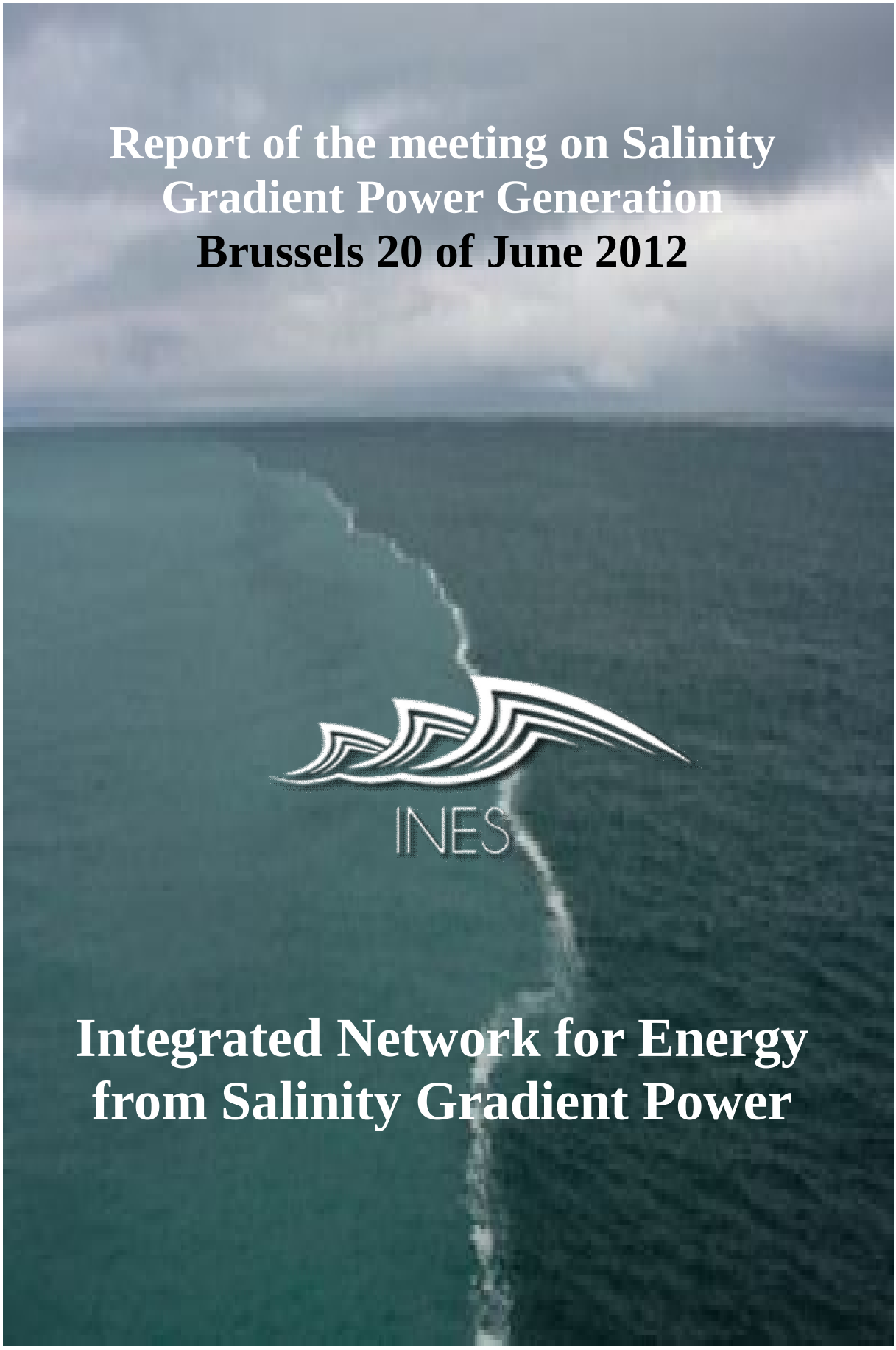
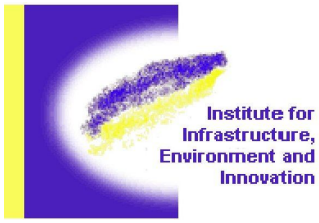
Report of the meeting on Salinity Gradient Power Generation
Brussels 20 of June 2012



Integrated Network for Energy from Salinity Gradient Power

Seminar organized by the Institute for Infrastructure, Environment and Innovation



Contributors:

Dr Frank Neuman
Director, INES project
Institute for Infrastructure, Environment and Innovation

Dr Bert Hamelers
Scientific coordinator of Capmix,
Program director of Wetsus.

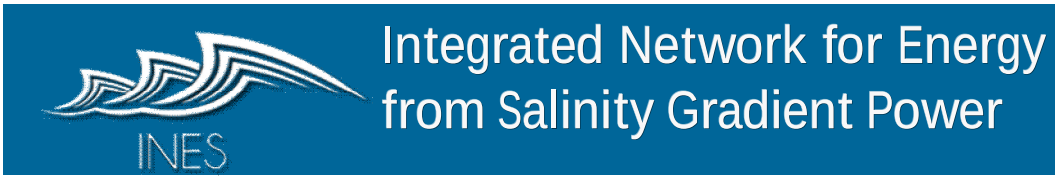
Dr Riek Siebers
REDstack Blue Energy Initiative
Director of REDstack

Dr Joost Helsen
REApower project
Flamish Research Institute VITO

Mr Rober Schroeder
Protection of Water Resources, DG Environment
European Commission

Dr. Peter Stenzel
Juelig Institute for Energy and Climate

Table of Contents



SUMMARY

This INES workshop was held in Brussels the 20th of June 2012. It was an official event from the Energy Week organized by the European Commission. The workshop was held in the permanent representation of The Netherlands to the EU and it was the first approach from the INES group to meet with European representatives and policy makers. Five different Directorate Generals where present in the meeting: External Action, DG Environment, DG Mare, DG Clima and DG Regio.

Amongst the objectives of this meeting was highly relevant the communication of the potential and difficulties on the sector added to the presentation of the different technologies on Salinity Gradient Power (SGP) generation. The members where successful in showing the state of the art and potential to the representatives of the EU and to new potential partners.

The presentations of this seminar were much focused on Reverse Electro Dialysis, Capacitive Mixing process and on the possibilities and hurdles for further developments on salinity gradient taking in account environmental effects which gave a robust vision of the general situation of the industry.

This approach was very useful to give more visibility on the developments on the SGP generation industry and to explore collaboration with European bodies such as the European Innovation Partnership on Water.

Programme

Permanent Representation of the Netherlands to the European Union

INES Seminar in Brussels 20/06/2012

Avenue de Cortenbergh 4-10 / Kortenberglaan 4-10
1040, Brussels—Belgium

09:00	Meeting room open

OPENING

09:15	Introduction and update INES. *Dr. Frank Neumann, Director of the Institute for Infrastructure Environment and Innovation (IMI).*
09:30	CAPMIX project *Dr Bert Hamelers, scientific coordinator of Capmix* *Program director of Wetsus*
10:15	Update RED pilot plant in Friesland *Dr. Rik Siebers, Director of REDSTACK Blue Energy initiative*
10:45	*Short Break*
11:00	REApower project progress - RED and energy from desalination - saline waste water *Dr. Joost van Helsen, VITO*
11:30	European Water Innovation Partnership. *Robert Schroder, European Commission*
12:00	International Perspective on Salinity Gradient Energy: possibilities and hurdles for further development – brief panel discussion- introduction by: *Dr Peter Stenzel Juelig Institute for Energy and Climate*
12:45	Conclusions and closure meeting ends
13.00	Network lunch

Dr. Frank Neumann
Institute for Infrastructure, Environment and Innovation

Dr. Frank Neumann was a moderator and he give an overview of the INES network and the potential of marine sources. He presented the problematic and potential of the different technologies on salinity gradient towards a more solid development.

