Panel Discussion
Water Management in Power Industry: MATChING project

Panelist

CHAIR
ENEL *Daniela Galla*

Utilities
EGP *Alessio Bardi*
ENGIE LAB *Dominique Corbisier*
ENDESA *Andres Sanchez-Biezma*

Research Organizations
CNR-ITM *Prof. Drioli*
DTI *Ricardo Losada*

VITO *Sofie Van Ermen*
Leo De Nocker
Johan Van Bael

Target

- Use of alternative (less quality) water sources
- Treat of wastewaters to make them compliant with environmental regulations
- Reuse of water streams
- Improve efficiency of cooling systems

Open Questions

- How is the Matching project responding to the water crisis and new future scenarios
- Water related projects in geothermal and thermal technologies
- New technologies and their potential.

Taking into account the climate change and the new global scenario how has the focus on research on water and cooling systems changed during the last 10 years and how is the Matching project responding to this?

ENGIE/ VITO (8')

Evolution on research focus on water and cooling systems in PP- Engie perspective

1 Evolution in PP R&D topics

Process Efficiency

Clean Flue Gas

Water scarcity

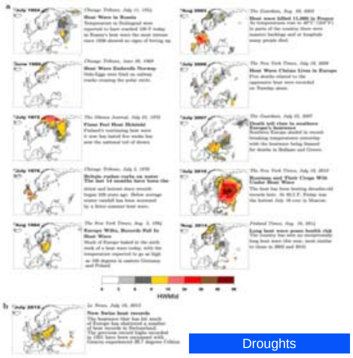
Creation of working groups

2

- Limited strategies: Stop or reduce the load

- Lime softening
- Alternative water sources
- Advanced water treatment
- Air cooled condenser

Rather limited
Always old technologies



3 Open questions: impact OPEX, CAPEX, REX, cost benefit for innovative solutions

Water make up | Blowdown | Plume

MATChING Answer!

vito

OPPORTUNITIES FOR ADVANCED COOLING TECHNOLOGIES FOR THERMO-ELECTRIC POWER IN A HOTTER, WATER-STRESSED EUROPE

- Water –stress ? Competition, conflict over water use

Less visible, but Real in Europe

impact on power output

impact on electricity prices (low flow, water temperature) (Dermot, 2012, Van Vliet et al, 2013)

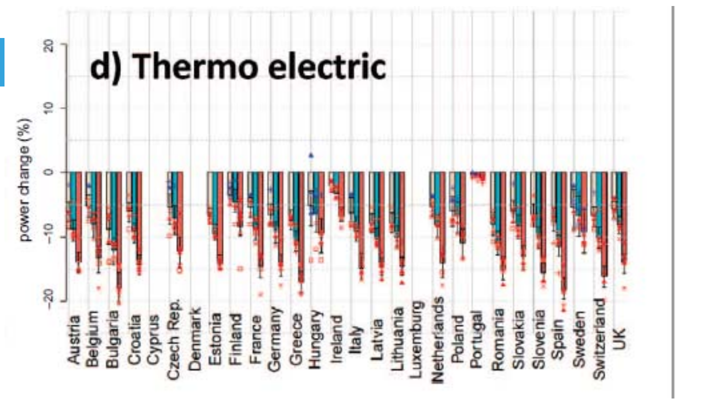
Demand for cooling water ⟺ **Availability** of water (consumption, temp.)

vito

AVAILABILITY OF WATER

EU Water Framework Directive *Good Ecological Status Water bodies* 2027

Quality
Water quantity (floods, droughts)
Competing uses



Vulnerabilities and resilience of European power generation to 1.5 °C, 2 °C and 3 °C warming

I Tobin[1], W Greuell[3], S Jerez[2], F Ludwig[3], R Vautard[1,4], M T H van Vliet[3] and F-M Bréon[1]

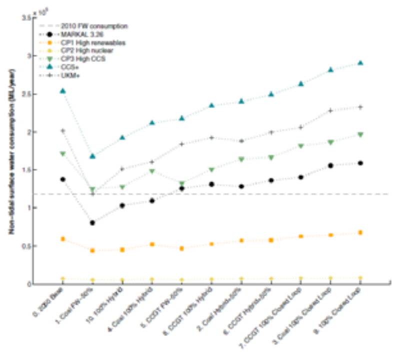
vito

DEMAND FOR COOLING WATER FOR POWER GENERATION

- Increases
- General studies at EU level
- Detailed studies UK
- Global warming
  - Carbon capture and storage
  - Concentration of plants

Table 3
Water requirements for several energy processes in Europe based on Aquastat, 2010; WEC Scenarios, 2007 (model updated in 2009); DOE-NETL, 2008; UNESCO-IHE, 2008; Gleick, 1994

Primary Production (EJ)	2005	2015	2035	2050
Electricity Generation				
Thermal, of which:	3.2	3.7	4.4	5.0



Electricity generation and cooling water use: UK pathways to 2050
Edward A. Byers, Jim W. Hall, Jaime M. Amezaga

RESULTS

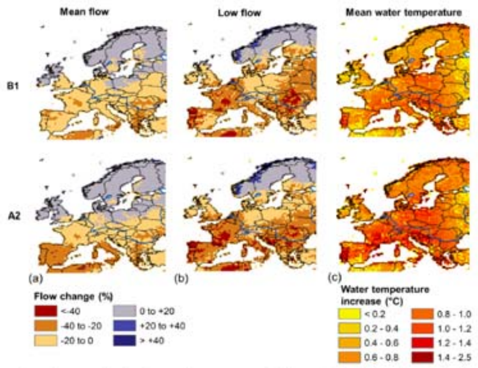
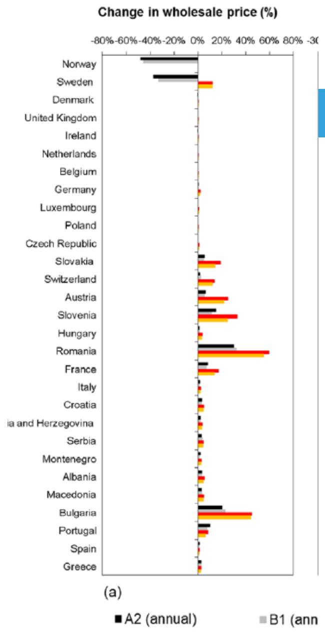


Figure 3. Climate change impacts on low river flows and water temperatures in Europe. Projected changes in mean flow (a) and low flows (10th percentile of daily distribution of river flow); (b) and mean water temperatures (c) for the 2031–2060 relative to 1971–2000. Changes are presented using the GCM ensemble mean changes for both the SRES A2 and B1 scenario relative to the reference period.

Water constraints on European power supply under climate change: impacts on electricity prices

Michelle T H van Vliet[1,2], Stefan Vögele[3] and Dirk Rübbelke[4,5]



LESSONS FOR MATCHING ?

