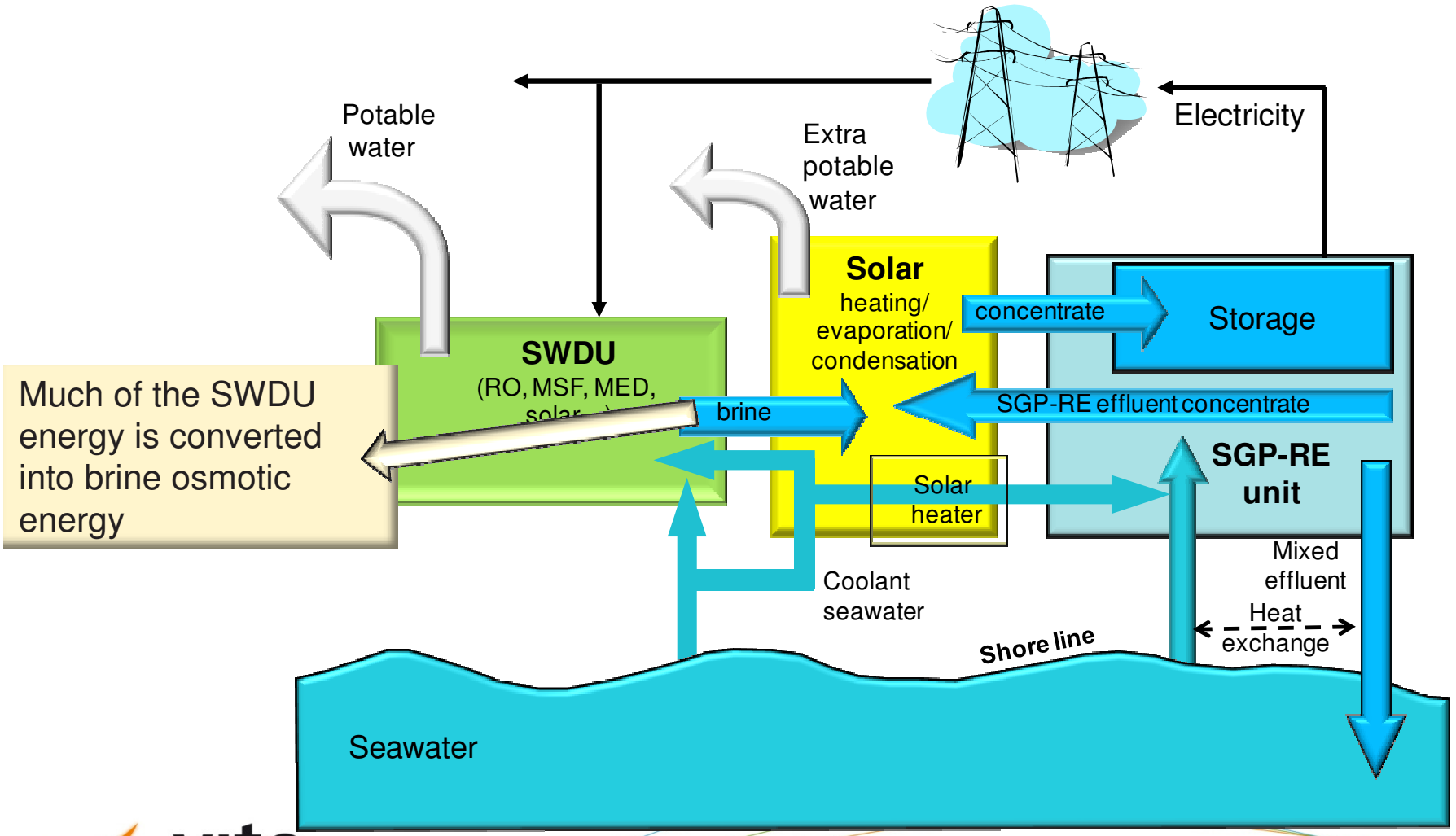
E. Brauns, Desalination and Water Treatment, 13 (2010) 53–62

E. Brauns, WO/2007/009196 [PCT/BE2006/000078]

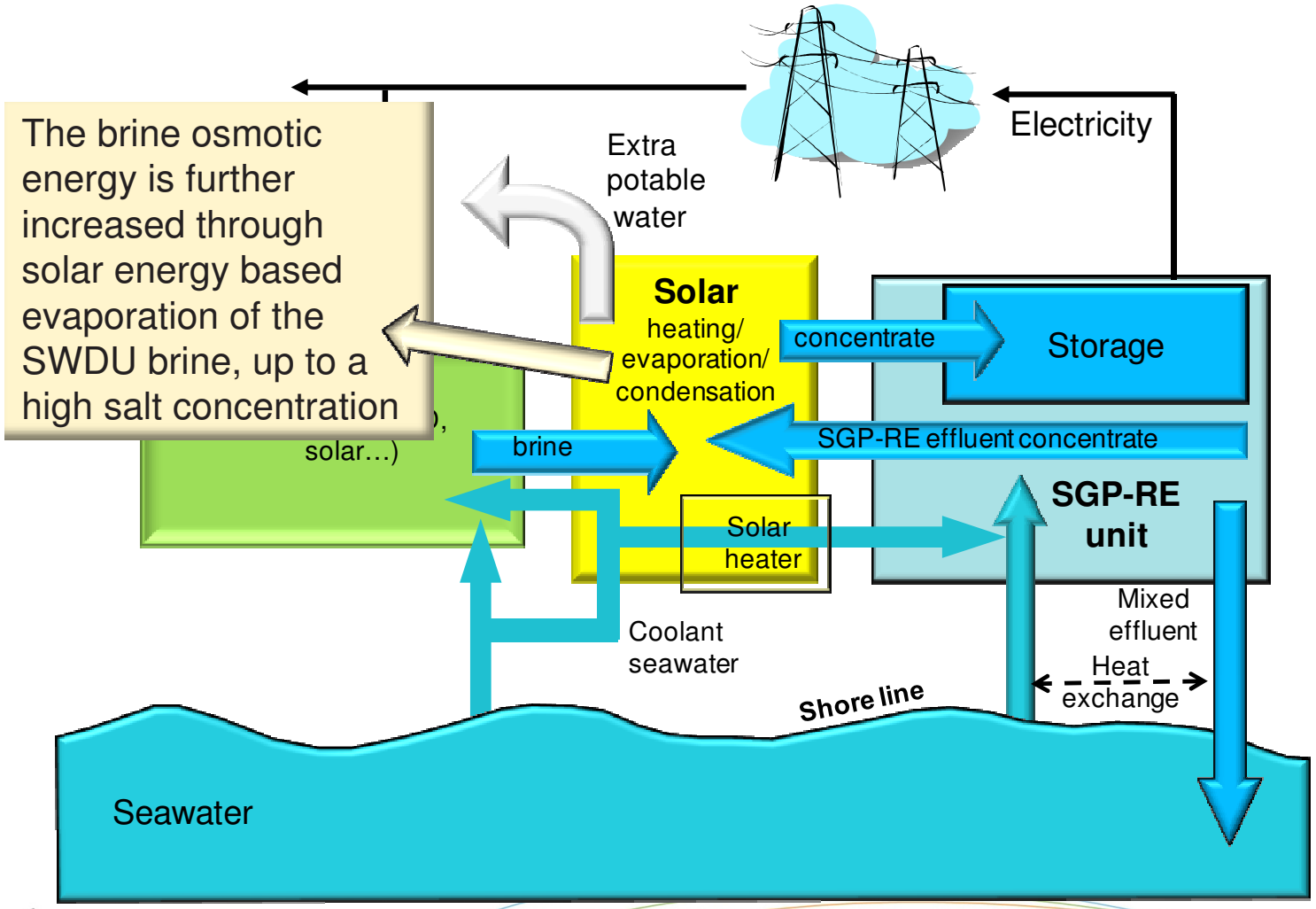
Hybrid system to produce energy and fresh water