Potential of marine resources:

Resource	Power (TW)	Energy Potential (m)
Ocean currents	0.05	0.05
Ocean waves	2.7	1.5
Tides	0.03	10
Thermal gradient	2.0	210
Salinity gradient	**2.6**	**240**

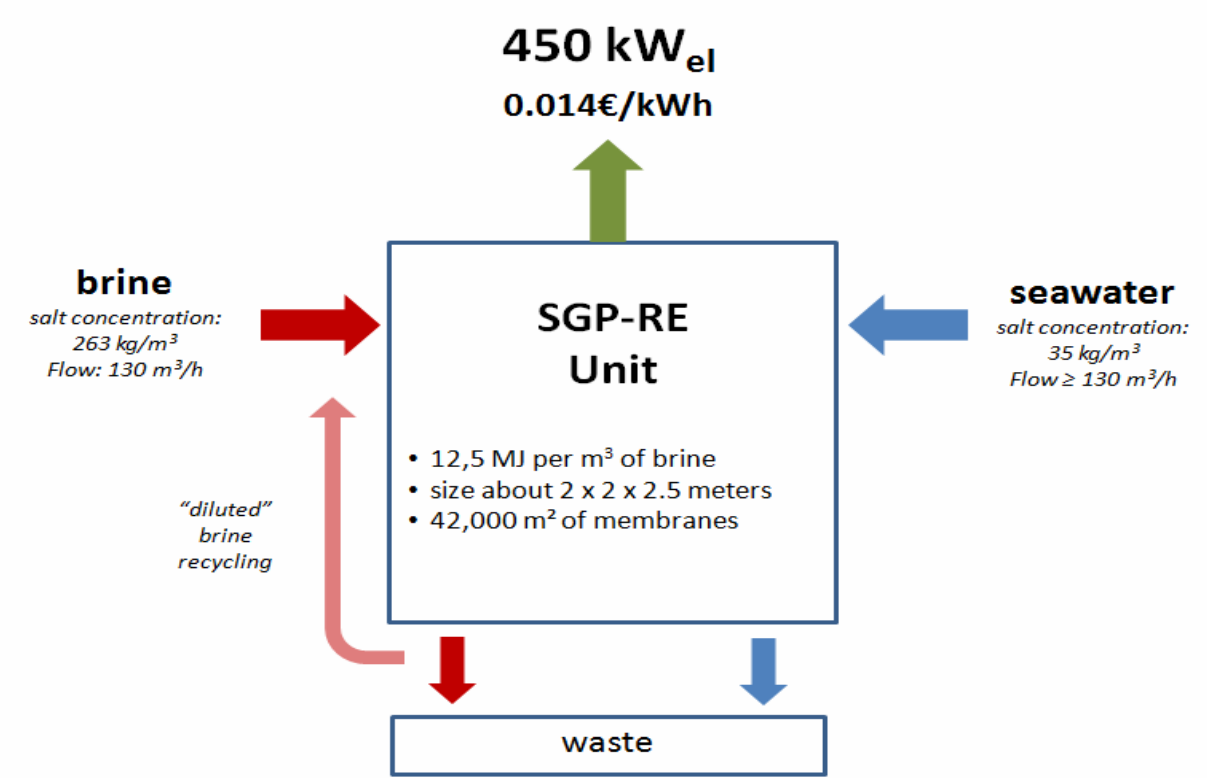
PRO perspectives of Statkraft:

- 2012
  - Selection and validation of the concept
  - Membranes producing 4W/m²

- 2014
  - Construction and deployment of a plant of 2MW (pilot project) to demonstrate the capacities of the concept
  - Energy efficiency of 60%

- 2017
  - Demonstration of a plant of 25MW. Production and selling of electricity on the market. Lowering of costs and construction of a plant with more capacity
  - Energy efficiency of 80%

REApower Vision:



Common Issues Salinity Gradient Power Sector

1) Membrane development/ biofouling of membranes.

2) Not much dedicated membrane producers yet.

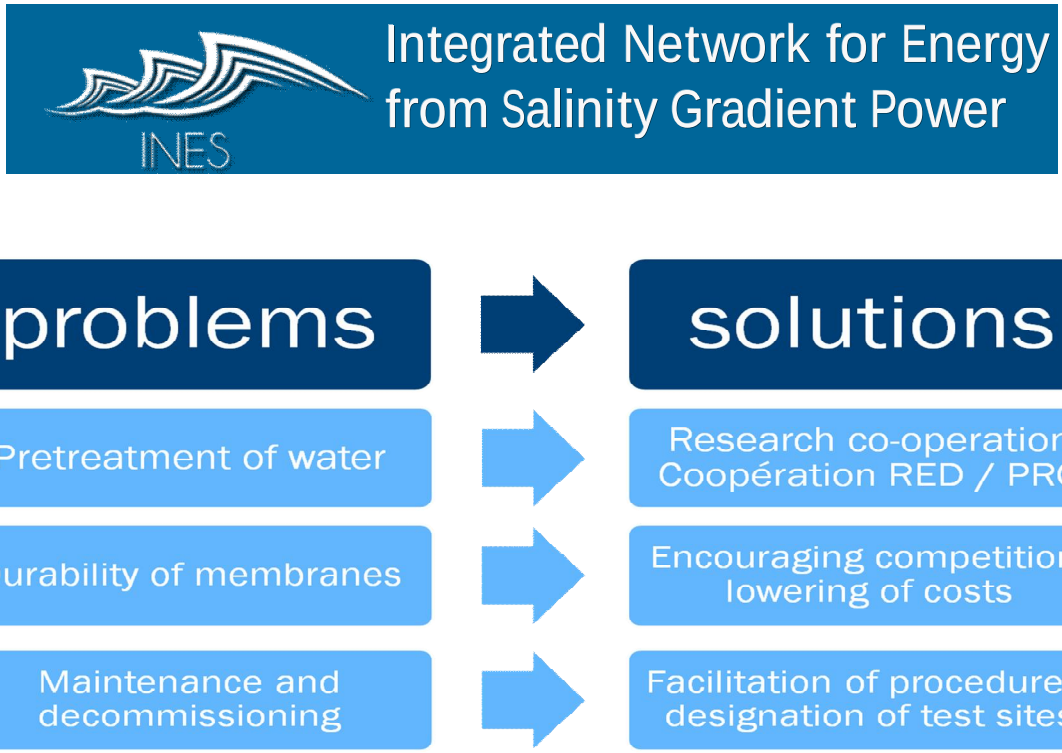
3) Lack of end-users (Energy Agencies, Installation builders) in the network.

4) Financing of pilot projects difficult for some.

5) Not very well known with relevant institutions (EU/IRENA/Investors).

6) Necessity of more actors in the supply chain in general.

7) Uncertainty about environmental/ecological aspects.



INES objectives:

1) Co-operation on common problems.

2) Aiding in developing a true market chain and ease the dissemination of information.

3) Join scientific, governmental and commercial partners to come to more solid and robuste development.

Priorities ahead:

- Focus on global resource analysis and general update salinity gradient energy for IRENA (International Renewable Energy Agency), other agencies.
- Increase co-operation with Asia, Middle East, Latin America, US.
- Pilot projects in Singapore, South Korea, Netherlands, Canada, Norway Australia.
- Global resource analysis on Salinity Gradient resources.
- Technology/ Project update for Policy makers.
- Pilot projects in Singapore, South Korea, Australia, The Netherlands and Middle East.