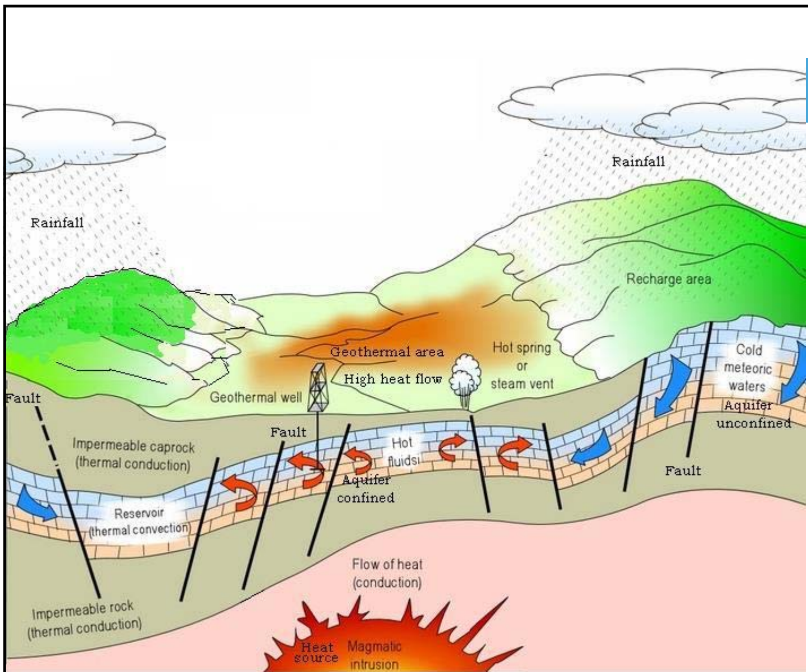
- There is a role for advanced cooling in Europe ?
- Benefits :
  - **energy security , more valuable KWh**

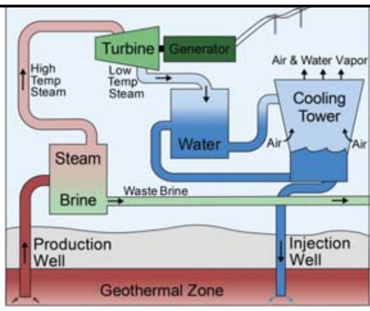
    Risk for constraints (days/year) x kWh/day x €/kWh
  - flexibility in siting
  - good status of water bodies
- Costs:
  - Energy security comes at a cost
  - Competitive to dry and hybrid cooling ?
- Explore drivers of costs and benefits of these technologies

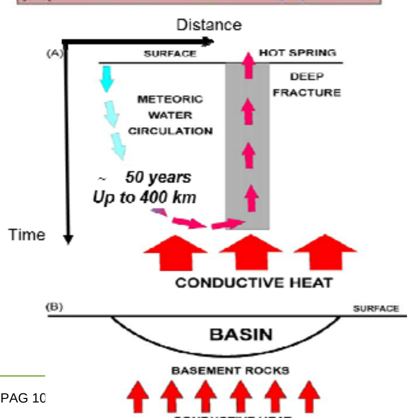
WP 4

How Innovation in Geothermal area can contribute to a sustainable use of hydric resources and energy production?

EGP (5')







Boron production from geothermal fluid

Electricity from geothermal steam

Heat for industry and civil applications

CO2 utilization and water purification

1800

2018

WP 3

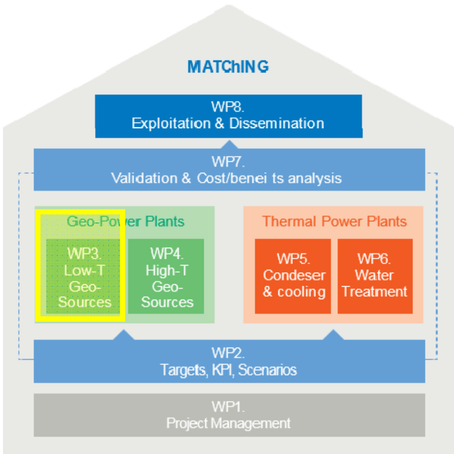
Is cooling of geothermal plants with reduced or without water consumption an option?

VITO (5')

Introduction on WP3

Main objective WP3

To improve electricity production processes from Low-T geothermal sources (100–175°C) considering both the geothermal fluid and the cooling water, maximizing the exergetic efficiency of the geothermal plant and support their exploitation in DG application.

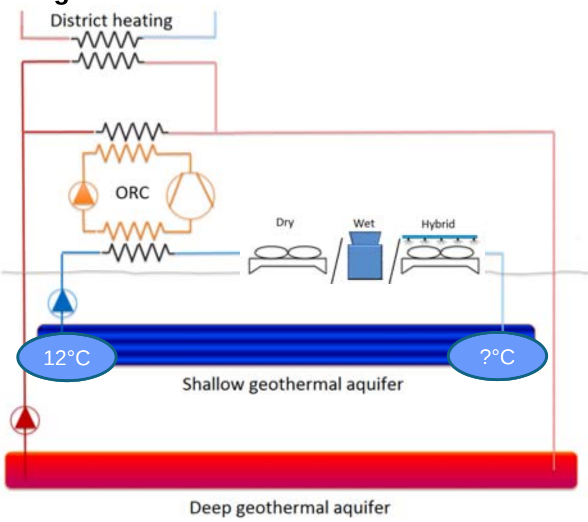


WP3. Hybrid cooling systems for Low-T geothermal source

MATChING
MATERIALS & TECHNOLOGIES FOR PERFORMANCE IMPROVEMENT OF COOLING SYSTEMS IN POWER PLANTS

Task 3.2 Conceptual design of hybrid cooling systems based on GWC for binary plants

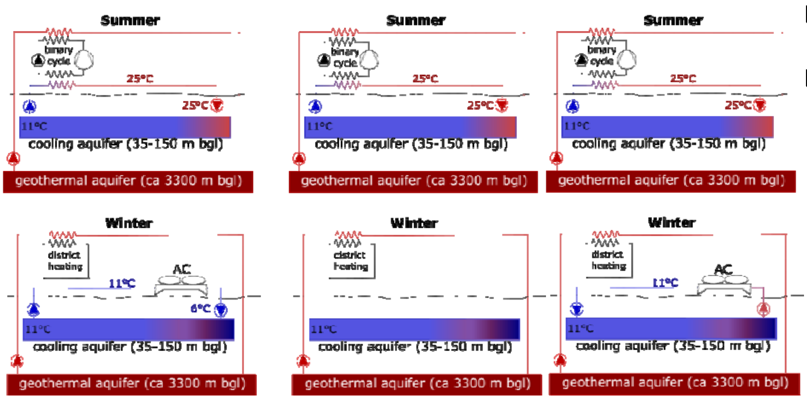
Plant configuration



1) What is the optimal cooling system configuration?
2) What is the optimal policy?

T3.2 Conceptual design of hybrid cooling systems based on GWC

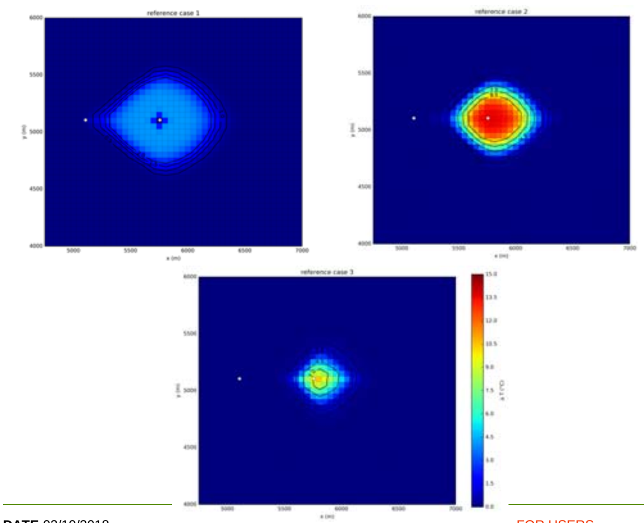
Impact of the use of groundwater for cooling



- ❑ Overview of 3 selected reference cases
- ❑ Combination of
  - ❑ Geothermal wells
  - ❑ ORC
  - ❑ District heating network
  - ❑ Dry cooler
  - ❑ Groundwater cooling