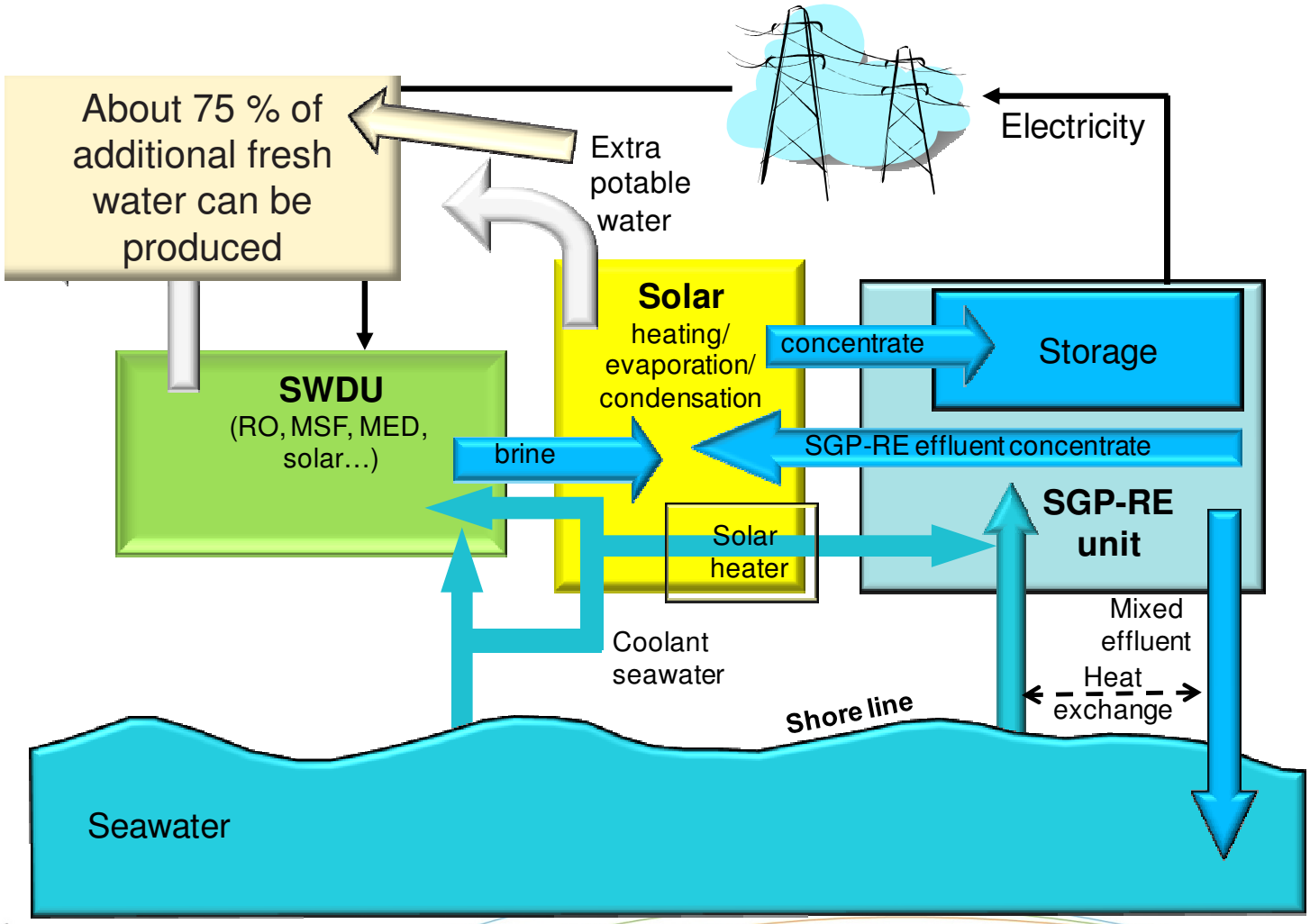
Hybrid system to produce energy and fresh water



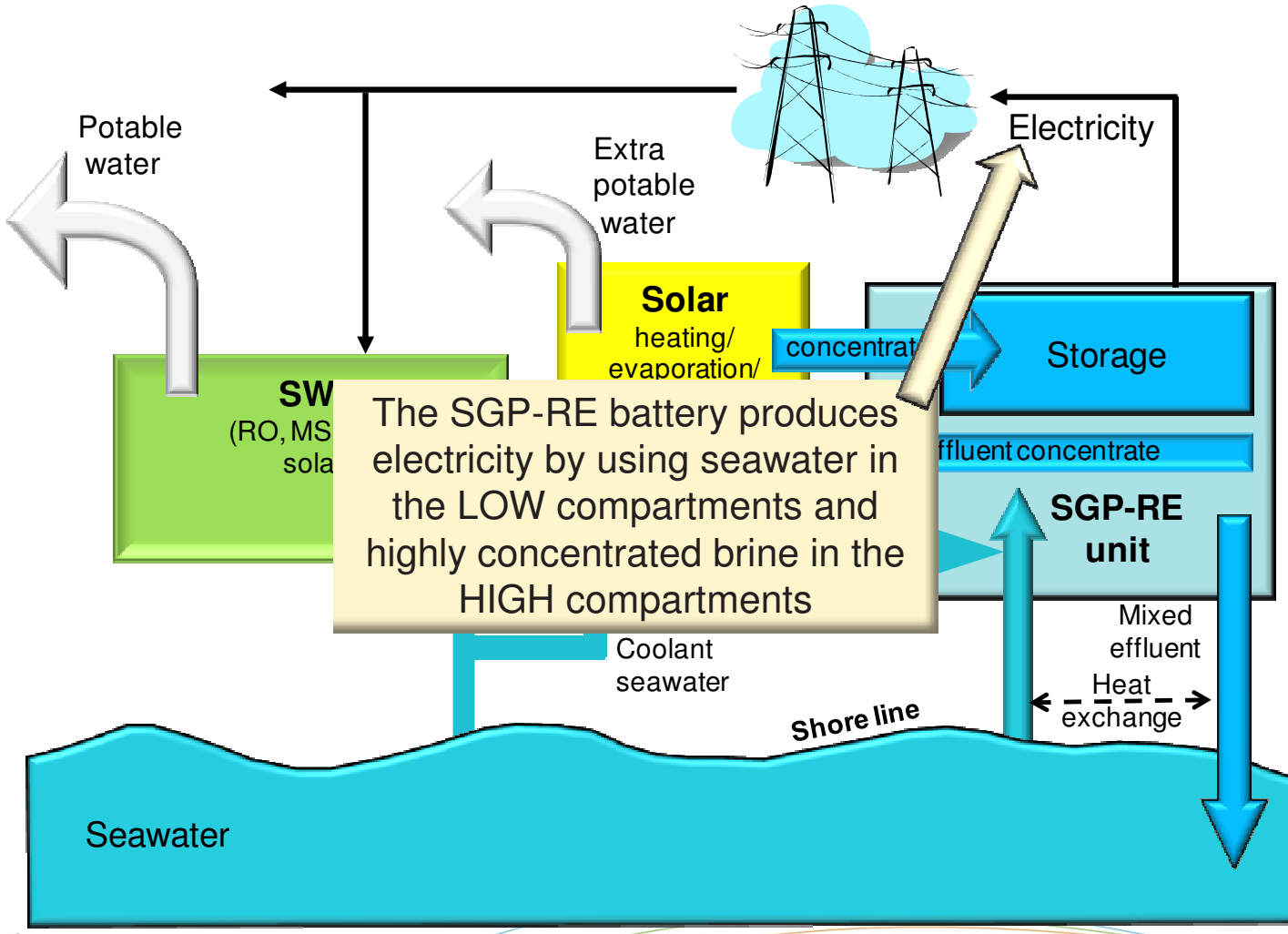
Hybrid system to produce energy and fresh water