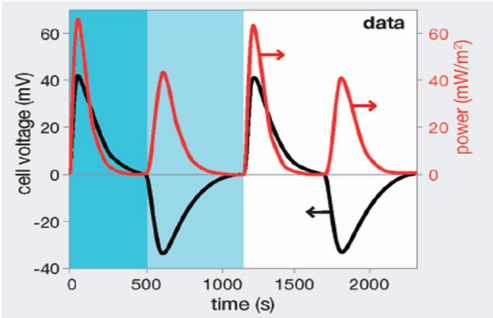
Integrated Network for Energy from Salinity Gradient Power

Dr Bert Hamelers
Program director of Wetsus

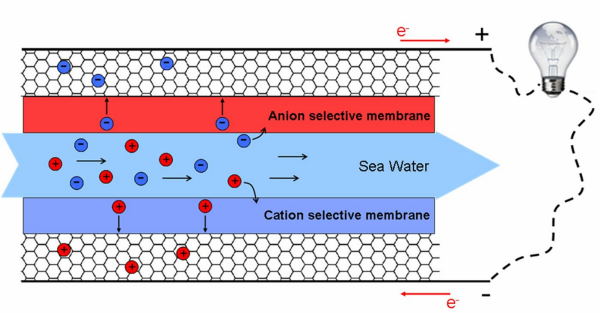
wetsus
centre of excellence for sustainable water technology

Dr Hamelers presented Capmix programme of Capacitive Mixing from Wetsus. He has presented the benefits and the basic pronciples of the Capmix project using the Donnan membrane driven process:

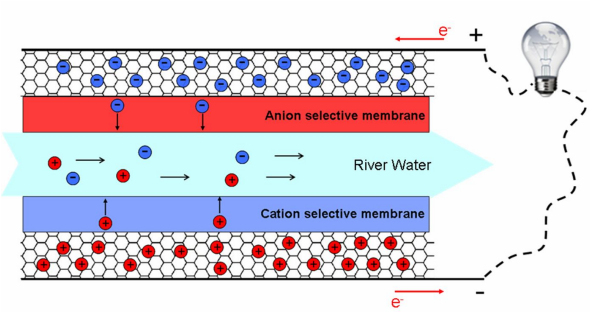
- Continuous energy extraction
- 2 step process
- No external energy supply



Charging process:



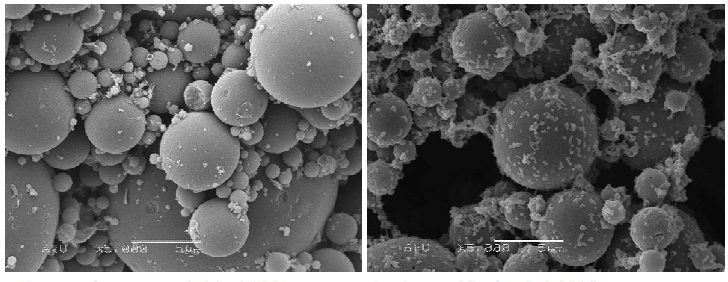
Discharging process:



Selective Absorption—Desorption

Activated carbon + polyvinylidene fluoride (PVDF) binder

- Sea: Absorption
- Fresh: Desorption
- Mixing Energy:
  + Transport from high to low C
  + Reversible operation
- Cicle Operation necessary
- Several driving forces

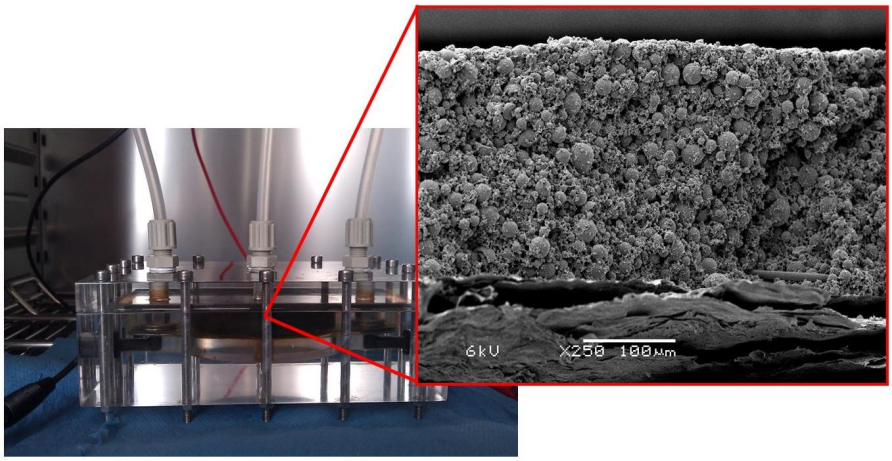


Raw carbon material (x 5000)

Carbon + binder (x 5000)

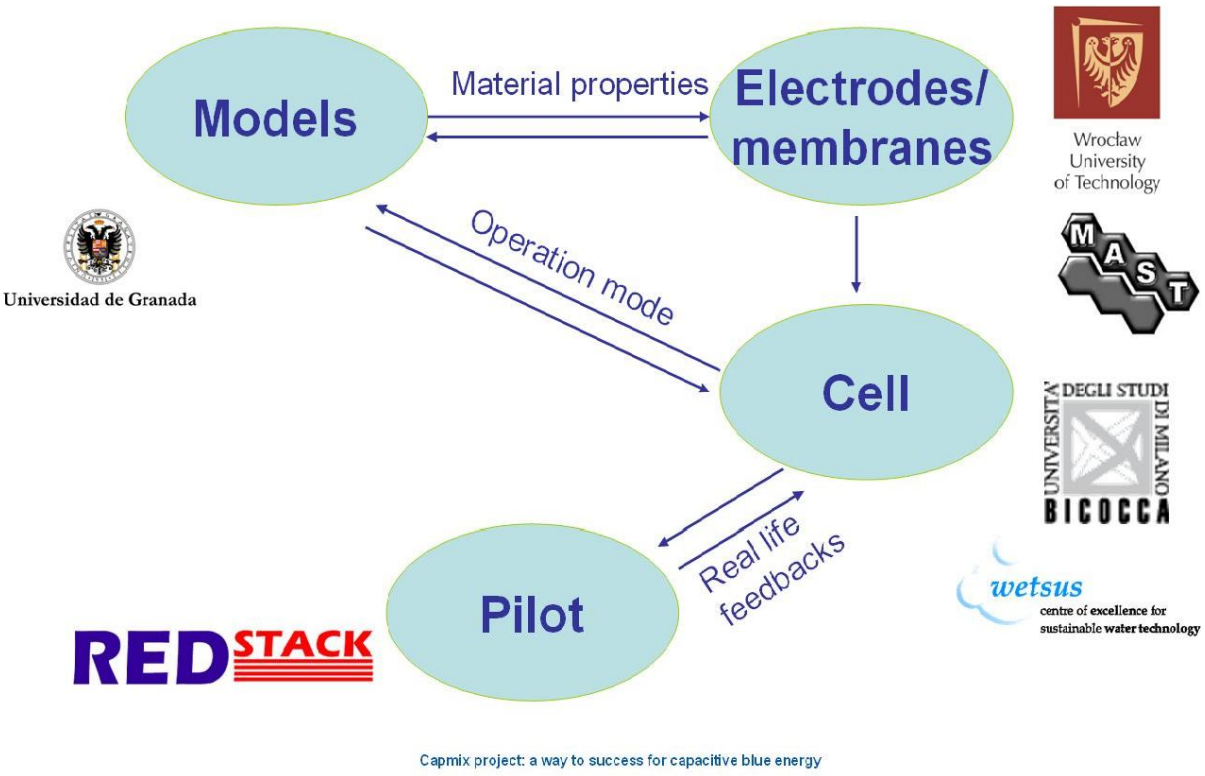
Competitive aspects

- New possibilities for cell-design
  + No stacks
- Direct power conversion
  + No turbine/ electrodes
- Possible positive effects bio-fouling
  + Charge/ discharge
  + No spacer



The Capmix project is working in the framework of the European Seventh Framework Programme (FP7), working with 6 European countries, with 2.4 million Euros of contribution from the European Union:

Capmix strategy and partners



Dr. Rik Siebers
Program director of REDstack

Dr. Siebers gave an update on the internal changes of REDstack and on the facts, financing aspects and schedule of the RED pilot plant in Afsluitdijk in The Netherlands.