T3.2 Conceptual design of hybrid cooling systems based on GWC

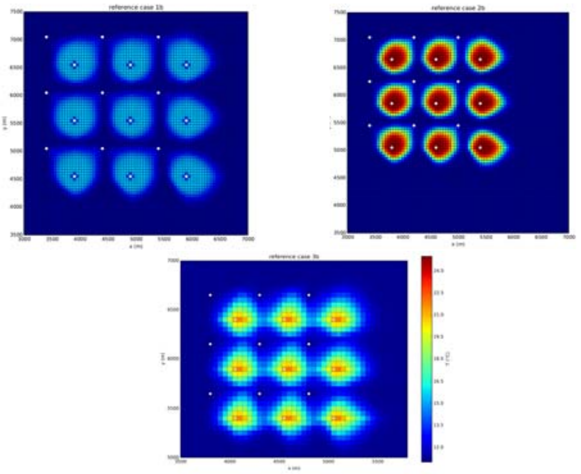
Impact of the use of groundwater for cooling – 1 doublet



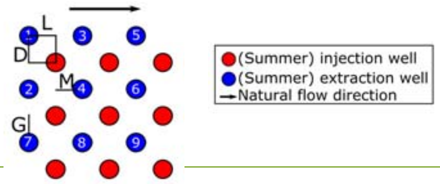
- ❑ Temperature difference after 30 years of operation (Q = 150 m³/h, K = 10 m/day) for the 3 reference cases
- ❑ Case 1 : the temperature remains closest to the natural temperature
- ❑ Case 2 : the thermal plume is smaller, but the temperature anomaly is more severe, with values up to 25°C in its center
- ❑ Case 3: there is also a thermal plume but mainly caused by the advective heat transport with the natural groundwater flow and conductive heat loss to the environment

T3.2 Conceptual design of hybrid cooling systems based on GWC

Impact of the use of groundwater for cooling – multiple doublets



- Temperature plume for the three reference cases after 30 years of pumping (Q = 150 m³/h, Tinj_summer=25°C
- Including additional wells does have an influence on the shape of the plumes, they are now 'pulled towards downstream extraction wells



T3.2 Conceptual design of hybrid cooling systems based on GWC

Impact of the use of groundwater for cooling - conclusions

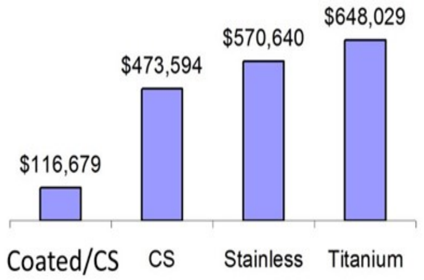
- The models demonstrated that the **well distances required to prevent arrival of the thermal front** within the lifetime of the geothermal system (thermal breakthrough) **need to be in the order of several hundreds of meters**, although the exact distances differ significantly for the three GWC systems evaluated.
- Therefore, it is of vital importance that design studies for specific GWC systems **include aquifer pump tests and analyses on the effects on water quality.**
- **It can be concluded that Groundwater Cooling provides a technically feasible alternative for cooling using Water Cooling Tower, also for larger cooling power, providing that a sufficient thick aquifer is present and a large concession area is available.**
- **VITO developed a groundwater model that can be used for large scale cooling of low-T geothermal ORC installations and industrial cooling**
    - **Optimal location of matrix of doublets to**
        - **Limit the environmental impact**
        - **Reduce thermal breakthrough during lifetime**
    - **Analysis of the thermal plume during lifetime**
    - **Optimisation between groundwater extraction per doublet and number of doublets**

WP 3

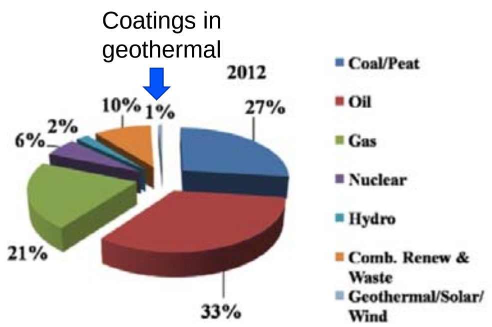
What is the added value of coatings in geothermal applications (test case Balmatt)?

DTI (5')

WP-3



*Thirty-year life-cycle cost comparison between the coating technology and traditional corrosion-resistant materials for a typical brine/working fluid heat exchanger having 800 40-foot-long tubes**



*Coatings in energy applications***

**Geothermal Today. US Department of Energy. Geothermal Technologies Program Highlights (2003)*

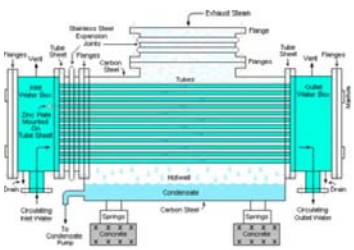
***Keshri A.K., Sribalaji M. (2015) Coatings for Energy Applications. In: Babu Krishna Moorthy S. (eds) Thin Film Structures in Energy Applications. Springer, Cham*

WP 5

In a thermal power plant most of the water is used for cooling. How can we reduce the intake of cooling water and what are the technologies under investigation in the MATChING project to achieve this?

ENDESA (10')

Cooling water in power generation



Around **60% of the heat** used in a thermal power plant is sent to the cooling circuit, requiring a huge amount of water.

Intake water for cooling purposes in As Pontes PP is around 4160 m^3/h

Typical thermal gap in a condenser design move between 8-10ºC, but during operation new inefficiencies appear:

- Climate variations
- Fouling and deposits in the water-side
- Damage on tubes.

…. additional **inefficiencies in the thermal cycle and less production**

HEAT TRANSFER IN THE CONDENSER OF A PP

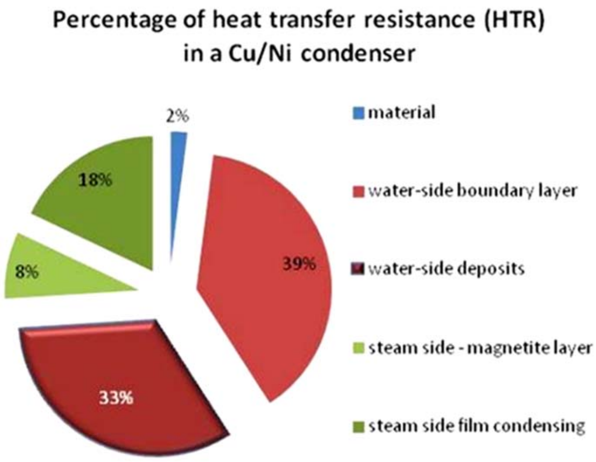
DRIVERS

Around **25% of the heat transfer resistance in a standard condenser comes from the steam side**, mainly due to the resistance of the steam film condensing.

Approximately **a third of the heat resistance comes from the deposits and fouling on the water-side**. This value will increase in the case of poor water quality and reduce cleaning maintenance.

Deposits and biofouling can promote corrosion and failure in condenser tubes, reducing the heat exchange in the equipment and

Coatings can be an advantageous option to limit water-side fouling in steam condensers and recover MWe however coating durability, stability, thickness and cost effectiveness can be and should be further improved



Solution in Matching to improve condenser performance

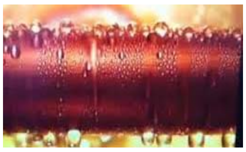
"Antifouling coatings"

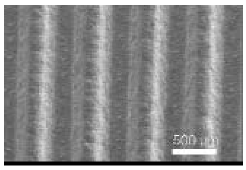
- Release biocide to kill micro-organisms.
- Fouling release coatings.

"New biocide stainless steel"
Modification of composition and use of thermal treatments to promote biocide characteristics.