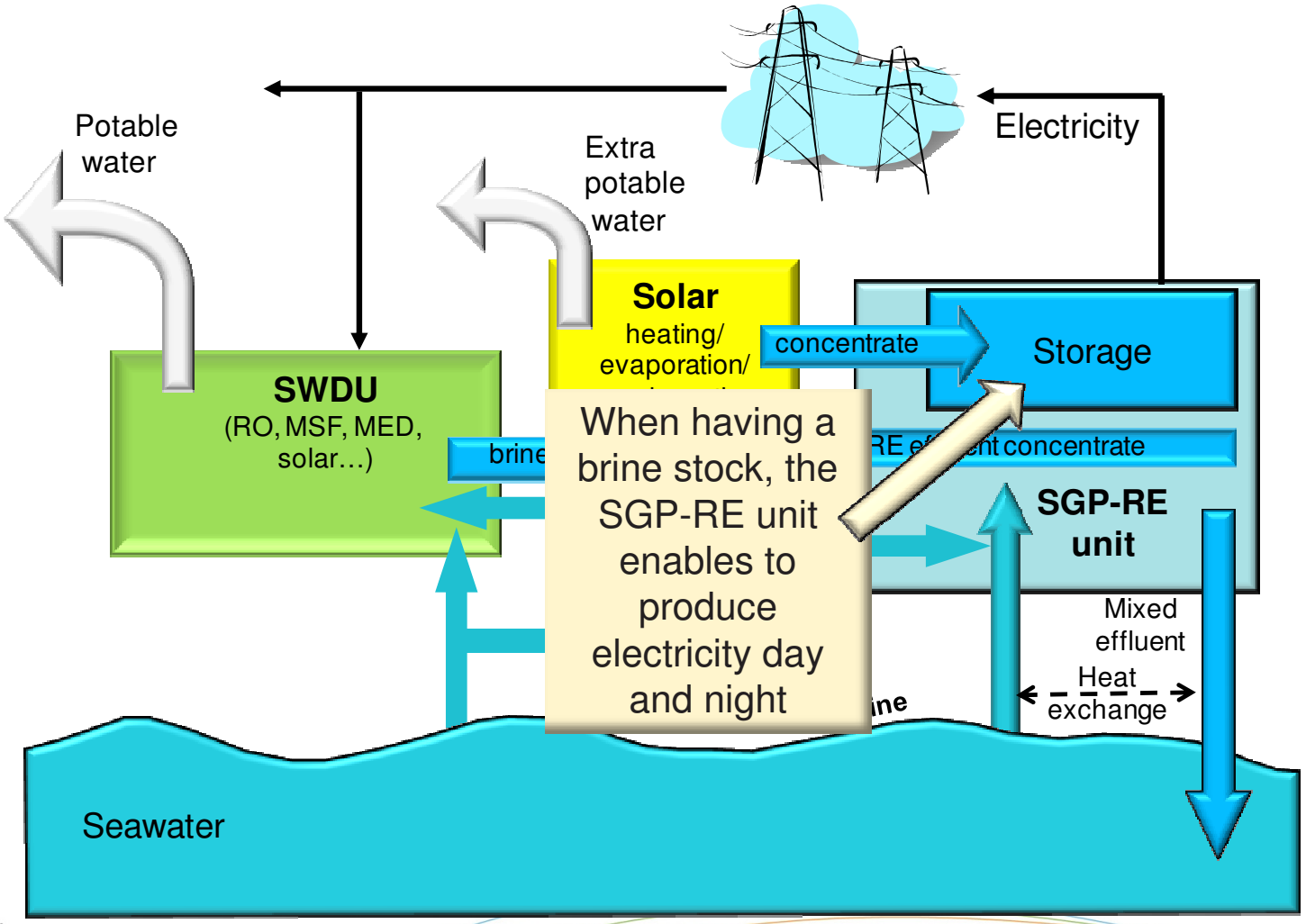
Hybrid system to produce energy and fresh water