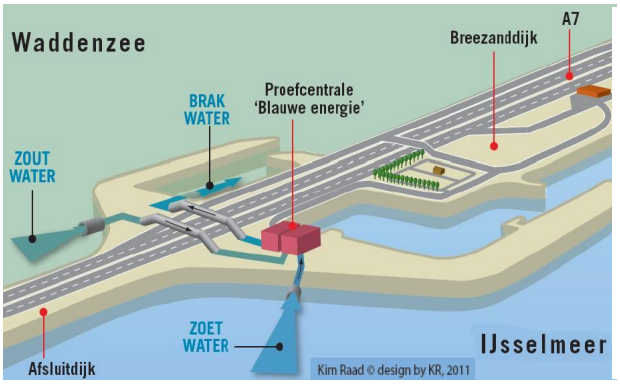
Changes in REDstack

- New Shareholder structure
  - W&F Magneto, Production of Special Anodes (P. Hack)
  - A. Hak, Contractor and Builder for Transportation Solutions
  - Allinder, Manage and Design Energy Infrastructures
- New director
- New funding

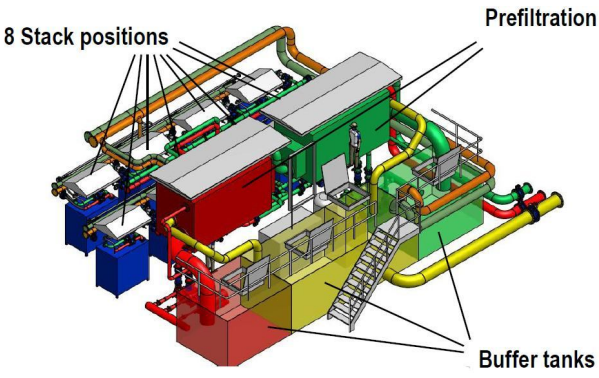
Funding Afsluitdijk

• Public funding	
- SNN and Province of Fyslan	3.35 M
• Private funding	
- Fuijifilm	1.00 M
- REDstack	2.36 M
- Wetsus (in kind)	0.61 M
• **Total**	**7.33 M**

Location



Design



Facts in Afsluitdijk

Numbers:

- 220 m3/h Sea water
- 220 m3/h Fresh water
- Goal after 4 years 50kW installed

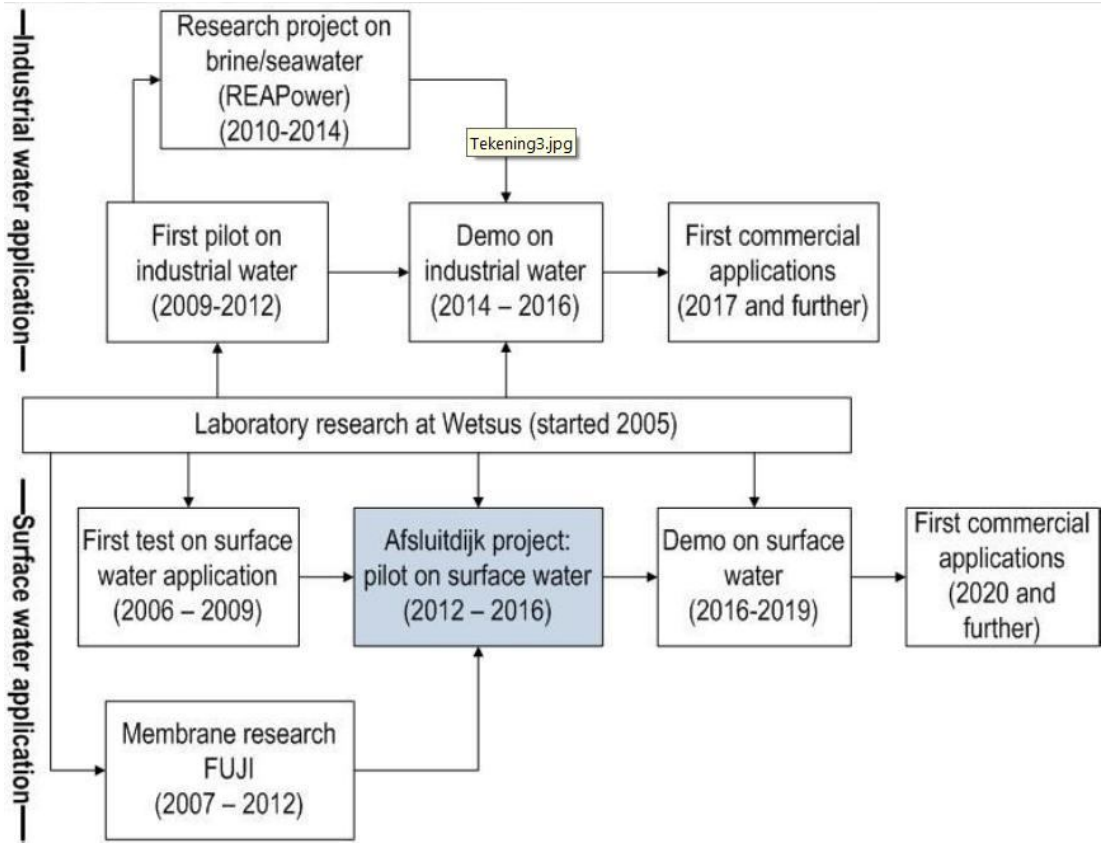
Research Topics:

- Membrane development
- Pretreatment
- Stack development
- System integration
- Environmental impact

Time schedule for Afsluitdijk

- Final design 3 months
- Construction 7 months
- Start-up 2 months
- Research phase 1 21 months
- Research phase 2 15 months

TOTAL **48 months**



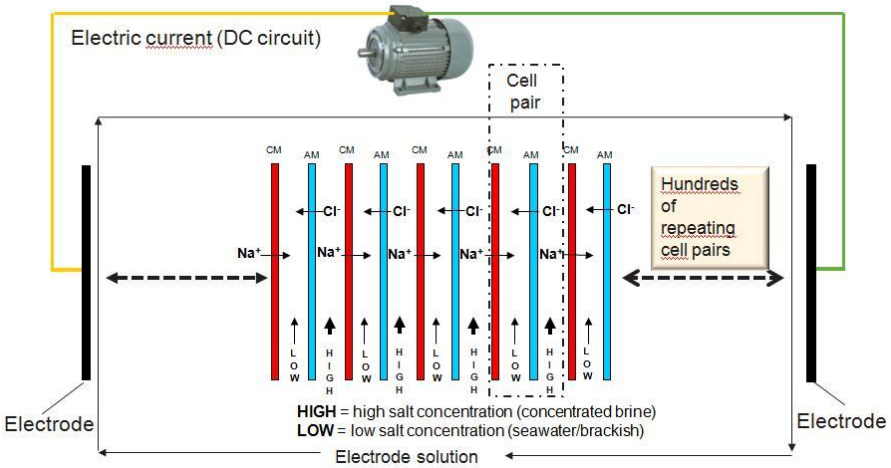
Dr Joost Helsen
Flemish Institute for Scientific Research VITO

Dr Helsen presented REApower project in desalination and power generation. Trough his presentation he presented not only the principle and objectives, but also the REA consortium, work-plan and concepts.