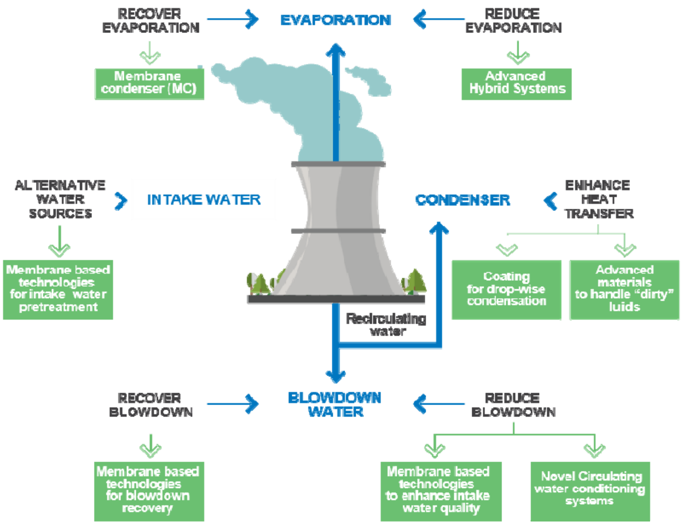
"Dropwise condensation coatings"
Hydrophobic coatings to change the condensation profile increasing heat transfer in the tube.

"Laser-based surface texturing of tubes"
Modification of tubes surface to promote dropwise condensation





MATChING approach cooling tower

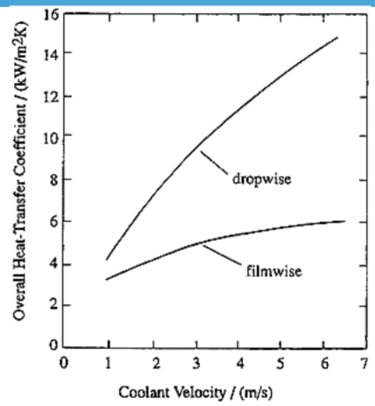


WP 5

What can we expect by the use of coatings: are coatings an option only for new units or also for already operating units ?

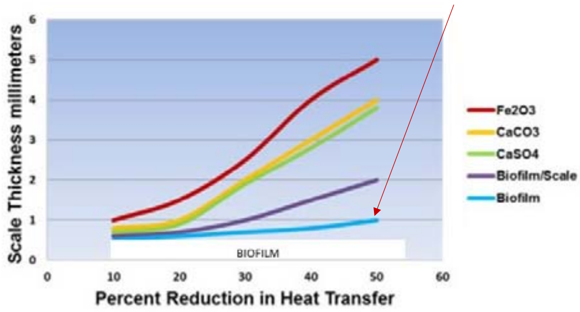
DTI (5')

WP-5



*Overall heat-transfer coefficient for steam at atmospheric pressure condensing on a water-cooled horizontal aluminium tube**

1 mm of biofilm reduces heat transfer efficiency by 50%



*Effect of Heat Transfer vs. Thickness of Scale/Biofouling.***

**Rose JW. Dropwise condensation theory and experience. A review. Proc Inst Mech Engrs Vol 216 Part A: J Power and Energy (2002)*

***How stripping biofilm from the cooling water loop impacts power plant prodcution output. Paper No TP13-09 Repair & Construction*

WP 6

Looking at wastewater treatment and recovery, how new membrane technologies can face the challenge of water demand reduction? What are the limits of these technologies In particular, what is ITM doing for this?

CNR / ITM (10')

ROUNDTABLE – MATCHING TARGETS AND EXPECTED BENEFITS FOR THE EUROPEAN POWER SECTOR

Enrico Drioli[a, b, c, d]

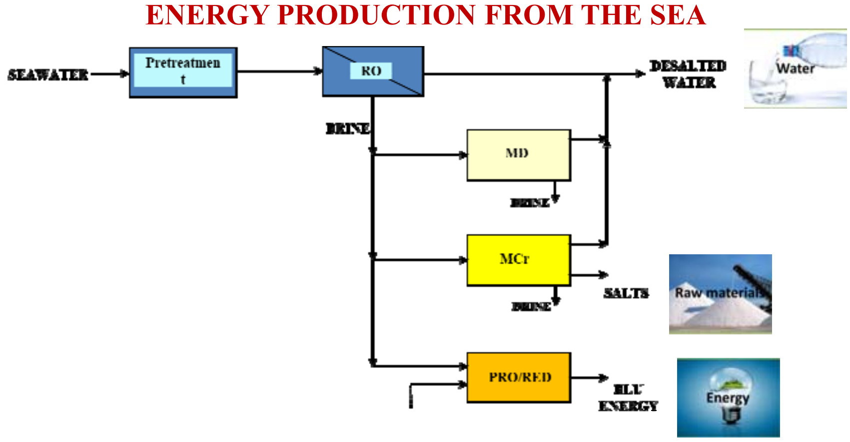
[a] Research Institute on Membrane Technology, ITM-CNR, Via Pietro Bucci 17/C, Rende 87036, Italy

[b] University of Calabria - Department of Environmental and Chemical Engineering, Rende, Italy

[c] Hanyang University, WCU Energy Engineering Department, Seoul, South Korea

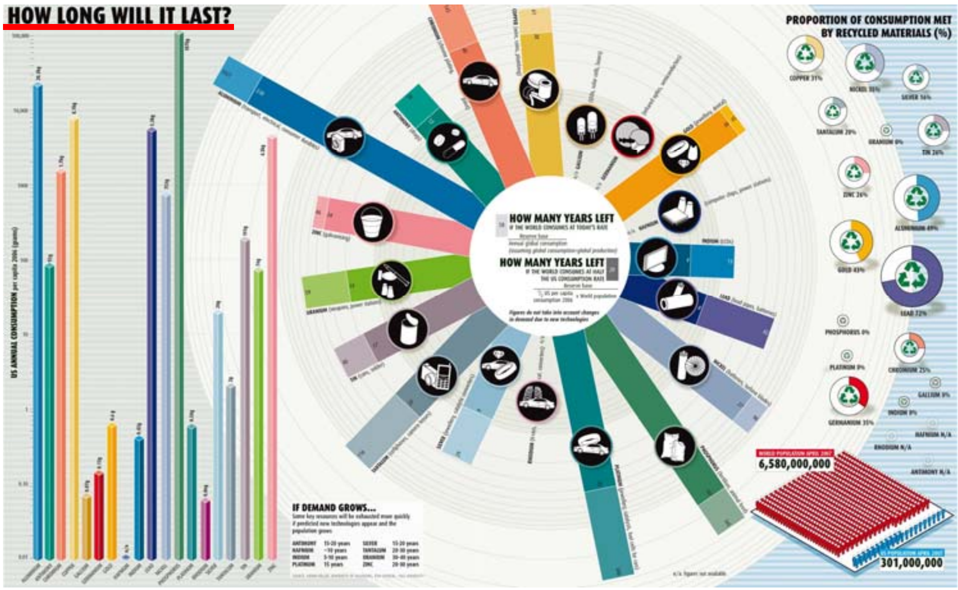
[d] Center of Excellence in Desalination Technology, King Abdulaziz University, Jeddah, Saudi Arabia

MEMBRANE TECHNOLOGIES FOR WATER, MINERALS AND ENERGY PRODUCTION FROM THE SEA



MEMBRANE TECHNOLOGY	GOAL
MEMBRANE DISTILLATION (MD) MEMBRANE CRYSTALLIZATION (MCr)	FRESH WATER RECOVERY RAW MATERIALS EXTRACTION
PRESSURE-RETARDED OSMOSIS (PRO) REVERSE ELECTRODIALYSIS (RED)	POWER GENERATION *(BLUE ENERGY)*