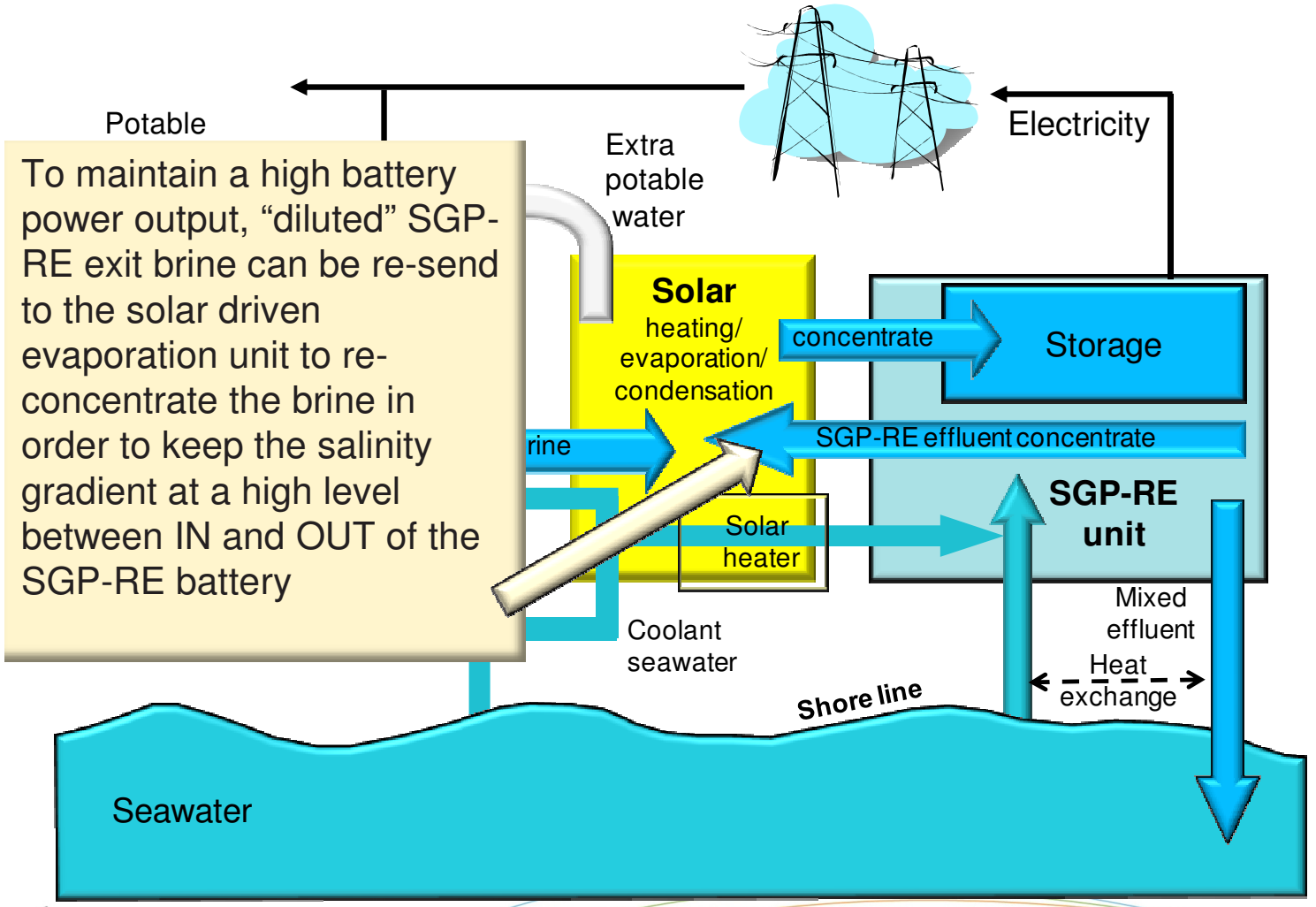
Hybrid system to produce energy and fresh water



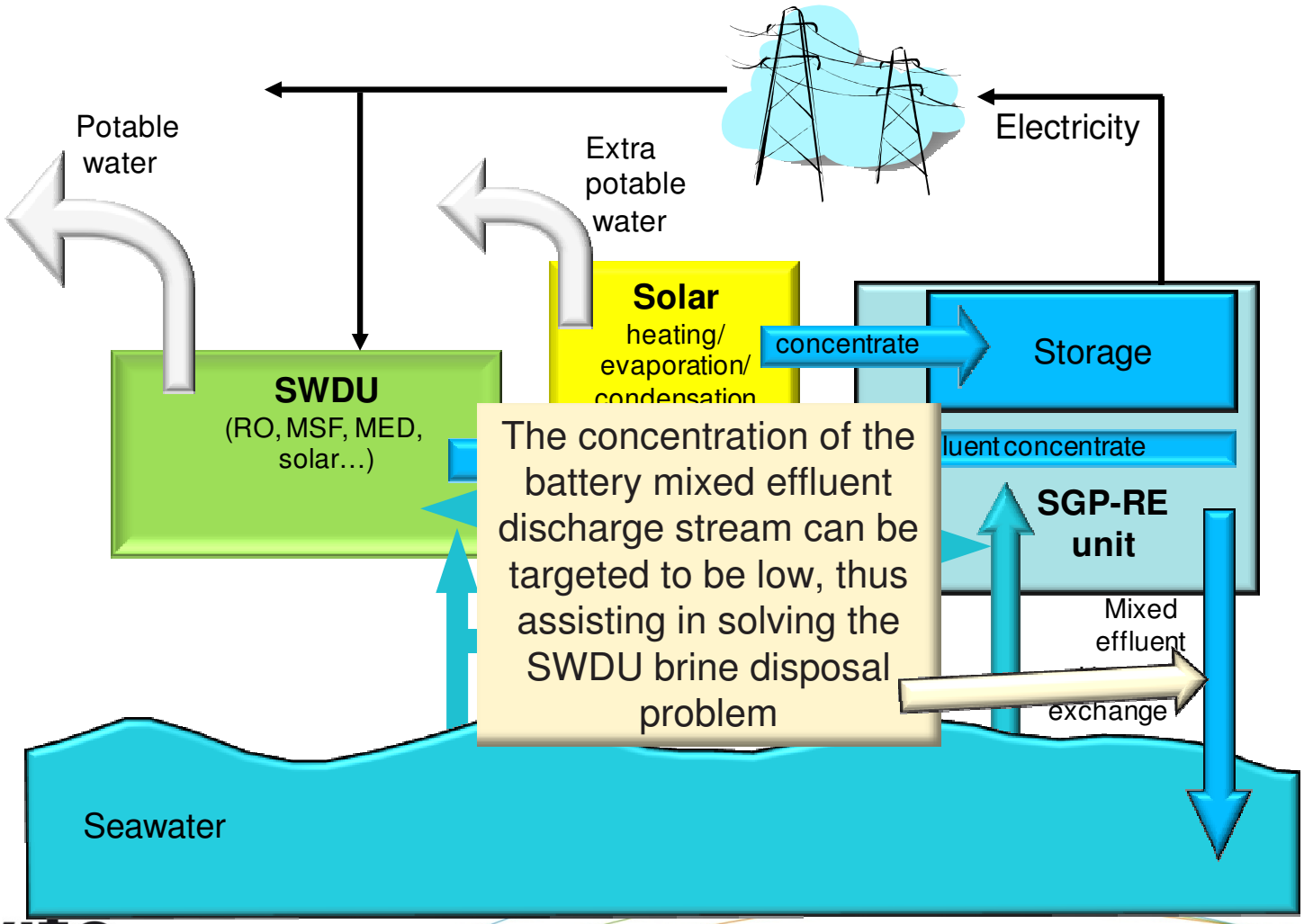
Hybrid system to produce energy and fresh water



Hybrid system to produce energy and fresh water



Hybrid system to produce energy and fresh water



The concentration of the battery mixed effluent discharge stream can be targeted to be low, thus assisting in solving the SWDU brine disposal problem