Objectives:

- Target an innovative concept based on RED technology
- Technology working with the extraction of 'osmotic energy' from 2 salt solutions
- Objective: - to prove the concept of Salinity Gradient Power using brine and sea water
  - to develop necessary materials, components and processes
- Time frame: 4 years (October 2012—2014)

EAPower Salinity Gradient Power—RE battery



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

Advantages:

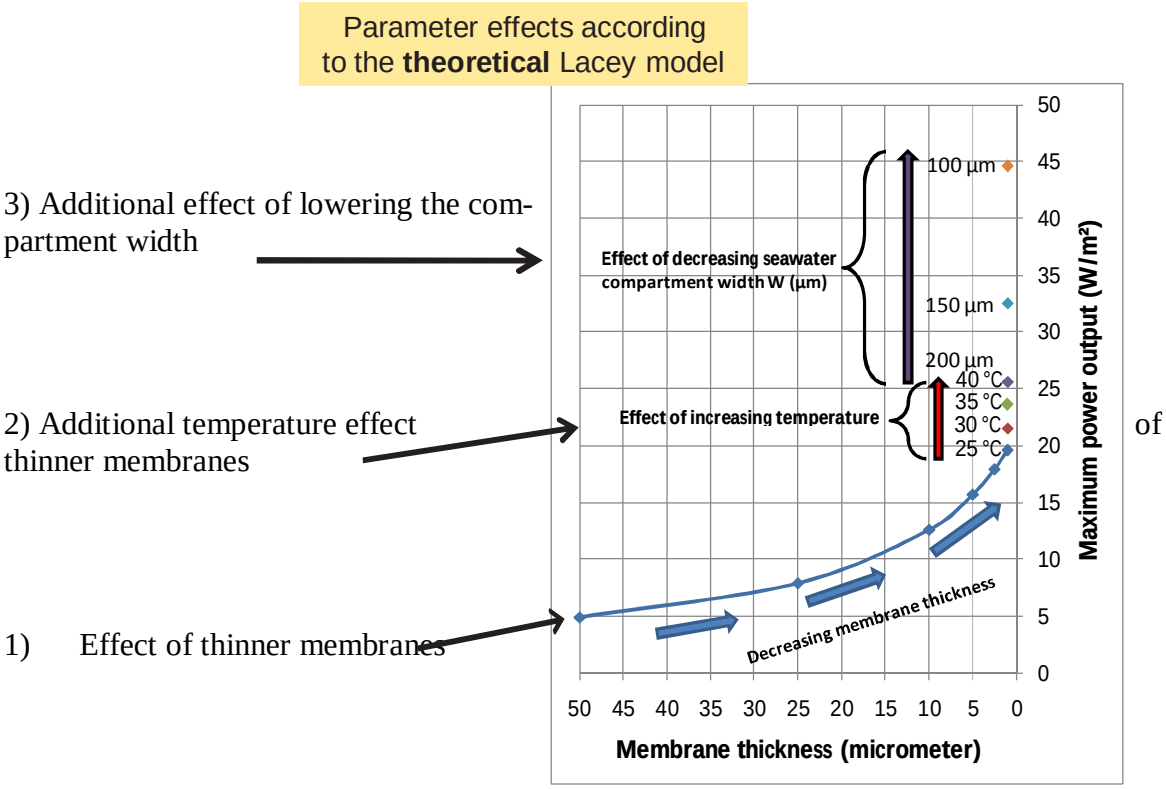
- The use of:
  - Highly conductive seawater (e.g 35 kg/m3) in the LOW compartment
  - even more conductive concentrated brine (e.g. 300 kg/m3) in the HIGH compartment

Creates a low resistance in both the HIGH and LOW battery compartments.

Results

- opportunity to target a low total internal resistance within the SGP-RE battery cell-pairs through the introduction of thinner membranes
- Lower, internal battery resistance should significantly promote a higher power density of the SGP-RE battery.

Theoretical effect of parameters



Internal battery resistance:

In theory, assuming :

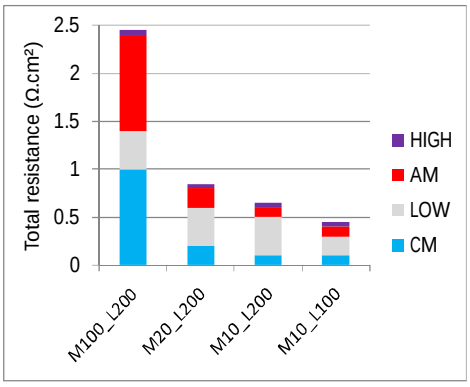
- simplified series of resistances
- AM and CM : specific membrane resistance of 100 Ω.cm
- seawater : 20 Ω.cm (about 50 times lower than fresh water !)
- brine : 2.5 Ω.cm

Theoretical indication of the internal cell pair resistance optimization window

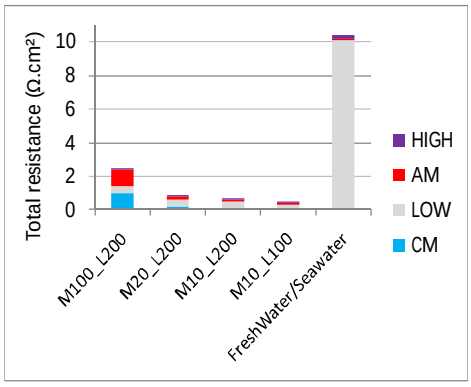
CM membrane		LOW compartment		AM membrane		HIGH compartment		Total resistance	
(µm)	(Ω.cm²)	(µm)	(Ω.cm²)	(µm)	(Ω.cm²)	(µm)	(Ω.cm²)	(Ω.cm²)	(%)
100	1	200	0.4	**100**	1	200	0.05	***2.45***	***100***
20	0.2	200	0.4	**20**	0.2	200	0.05	0.85	35
10	0.1	200	0.4	**10**	0.1	200	0.05	0.65	26
100	1	**100**	0.2	**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

Lowering the internal battery resistance:

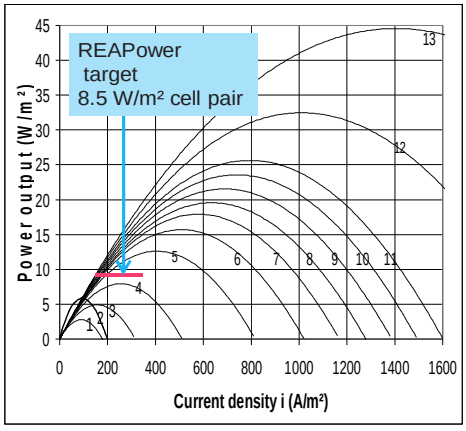
Brine and seawater



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

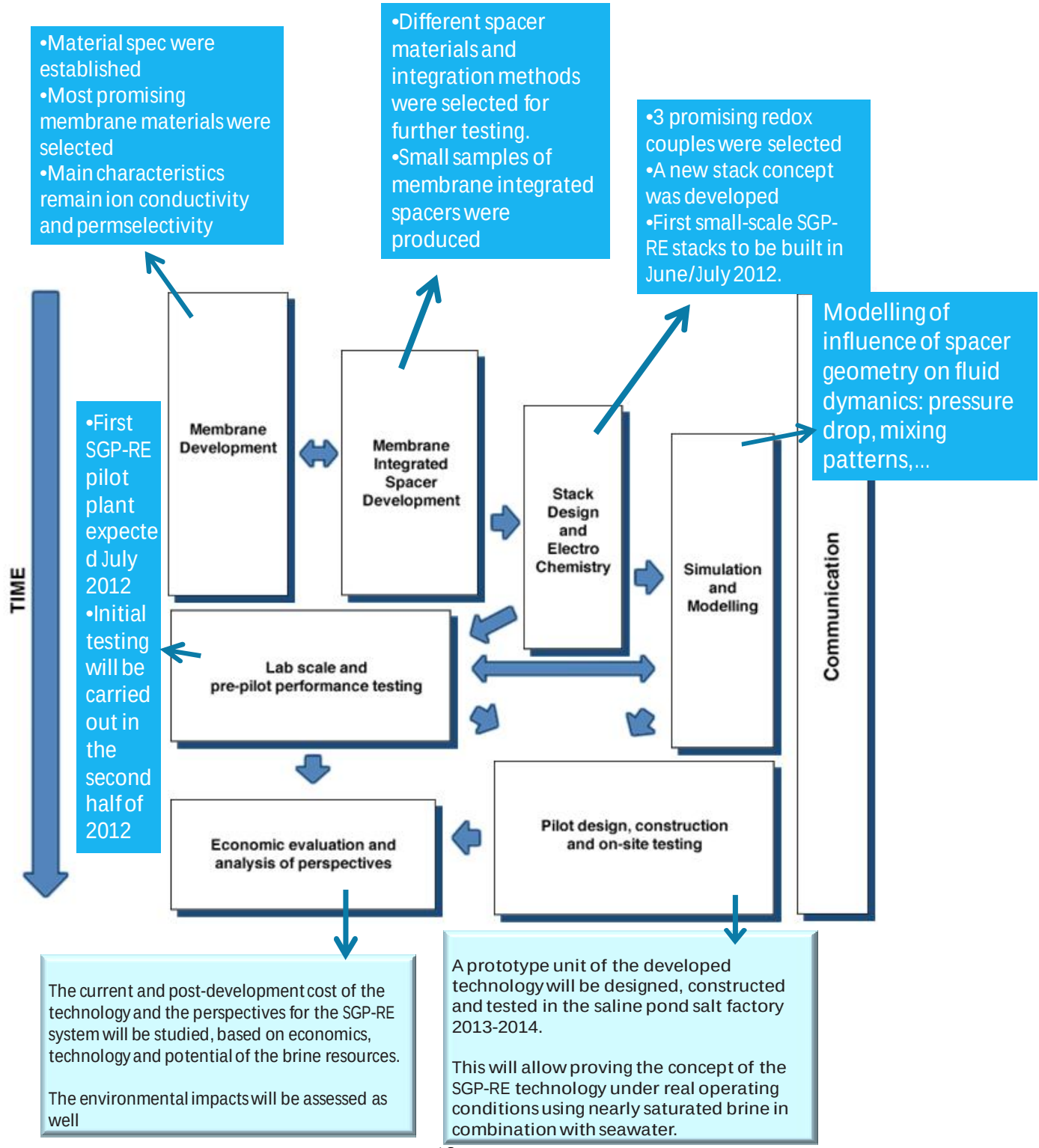


Power output indications from Lacey model



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

Repower work plan – status



Challenges for coming years

- Development of thinner membranes in an integrated membrane-spacer design
- feed pre-filtration at low cost
- Fouling/scaling issues?
- prove technology on lab-scale and scale up to fieldtest pilots

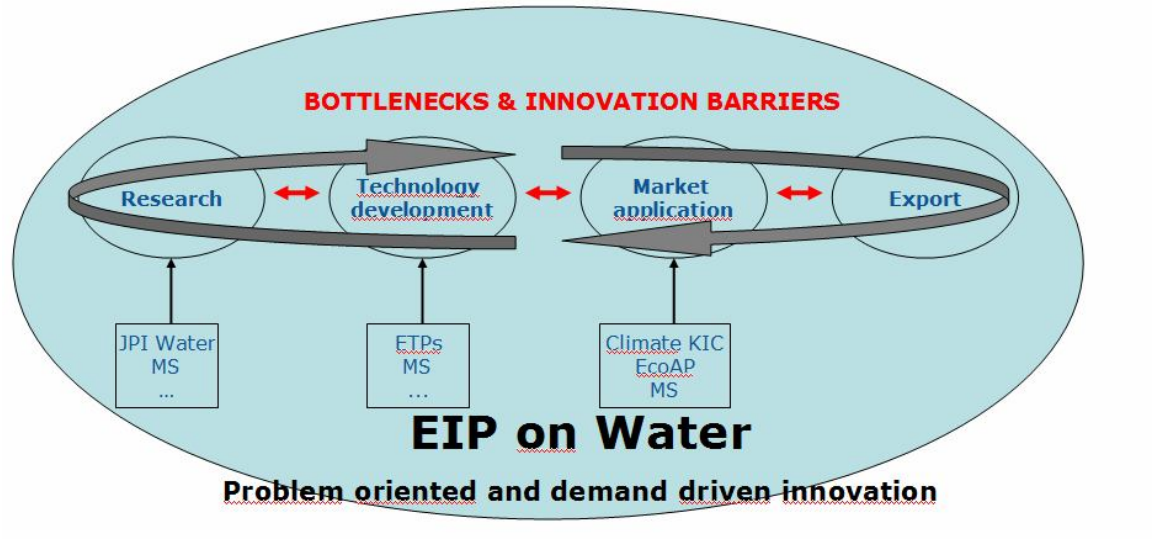
REAPower consortium

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	

Rober Schroeder
DG Environment, European Commission

The European Innovation Partnership on Water was presented by Mr Schroeder. This is a new European body crated in 2012. It aims to tackle specific problems of innovative water innovation.