Raw material depletion: one problem of today and tomorrow



https://deepresource.wordpress.com/category/raw-materials/

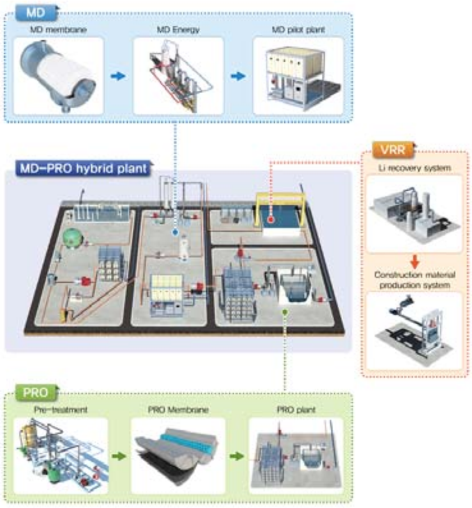
Raw material depletion: one problem of today and tomorrow

	HOW MANY YEARS LEFT if the world consumes at today's rate	HOW MANY YEARS LEFT if the world consumes at half the US consumption rate	IF DEMAND GROWS (some resources will be exhausted more quickly if predicted new technologies appear and the population grows)
Antimony (drugs)	30	13	15-20 years
Indium (LCDs)	13	4	5-10 years
Platinum (jewellery, catalysts, fuel cells for cars)	360	42	15 years
Silver (jewellery, catalytic converters)	29	9	15-20 years
Tantalum (cellphones, camera lenses)	116	20	20-30 years
Uranium (weapons, power station)	59	19	30-40 years
Zinc (galvanising)	46	34	20-30 years

https://deepresource.wordpress.com/category/raw-materials/

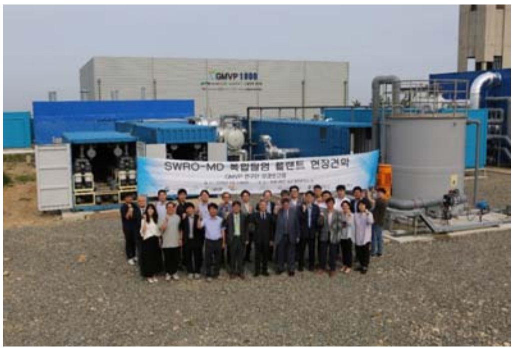
Five years Global MVP research program (2013-2018) in Korea

- Recourse to MD and/or MCr for water recovery factor increase, brine disposal reduction, raw materials production
- Use of PRO for blue energy production from the sea
- New design of desalination process via Integrated membrane based desalination systems



http://www.globalmvp.org/

Five years Global MVP research program (2013-2018) in Korea



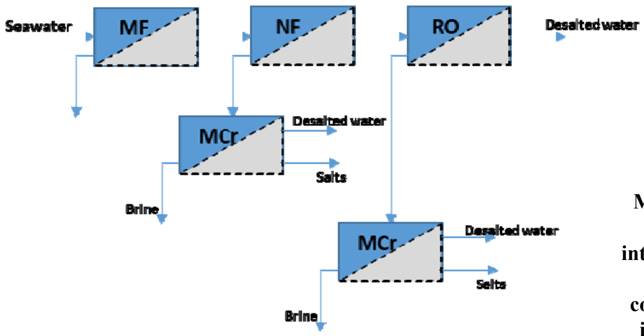
The pilot plant consists of two VMD units with a total water production capacity of 400 m^3/d. The hollow fiber membrane module with membrane area of 10 m^2 is used for the pilot plant. The unit 1 has the 120 membrane modules and the unit 2 reduced the module number to 104. Average flux was 7 LMH for the unit 1, and 8 LMH for unit 2.

The pilot plant targets to reduce the SWRO brine discharge by 30%. After operation of the MD plant with the SWRO brine, GMVP has become confident about the technical feasibility of MD for reducing SWRO brine discharge volume.

Membrane-Based Desalination: An Integrated Approach (acronym MEDINA)

SIXTH FRAMEWORK PROGRAMME - PRIORITY 1.1.6.3 - Global Change and Ecosystems

Aim: **improving the overall performance of membrane-based water desalination processes through the integration of different membrane operations in RO pre-treatment and RO post-treatment stages.**

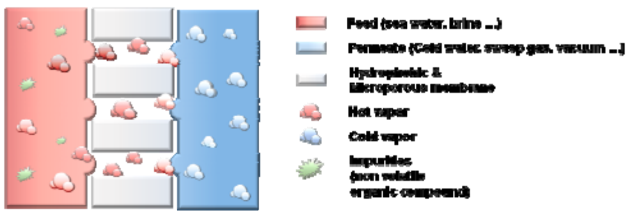


MCr units on NF and RO retentate streams of an integrated membrane-based desalination system constituted by MF/NF/RO increases plant recovery factor until 92.8%. Around 19.5kg of salts ($CaCO_3$, NaCl and/or $MgSO_4$*$7H_2O$) are produced per m³ of seawater

Membrane-based Desalination: An Integrated Approach. Edited by E. Drioli, A. Criscuoli, F. Macedonio. IWA Publishig. 2011. ISBN: 9781843393214

MEMBRANE DISTILLATION / MEMBRANE CRYSTALLIZATION FOR DESALTED WATER *AND/OR* MINERALS PRODUCTION FROM SEAWATER

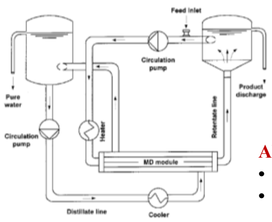
Membrane Distillation



ADVANTAGES

- Not limited by osmotic pressure
- 100% theoretical rejection of all nonvolatile compounds
- Low-grade heat could be employed (no high pressure pump required)

Membrane Crystallization

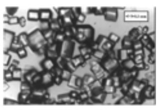


ADVANTAGES

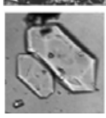
- Heterogeneous Nucleation
- Possibility to control the nucleation kinetics, energy level, and crystal polymorphism

$CaCO_3$

NaCl



Some salts recovered from brine.