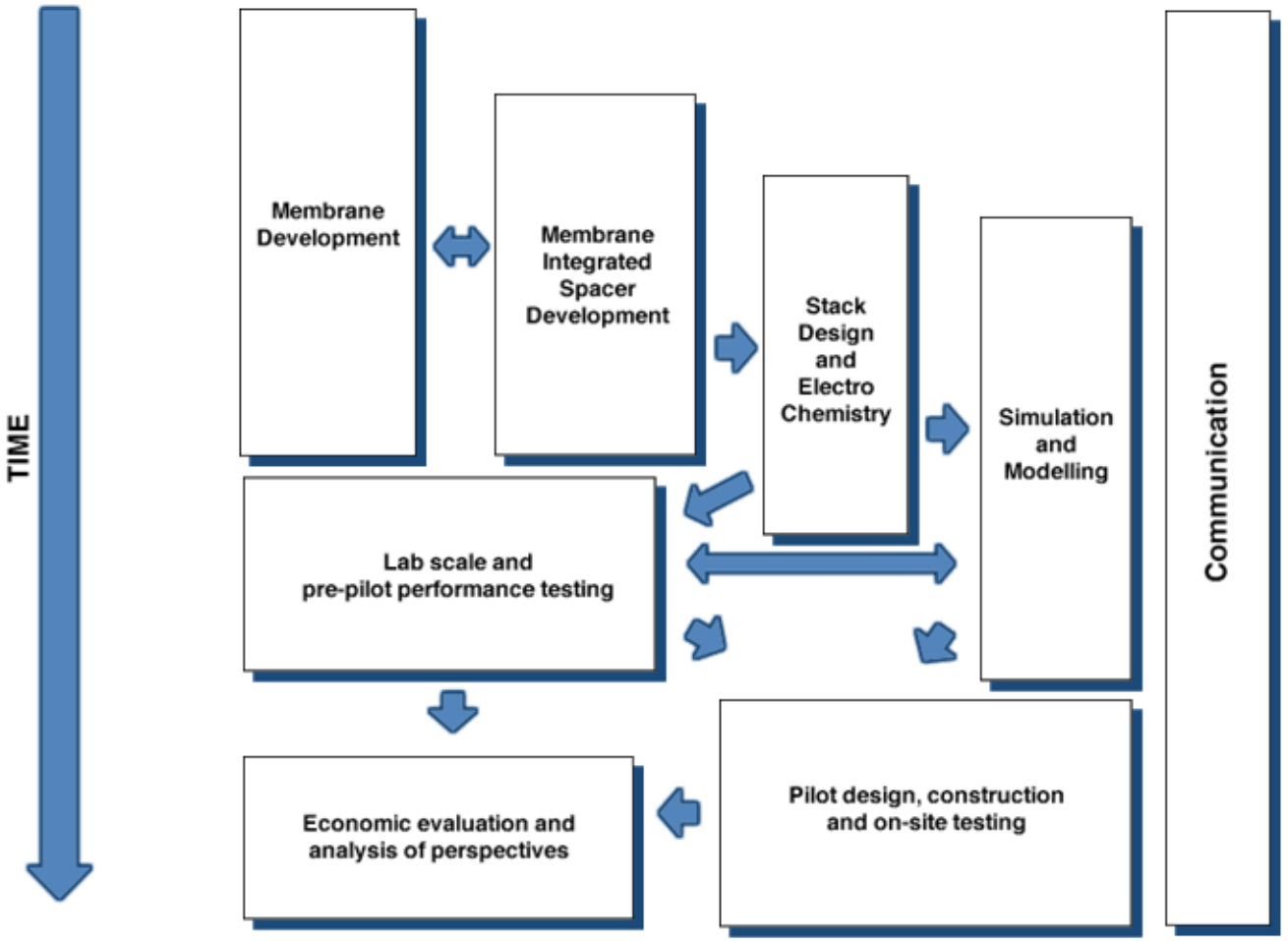
REAPower consortium

Participant	Country	Logo
Wirtschaft und Infrastruktur GmbH & Co Planungs-KG (WIP) - more info -	DE	
Vlaamse instelling voor technologisch onderzoek N.V (VITO) - more info -	BE	
Università Degli Studi Di Palermo (UNIPA) - more info -	IT	
Fujifilm Manufacturing Europe B.V. (FUJI) - more info -	NL	
Next Technology TECNOTESSILE Società Nazionale di Ricerca r.l. (NTT) - more info -	IT	
KEMA NEDERLAND BV (KEMA) - more info -	NL	
Università della Calabria (DICEM-UNICAL) - more info -	IT	
The University of Manchester (UNIMAN) - more info -	UK	
REDstack B.V. - more info -	NL	
Kraton Polymers, LLC (KRATON) - more info -	US	
SolarSpring GmbH - more info -	DE	