EU added value



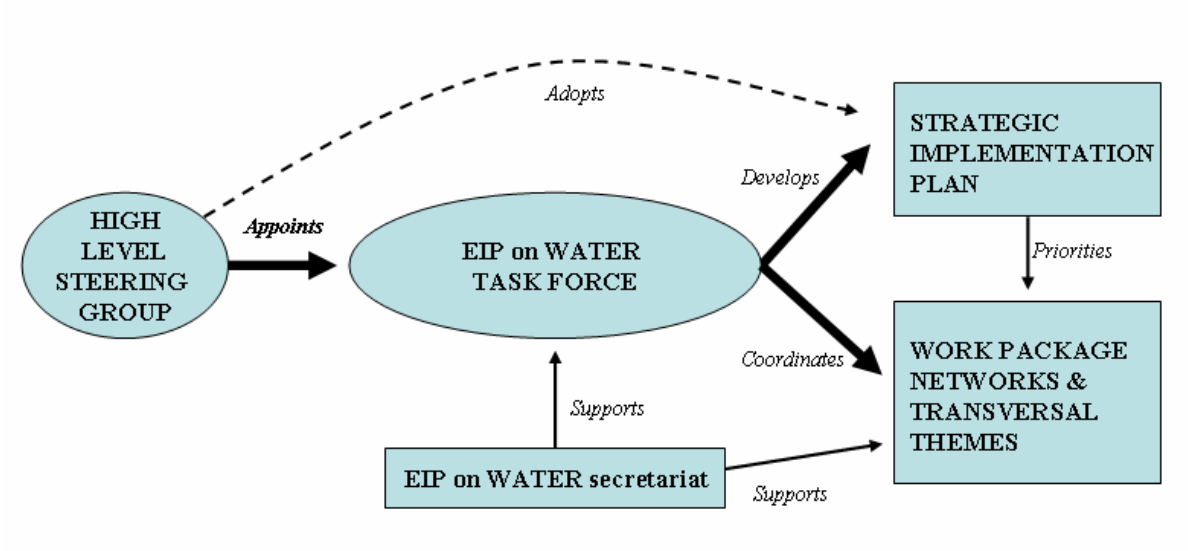
Output of the EIP

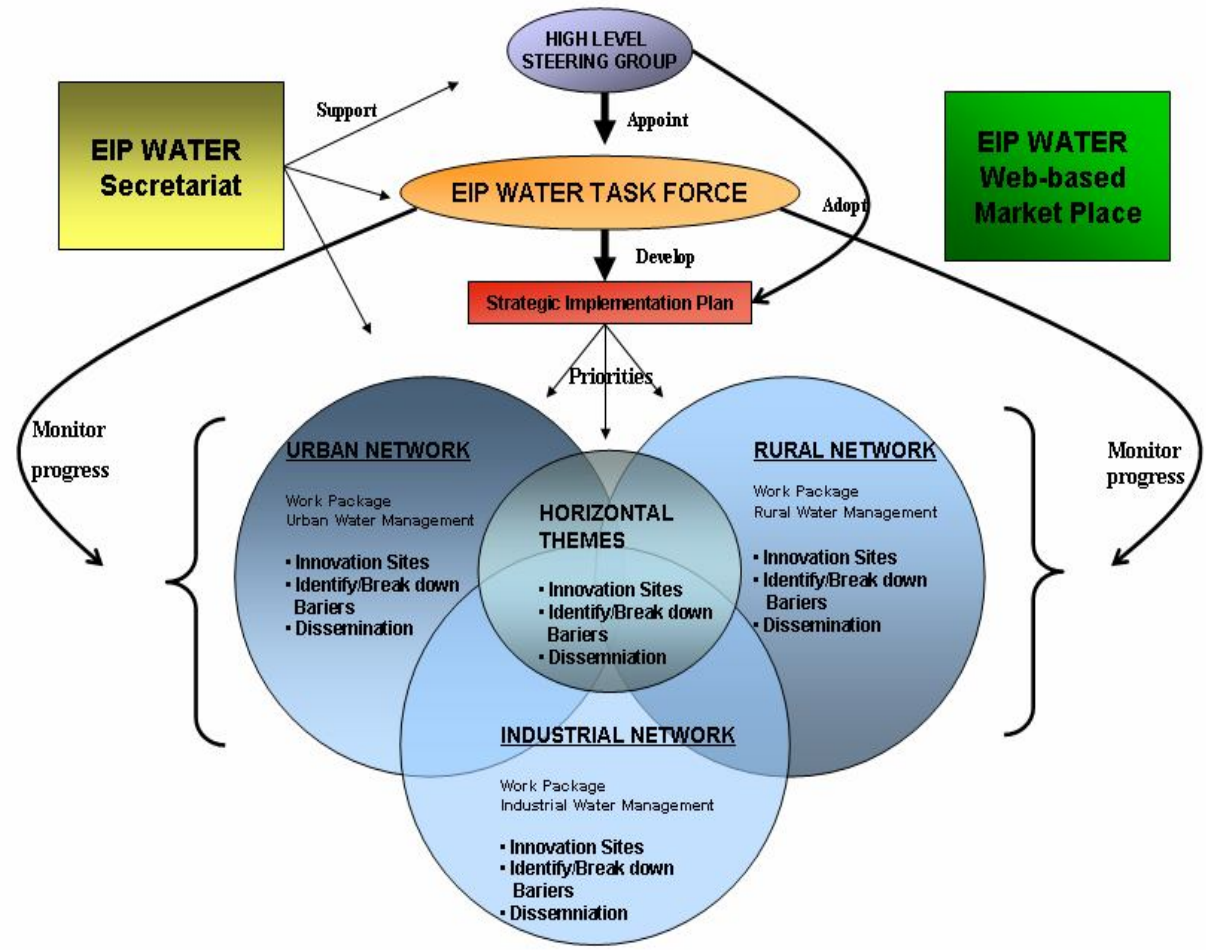
- 2013 - Web-based Market Place
- 2015 - Identifying and breaking down barriers to innovation
- 2020 – Solutions to 10 major water challenges
  - Innovation Sites – demonstration projects
  - Dissemination strategies

The EIP on Water is NO new funding instrument – but:

- Mobilize various existing EU funding mechanisms
  - •FP7 – call 2013 work programme Environment theme – under negotiation
  - •Horizon 2020
  - •Structural and cohesion funds
  - •LIFE
- Leverage with National / regional / private funding

Governance


Adopts
STRATEGIC IMPLEMENTATION PLAN
Develops
HIGH LEVEL STEERING GROUP
Appoints
EIP on WATER TASK FORCE
Priorities
Coordinates
WORK PACKAGE NETWORKS & TRANSVERSAL THEMES
Supports
EIP on WATER secretariat
Supports


HIGH LEVEL STEERING GROUP
EIP WATER Secretariat
Support
Appoint
EIP WATER TASK FORCE
Adopt
EIP WATER Web-based Market Place
Develop
Strategic Implementation Plan
Priorities
Monitor progress
URBAN NETWORK
Work Package
Urban Water Management
• Innovation Sites
• Identify/Break down Bariers
• Dissemination
HORIZONTAL THEMES
• Innovation Sites
• Identify/Break down Bariers
• Dissemniation
RURAL NETWORK
Work Package
Rural Water Management
• Innovation Sites
• Identify/Break down Bariers
• Dissemination
Monitor progress
INDUSTRIAL NETWORK
Work Package
Industrial Water Management
• Innovation Sites
• Identify/Break down Bariers
• Dissemniation

Dr Peter Stenzel
International Perspective on Salinity Gradient Energy

Dr Stenzel presented the applications for salinity gradient power plants.

Open systems (continous operation)

- River and sea water
- Wastewater (e.g. industrial waste water, mining solutions, desalination brine)
- Natural salt resources (e.g. salt lake, salt domes underground gas storage)
- Hydrothermal solutions (combination with geothermal energy)

Interesting:

Solutions with a high concentration difference

➡ High osmotic and operation pressure

➡ High specific membrane power

➡ Good economics

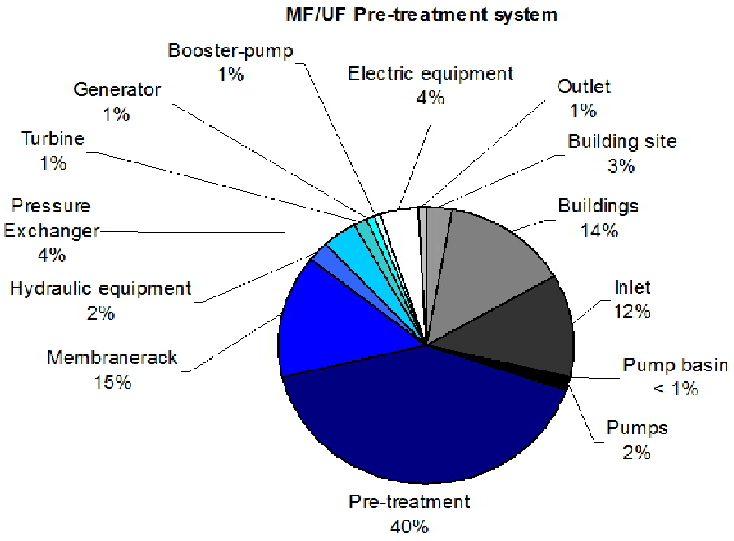
Closed systems

- Osmotic heat engine (continous operation)
- Osmotic storage plant (batch operation)

River and sea water

Economic modelling:

Cost share for the components of a PRO plant (1 m³/s, volume flow ratio 1:1) with MF/UF pre-treatment and open intake



Key aspects to reach a reasonable cost range:

- Operation with limited pre-treatment system

  - Robust membrane modules with a long lifetime required

  - Membrane development is more than optimizing the membrane performance (W/m^2)

- Short water transport system to limit the intake costs

  - Selection of suitable sites

Wastewater

Industrial waste water and mining solutions (e.g. potash or hardcole mining)

- Legal framework limits the impacts on the river ecosystems
- Amount and concentration limits for waste water discharge
- Power plant operation depends on the waste water availability
- Difficult (financial) planning (long term availability unclear)
- High concentrated solutions limited to individual cases e.g. potash mining