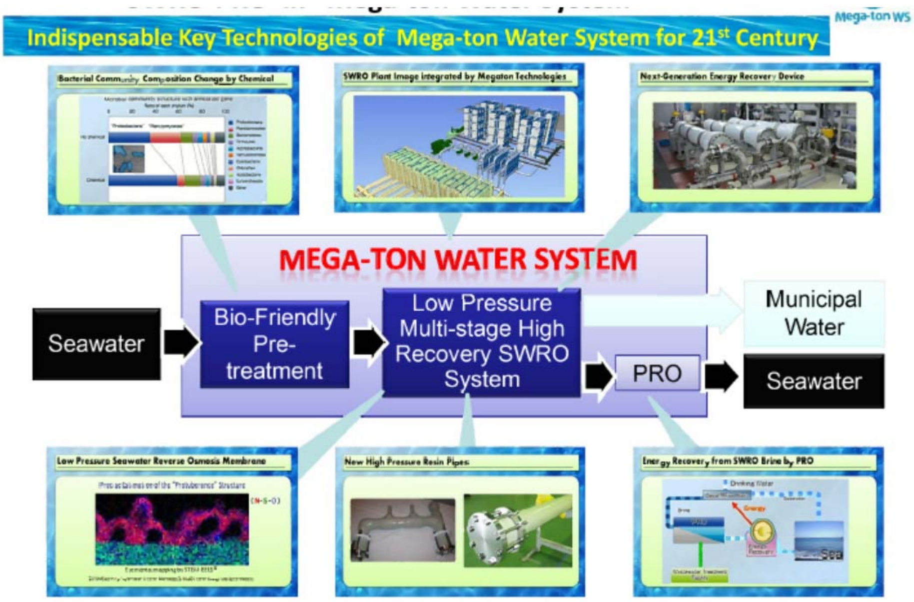
$MgSO_4 \cdot 7H_2O$

LiCl crystals from single salt solution

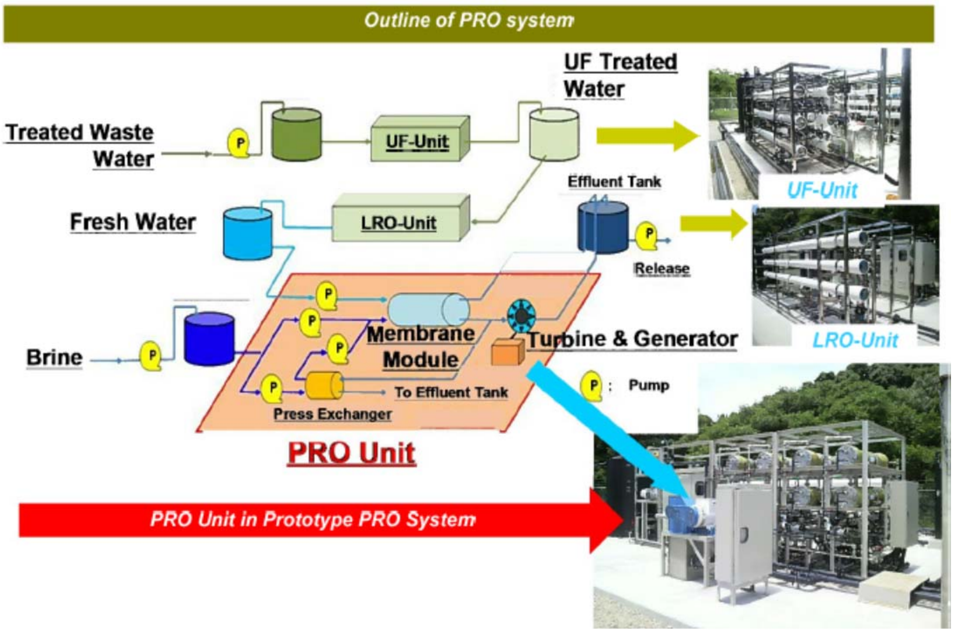
Drioli et al., *Ind. Eng. Chem. Res.*, **2001**, 40(12), 2679 - 2684

36

MEGA-TON

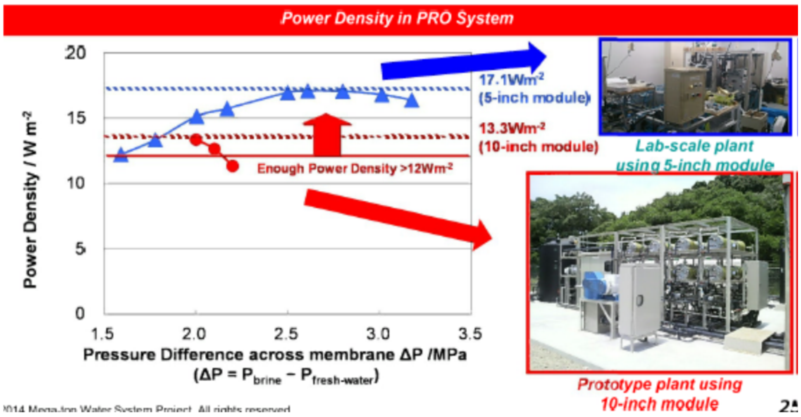


http://www.desaltech2015.com/assets/presenters/Kurihara_Masaru.pdf



http://www.desaltech2015.com/assets/presenters/Kurihara_Masaru.pdf

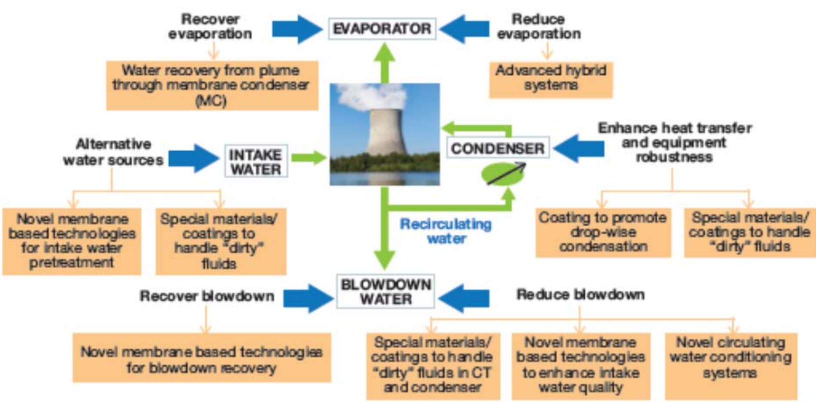
MEGA-TON project: achieved power density



1. Prototype plant performs at max. output of 13.3W/m² (10-inch module) which is enough power density for industrial power plant construction, and lab-scale runs at 17.1W/m² (5-inch module) using SWRO concentrated brine and fresh water.
2. Energy recoveries are estimated from ca. 9% to 10% at megaton scale SWRO plants, and PRO offers much more environmentally-friendly SWRO system than ever.

http://www.desaltech2015.com/assets/presenters/Kurihara_Masaru.pdf

H2020 MATChING project (GA 686031): approach and methodology



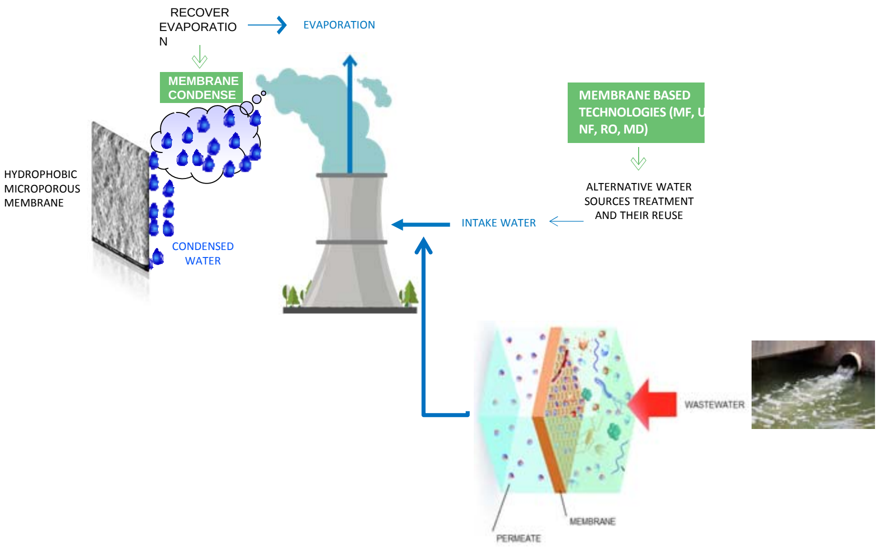
MATCHING aim: to reduce the demand of water and improve energy efficiency of cooling systems in the energy sector through the use of advanced materials and nano-technology based materials.
MATChING got started in March 2016 and the project lasts 42 months.