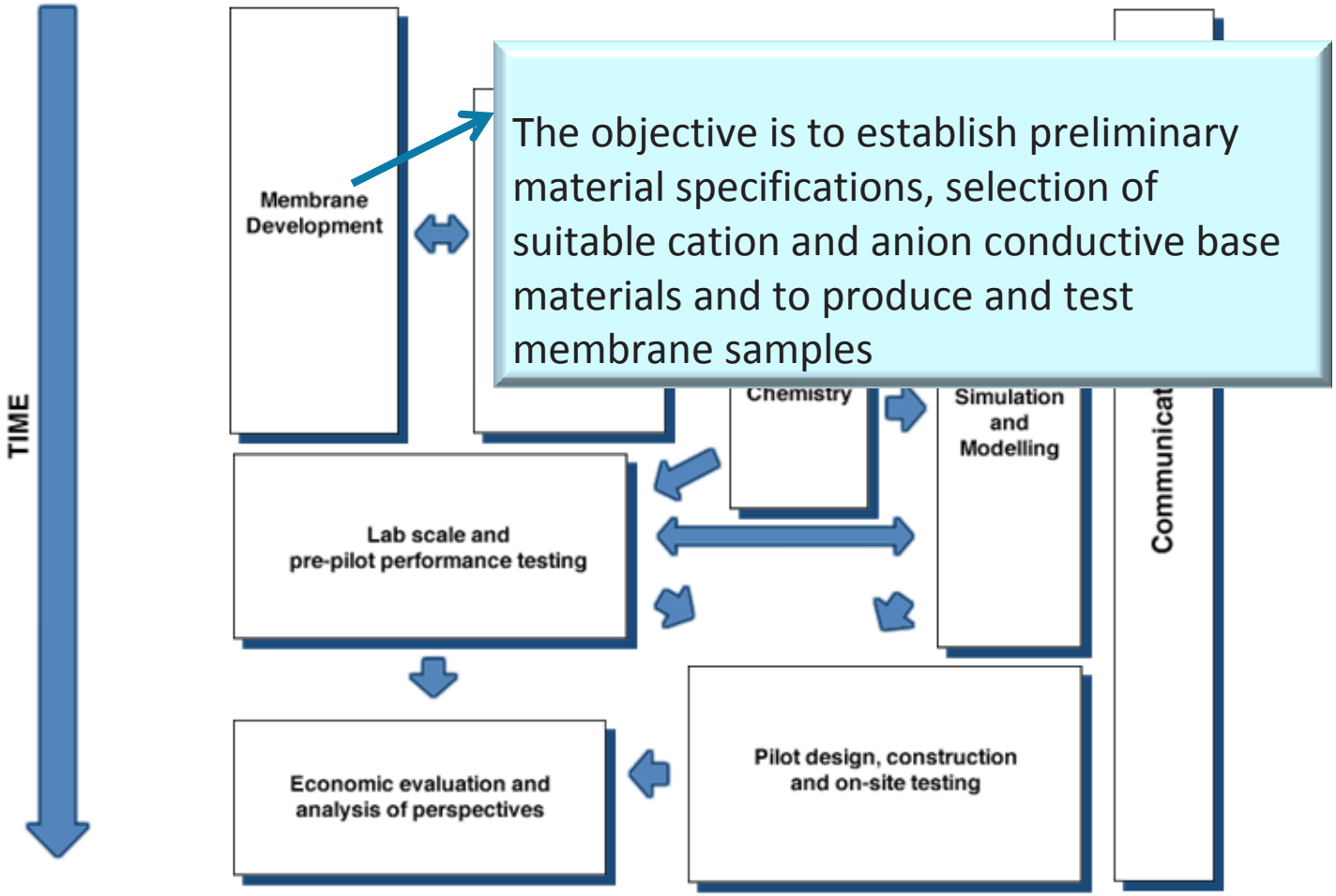
REAPower consortium

- FUJIFILM, the University of Calabria and VITO are membrane experts
- KRATON is active in the materials field
- Next Technology Tecnotessile and the University of Manchester cover the textile technology
- REDSTACK is specialized in the reverse electrodialysis technology
- The University of Palermo is specialized in modeling, simulation and pilot installations
- The University of Palermo also participates with its electrochemistry research unit with respect to the SGP-RE stack electrodes
- Solar Spring develops desalination and water treatment technologies
- WIP and KEMA are consultants in desalination and renewable energy technologies