Top 20 chlorine dischargers in Germany

Company	Location	chlorine load per year	c
Dow Deutschland GmbH & Co. OHG	Stade	1.910.000 t	
K+S KALI GmbH	Philippsthal	1.240.000 t	
Solvay GmbH	Rheinberg	652.000 t	
K+S KALI GmbH	Heringen	574.000 t	
Solvay GmbH	Bernburg	516.000 t	
K+S KALI GmbH	Unterbreizbach	496.000 t	
Emschergenossenschaft	Dinslaken	340.000 t	
Bayer AG/Lanxess AG	Dormagen	320.000 t	
Sodawerk Staßfurt GmbH & Co. KG	Staßfurt	308.000 t	
BASF SE	Ludwigshafen	245.000 t	
RAG Deutsche Steinkohle	Ibbenbüren	205.000 t	
Bayer AG/Lanxess AG	Leverkusen	200.000 t	
RAG Deutsche Steinkohle	Hamm	164.000 t	
Bayer AG/Lanxess AG	Krefeld	120.000 t	
RAG Deutsche Steinkohle	Bottrop	93.800 t	
RAG Deutsche Steinkohle	Gelsenkirchen	78.900 t	
K+S KALI GmbH	Zielitz	77.700 t	
K+S KALI GmbH	Neuhof	71.700 t	
GRACE Manufacturing	Worms	61.600 t	
RAG Deutsche Steinkohle	Duisburg-Walsum	56.100 t	

< 35 g/l

> 100 g/l

Desalination:

- Operation with desalination brine and ocean water (low concentrated solution) is not applicable
- Limited concentration difference and membrane polarisation problems
- Solution with low salinity is required – Availability and Applications?!

Natural salt resources

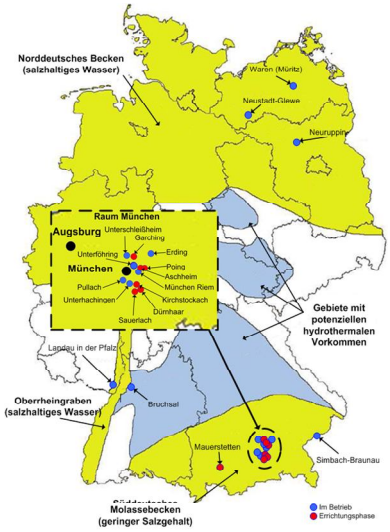
Salt lakes

- High concentrated brine available (100 to > 300 g/l)
- Fresh water availability constricted (site specific)
- Ecology and water management of the salt lake has to be considered

Salt domes / salt caverns

- Combination with underground gas storage projects possible
- High concentrated brine available (approx. 300 g/l)
- Brine discharge into the ocean to limit environmental impacts
- Brine avilability linked to the production process (fluctuating, no long term availability)
- Brine might contain significant amounts of dissolved solids (depending on geology and feed water quality)
- Possible synergies with existing infrastructure (e.g. inlet, water transport system)

Geothermal energy in Germany



Hydrothermal solutions

- High concentrated solutions available (depending on geology)
  - Neustadt-Glewe: 204 g/l
  - Neuruppin: 200 g/l
  - Bruchsal: 125 g/l

Problems:

- Volume flow increases due to salinity gradient power generation
- Re-injection and / or disposal of the water mixture problematic
- Degasification of dissolved gases
- Controlled degasification and disposal required
- Typically low volume flows (site specific - depending on geology)

Applications for salinity gradient power plants

1. Open systems (continous operation)

- River and sea water → High potential but limited concentration difference (economics very site specific and depending on further membrane development)

- Wastewater
- Natural salt resources

→ Limited overall potential but very interesting individual applications existing (high concentrated solutions, good economics expacted, multi-stage concepts possible)

Different, high pressure membranes required?!

- Hydrothermal solutions → Applications unlikely

INES Workshop conclusions

Five representatives of different General Directorates from the European Commission were present at the meeting in Brussels: External Action, DG Environment, DG Mare, DG Clima and DG Regio. A selected group of specialists gave a practical and dynamic approach on SGP industry.

On the other hand, it was particularly interesting to have some feedback from an institutional point of view.

The EU representatives had shown great interest for Salinity Gradient Power (SGP). Even if the general approach to SGP technologies is generally underestimated due to its early development stage, policy and decision makers are increasingly interested in this renewable source.

In a future perspective, this meeting was helpful to start conversations to include SGP as a reliable renewable source in the next European funding programmes in order to facilitate the development of the industry.

Some important points to set after the meeting:

- INES was invited to participate on the new European initiative from the commission: the European Innovation Partnership on Water (EIPW). This was a very important and positive input and a clear interest from the European Commission. Their aim is to facilitate existing platforms working on water and marine energy and to tackle the main difficulties to develop technology. This partnership is due to help out talking the main obstacles for development.

- INES was invited to react on the new Ocean Energy consultation (DG Mare) that the European Commission is currently working on. This will be very helpful to introduce salinity gradient energy as a RES and be officially recognized by the European and International Institutions.

- From the side of the European Commission, desalination is becoming increasingly an important issue. Salinity gradient energy could be a potential solution to tackle energy consumption in desalination plants.

INES Workshop conclusions

- The possibility of developing a global resource analysis will be explored in order to state a SG global potential. This issue will be discussed in our next meeting in Milan in September 2012.

- The interest for the Network was expanded to the far east where a new partner formalised its membership after this meeting. The Yamaguchi University of Japan and the University of Palermo will be of great importance as expert members and will be introduced in our future meetings.

Follow-up actions:

- Follow-up with the interested European bodies and representatives of international relevant bodies. Keep on assessing European and International bodies to be part of their agenda (such as the new KIC's, horizon 2020, WDB, etc).

- Starting-up a general discussion between INES' members in order to standardize the measurements on efficiency of membranes in order to be able to made a comparable analysis and drive the industry towards a more clear way to state a pricing base to work on later commercialization. This should kick-off next September in our meeting in Milan.

- Furthering international cooperation not only in an academic but also in a practical way. This should stimulate competition in order to lower prices and encourage the private sector to take a more active role on the development of the sector.

- Presenting new developments and pilot projects (stating aims and goals) to stimulate the development of new pilot plants following the example of the initiatives of Singapore and The Netherlands.

- Stimulating environmental companies and organizations to collaborate in the project. This is aimed to start a deep exploration on the ecological aspects of the application of a power plant in order to avoid future barriers obtaining permits and licences to facilitate the implementation of power plants.

Pictures from the conference

INES participants photo

Pictures from the conference

INES presentation


Presentation DG Environment


Presentation from VITO


Networking and coffee break


Julich institute presentation


Discussion on technical aspects

THE INSTITUTE FOR INFRASTRUCTURE, ENVIRONMENT AND INNOVATION is an independent Brussels-based non-profit organization. Its mission is to initiate and implement projects at European and local level that demonstrate that the development of infrastructure can be reconciled with nature protection and environmental goals.

Apart from initiating, financing, and developing European and International co-operation focusing on sustainability, occasionally the Institute also gives individual, practical, organisational and legal advice with respect to the implications of European and International Nature Protection Policy for projects and plans.
IMI gives advice on infrastructure projects, management plans and nature restoration measures, in relation to Natura 2000, not only in coastal zones and estuaries, but also on land based projects, and provides legal risk analysis and checks conformity with International and European nature protection legalization for development projects, nature restoration measures and integral management plans.

Project funding of the Institute comes mainly from national, local, and regional governments and government project organisations. The start-up of new projects is mostly done independently by the Institute on its own behalf. So far, the working programme has particularly focused on infrastructure within coastal zones, coping with environmental protection and also renewable energy production, implementing and promoting innovative techniques.
IMI is also involved in Marine, Wind and Solar energy and more recently energy generation through salinity gradient and network creation on tidal energy for knowledge sharing. These are the fields in which IMI is active.

The Institute employs a small multi-disciplinary and international staff. Working languages include English, French, Dutch, Spanish and German.

Institute for Infrastructure, Environment and Innovation (IMI)
125, Hoogstraat/ Rue Haute
BE-1000 Brussels
Belgium
Tel: +32 (0)2 511 66 02
Fax: +32 (0)2 511 24 66
www.imieu.eu