Website: www.matching-project.eu

Modern Power Systems (2016). Reducing the abstraction of fresh water in power plants. Modern Power Systems, December 2016, 28-29

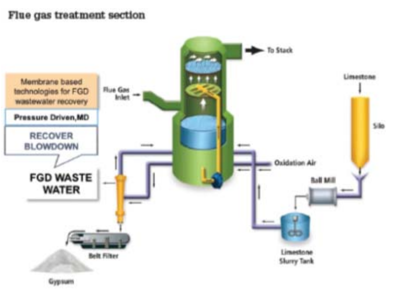
40

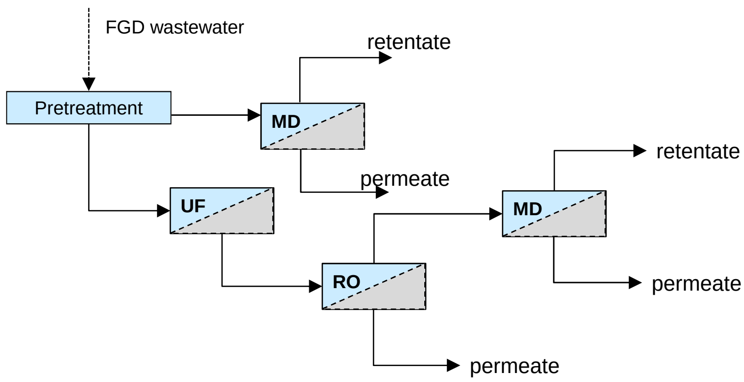
H2020 MATChING project (GA 686031): approach and methodology



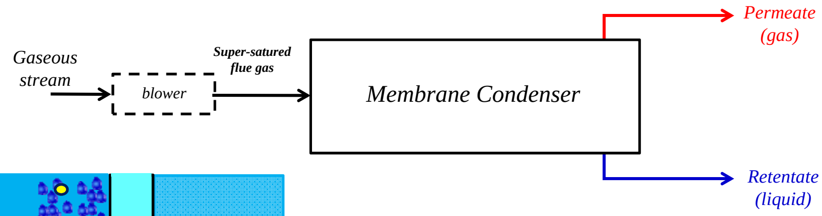
41

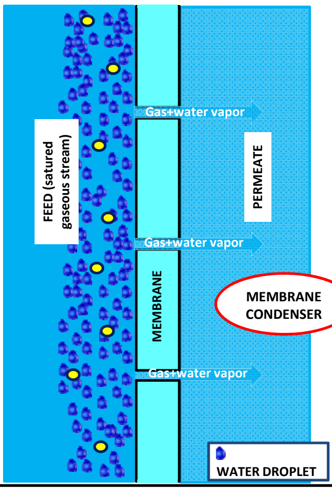
H2020 MATChING project (GA 686031): approach and methodology





Membrane assisted condensation

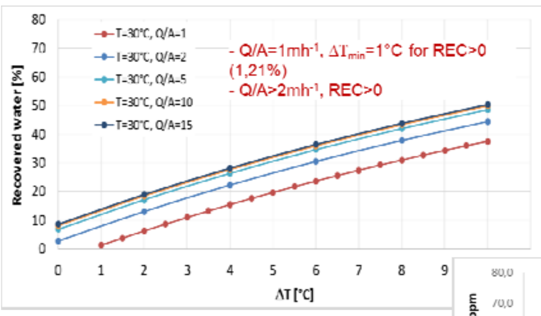




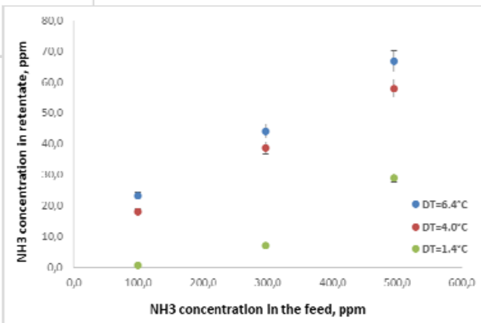
Microporous hydrophobic membranes for water recovery from the retentate side and the simultaneous transfer of the other gases across the membrane. Technology useful for the dehydration of gaseous streams and for water recovery from waste gaseous streams.

Macedonio F., Brunetti A., Barbieri G., Drioli E., Membrane Condenser as a new technology for water recovery from "waste" humidified gaseous streams, Ind. Eng. Chem. Res., 2013, 52 (3), pp 1160–1167

Membrane condenser for water and chemicals recovery from plume



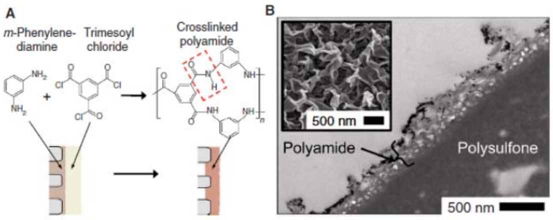
T_{plume} = 30°C, RH_{plume}=110%



NH_3 concentration in the recovered water at various NH_3 concentration in the feed. T_{plume} ≈30°C, Q/A= 2.7, RH_{plume}≈105%, 1,4°C<ΔT<6.40°C

ALL THE RO MEMBRANES EXISTING ON THE MARKET ARE ALREADY EXCELLENT

The fabrication and performance of thin film composite membranes have been greatly improved in the past few decades and today, nearly all RO desalination operations use such membranes. Thin-film composite membranes exhibit water permeabilities around 3.5 × $10^{-12} m^3 m^{-2} Pa^{-1} s^{-1}$ and can reject 99.4 to 99.8% of the salts dissolved in the seawater feed.



Empirical evidence suggests that it is difficult to further increase the water permeability of these membranes without sacrificing selectivity.

Product	Description	Stabilized Rejection %
FILMTEC SW30-4040	SWRO elements for marine systems	99.4
FILMTEC SW30HR LE-4040	SWRO element	99.75
Koch Membrane Systems, MegaMagnum® RO Element	Membrane element for • Brackish Water Treatment • Municipal Water Reuse • Seawater Desalination	
TM820-400	High productivity RO element for sea water applications	99.75
TM820L-370	High flow RO element for sea water applications	99.7
TM820A-400	High Boron Rejection RO element for sea water applications	99.75

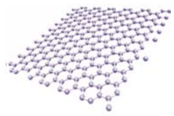
New materials

- Carbon nanotube

(1D)

CNT membranes show good mechanical and thermal stability, fouling resistance, pollutant degradation and self-cleaning functions.

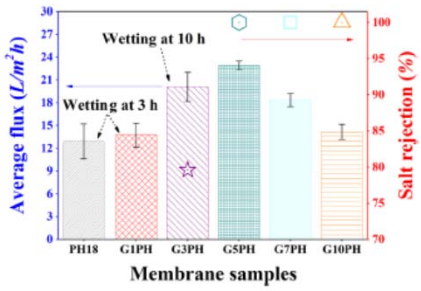
- Graphene



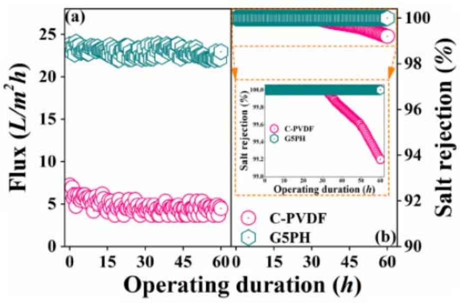
(2D)

The most studied 2D material is 'Graphene' because of its exceptional electronic, opto-electronic, electrochemical, biomedical applications and record thermal conductivity (outperforming diamond) !!!!!!

Thermal conductivity (W $m^{-1} K^{-1}$)	
PP	0.10-0.22
PVDF	0.19
PTFE	0.24-0.35
GRAPHENE (MONOLAYER @300K)	~ 5000

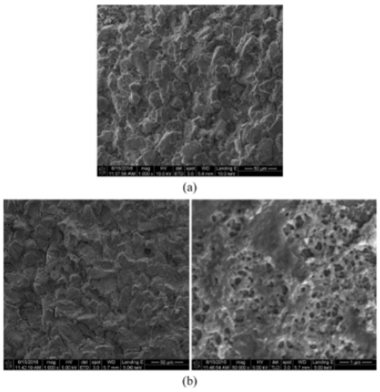


Flux and salt rejection performances of the G/PH and neat PH membranes for 20h operation (Inlet feed T 60 °C; Inlet coolant T 20 °C).



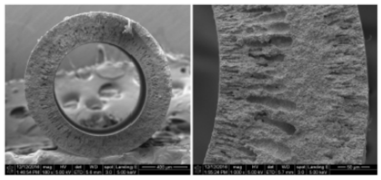
(a) Flux and (b) salt rejection of the G5PH electrospun nanofiber membrane and commercial PVDF membrane.

CERAMIC MEMBRANES



(a)

(b)



(c)

Membrane morphologies (a) before and (b) after the coating of PMSQ aerogel and (c) cross-sectional morphology.