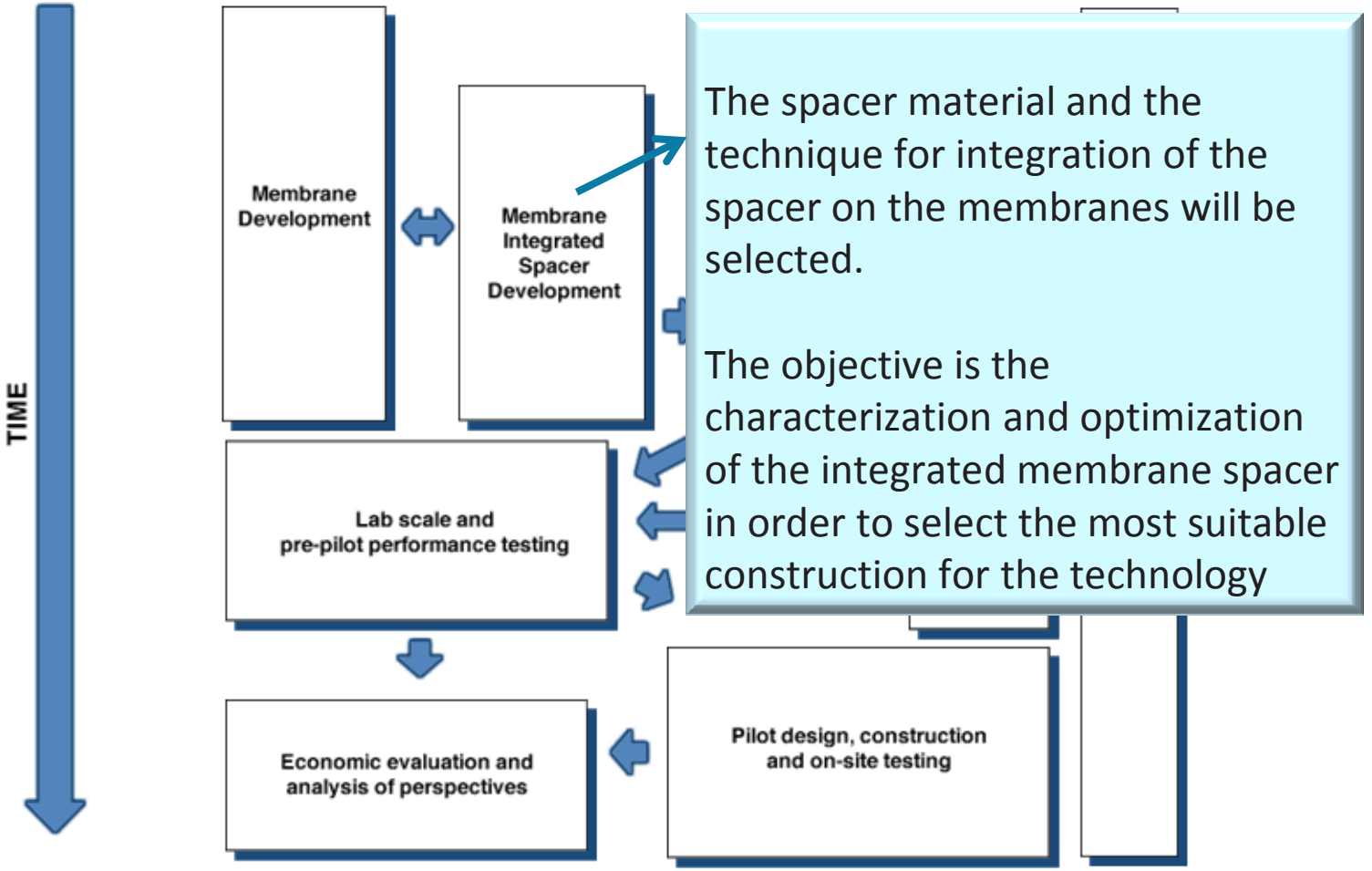
REAPower Workplan



Membrane Development



Membrane Integrated Spacer Development

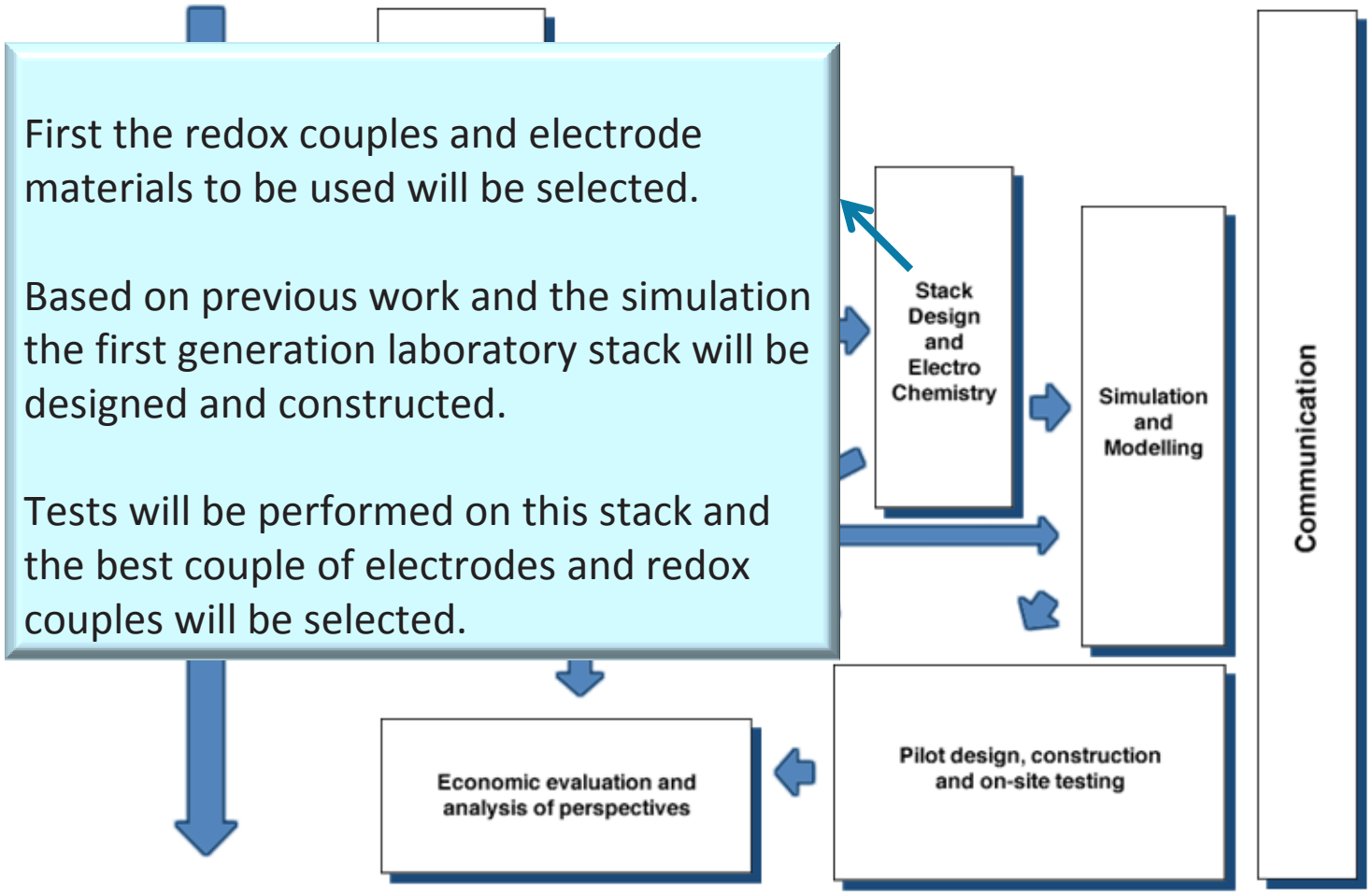


Electrochemical engineering / stack design

First the redox couples and electrode materials to be used will be selected.

Based on previous work and the simulation the first generation laboratory stack will be designed and constructed.

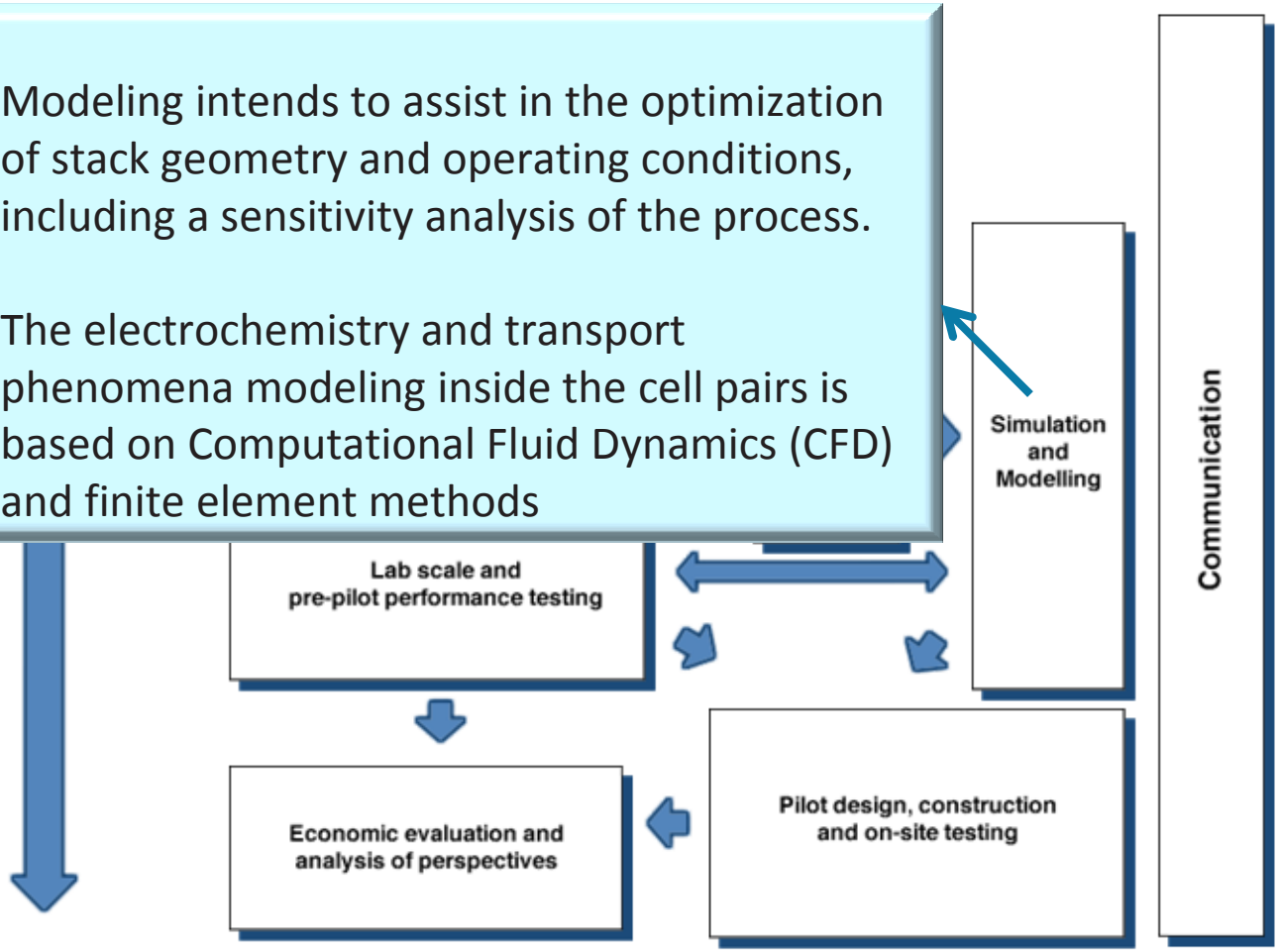
Tests will be performed on this stack and the best couple of electrodes and redox couples will be selected.



Process simulation

Modeling intends to assist in the optimization of stack geometry and operating conditions, including a sensitivity analysis of the process.