Ceramic membranes possess excellent mechnical, thermal and chemical stability. Materials for synthesis of ceramic membranes mainly include TiO_2, alumina, silica and zirconia. These materials have hydroxyl groups at the surface which render hydrophilic character to the membranes. This aspect prevents their widespread use in MD. Several modifications have been introduced to confer the hydrophobic character to these membranes and one of the most common approach is based on the use of fluoroalkylsilanes as surface modifier. The long lasting character of the various applied modifications, however, is still an issue.

C.-C. Ko et al. *Desalination 440 (2018) 48–58*

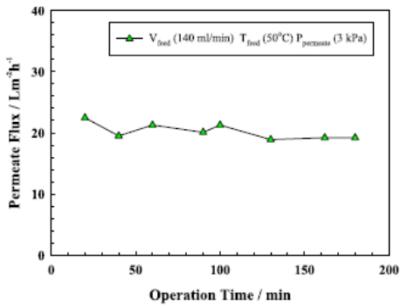
48

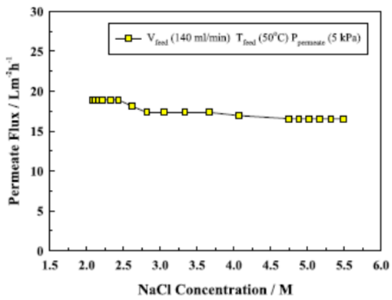
MCr performance for ceramic membranes

Module and ceramic membrane dimensions for CM-S.

Membrane effective length [cm]	9.1
Membrane inner diameter [mm]	0.8
Membrane outer diameter [mm]	1.2
Membrane thickness [mm]	0.2
Module internal diameter [cm]	1.9
Effective membrane surface area[a] [cm^2]	25.38

Figure3. Ceramic module CM-S.



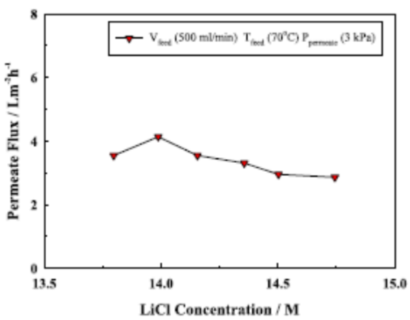


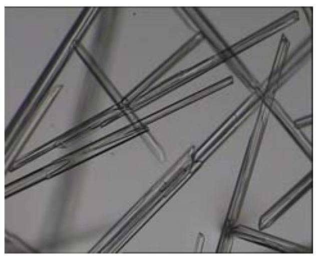
Permeate flux of CM-S using VMD configuration with 1M NaCl as feed solution

C.-C. Ko et al. Desalination 440 (2018) 48–58

49

MCr performance for ceramic membranes





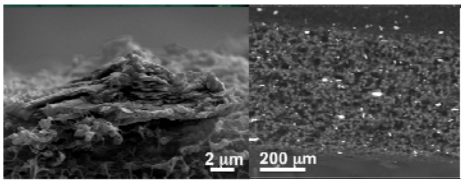
LiCl

Permeate flux obtained for LiCl solution with initial concentration of 13.5 M (T feed = 70 °C). The initial flux was around 4 L/m2·h. The flux gradually decreased to 2.8 L/m2·h when the feed solution concentration reached 14.8 M.

C.-C. Ko et al. Desalination 440 (2018) 48–58

Bismuth chalcogenides - Bi2Se3 and Bi2Te3

Bismuth chalcogenides have attracted a considerable interest arising from the presence of massless Dirac fermions in spin-polarized topologically protected surfaces states, which are robust even at room temperature in this class of compounds.

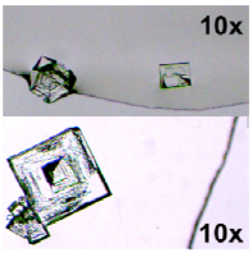


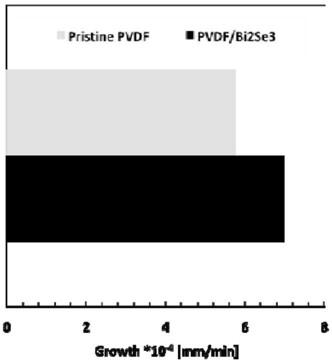
Bi_2Se_3 platelets in polyvinylidine difluoride membranes

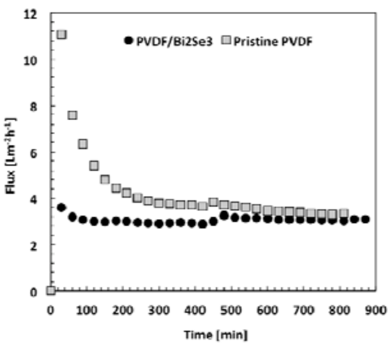
Bismuth chalcogenides could be an attractive opportunity for new interdisciplinary applications including membrane processes

F. Macedonio, A. Politano, E. Drioli, A. Gugliuzza, ,*Mater. Horiz.*, 2018, DOI: 10.1039/C8MH00612A.

Bismuth chalcogenides - Bi2Se3 and Bi2Te3







MCr tests on NaCl solutions. Comparison between pristine and Bi_2Se_3-modified PVDF membranes.

F. Macedonio, A. Politano, E. Drioli, A. Gugliuzza, *Mater. Horiz.*, 2018, DOI: 10.1039/C8MH00612A.

Conclusions

FURTHER PROGRESS IN MEMBRANE ENGINEERING OPERATIONS WILL MORE AND MORE REQUIRE INTEGRATION BETWEEN ADVANCED PROCESSES ENGINEERING AND ADVANCED MATERIAL ENGINEERING

Thank you for your attention

WP 6

How can we reduce the intake of cooling water and what are the water treatment technologies under investigation in the MATChING project to achieve this?

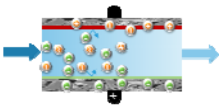
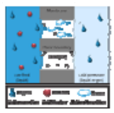
VITO (8')

Reduce intake of cooling water

Water use depending on
- Cooling capacity needed
- Quality of intake water – concentration limited by scaling, corrosion
- Design CT
- Operational parameters (pH, chemicals, COC,..)
- Permit limits
  - Temperature
  - Discharge limits blowdown water

Pilot tests using Merades pilot (Engie Laborelec)
- 2 parallel and independent circuits
- Comparison of 3 technologies tested on same intake water from the channel Charleroi-Brussels

Parameters	Min – Max
pH	7.5 – 8.0
Conductivity	740 – 830 µS/cm
Alkalinity	220 – 250 mg/l $CaCO_3$
Calcium Hardness	250 – 350 mg/l $CaCO_3$
Chloride	67 – 89 mg/l Cl_2

Technology	no technology acid dosing			
Results				
COCmax at pH 8,0	2,2	6,7 - 45	3,1	4,9
Water saving	-	25 - 75%	12 %	38 %
Acid saving	-	tbd	0 %	0 %
Experiences				
Performance		stable	adherence of scaling lower	stable flux with and without pretreatment
Pretreatment		5 µm prefiltration required	-	test with and without Ca removal (IEX)
Corrosion rate		slightly higer	no impact	slightly higher
Biological development		no impact	no impact	no impact
Cleaning		2 full CIP during 3 months shorts CIP in between tests	-	after 3-10 days (with pretreatment) after 25 days (with pretreatment)
Remarks		low energy use (0,1 kWh/m³)	Additional tests planned with adjusted filter	

Conclusions

- Water reduction possible using membrane technology based on pilot results
- Evaluation of
  - -scale up of technology
  - -performance using other intake water quality
  - -cost (investment and operational costs)
  - -implementation and follow up
  - -discharge of concentrate streams