The electrochemistry and transport phenomena modeling inside the cell pairs is based on Computational Fluid Dynamics (CFD) and finite element methods

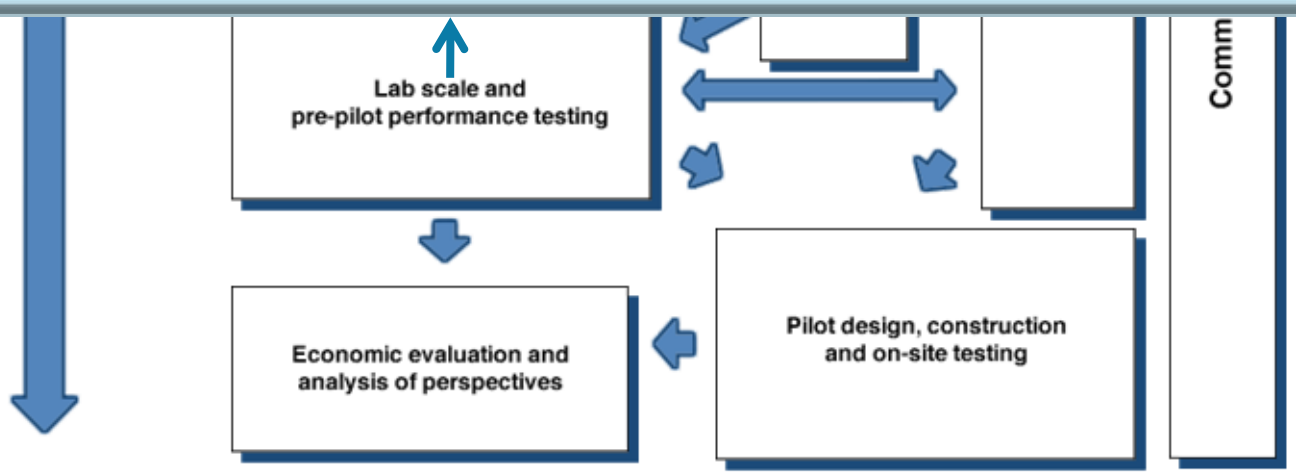


Lab-scale performance testing

Extensive testing of the laboratory stack in order to evaluate the effect of the hydraulic conditions and to study the effect of the real feed composition on the process.

The effect of hydraulic conditions on the power density will be evaluated on a larger laboratory stack.

The combination of this technology with a membrane distillation concept and the pre-treatment requirements of different brine inputs will be assessed.



Design, construction, testing of prototype installation

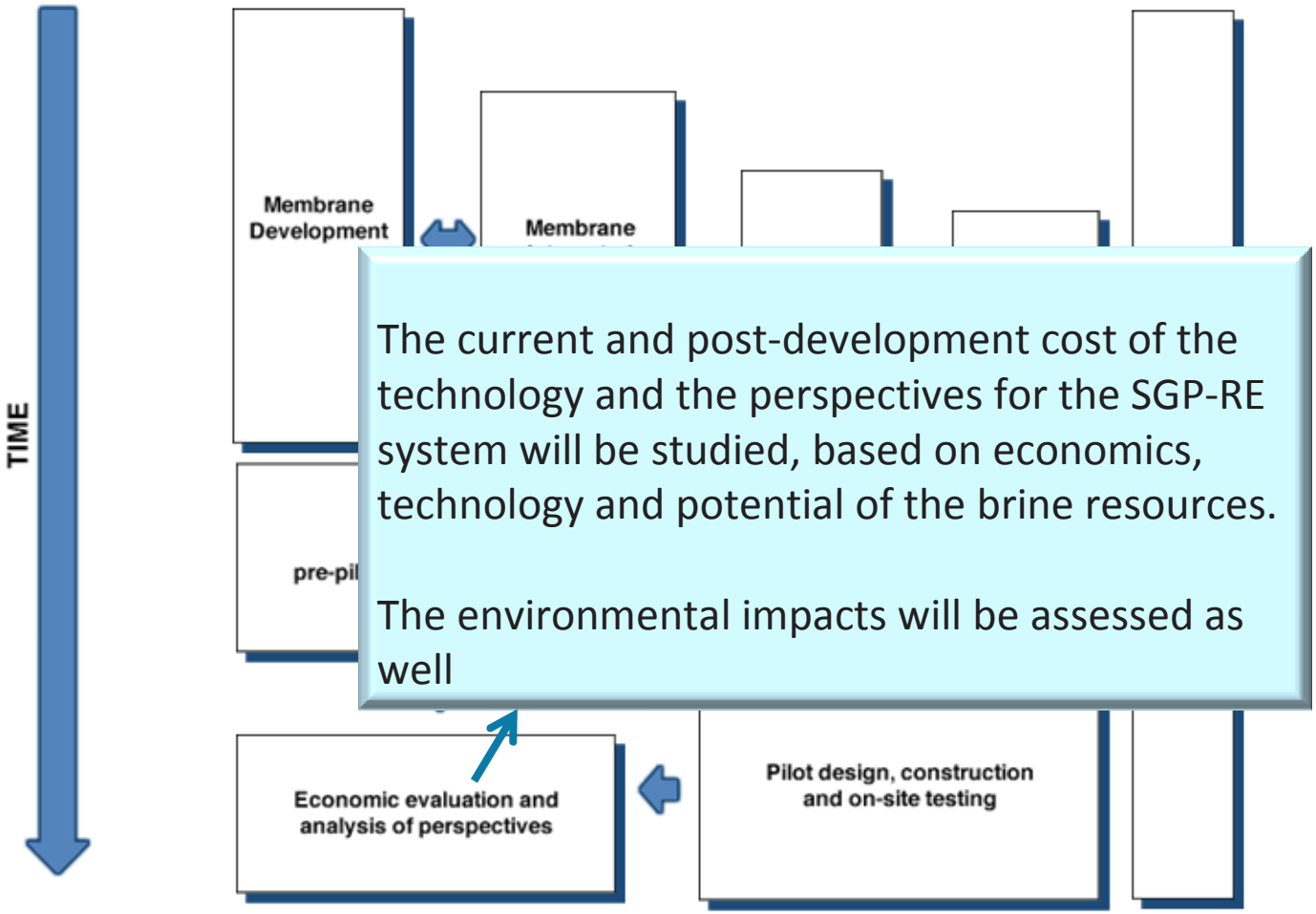
A prototype unit of the developed technology will be designed, constructed and tested in the saline pond salt factory.

This will allow proving the concept of the SGP-RE technology under real operating conditions using nearly saturated brine in combination with seawater.

Pilot design, construction and on-site testing

Economic evaluation and analysis of perspectives

Economic evaluation / analysis of perspectives



The current and post-development cost of the technology and the perspectives for the SGP-RE system will be studied, based on economics, technology and potential of the brine resources.

The environmental impacts will be assessed as well

Acknowledgements

- ***REAPower has received funding from the European Union Seventh Framework Programme (FP7/2007-2013), Future Emerging Technologies for Energy Applications (FET) (Project No FP7-256736)***

- The sole responsibility for the content of this presentation lies with the authors. It does not necessarily reflect the opinion of the European Union. The European Commission cannot be held responsible for any use that may be made of the information contained therein.

REAPower

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Thank you for your attention