Research and Innovation through LIFE and HORIZON projects

Prof. Maria Loizidou
School of Chemical Engineering, NTUA
mloiz@chemeng.ntua.gr
We have only one planet

Until 2050, we will consume as we have 3 ...

Need to change habits…
Commerce balance in the EU-27

**Total trade from EU-27 to ROW**
- In 1999: 397 million tonnes
- In 2008: 536 million tonnes
- In 2011: 568 million tonnes

**EU-27 exports (2011)**
- Biomass (172 million tonnes)
- Manufactures (183 million tonnes)
- Fuels/mining products (1,274 million tonnes)

**Total trade from ROW to EU-27**
- In 1999: 1,340 million tonnes
- In 2008: 1,798 million tonnes
- In 2011: 1,629 million tonnes

**EU-27 imports (2011)**
- Biomass (141 million tonnes)
- Manufactures (212 million tonnes)
- Fuels/mining products (215 million tonnes)

**Rest of the world (ROW)**
Climate change leads to economic losses

The financial losses caused by extreme weather and climate-related events exceeded €487 billion in the EU-27 over the last 40 years. The overall cost was the highest for Germany, Italy, France.
Green Deal Ambitions

- Become climate-neutral by 2050
- Protect human life, animals and plants by cutting pollution
- Help companies become world leaders in clean products and technologies
- Help ensure a just and inclusive transition
Research and Innovation to drive Green Deal
Climate change and water scarcity
• $260 billion is lost globally each year due to lack of fresh water and sanitation.

• The increase in freshwater consumption combined with the effects of climate change will lead to increase in social, economic, environmental and geopolitical risks. According to the 2019 Global Risks Report of the World Economic Forum (WEF), a crisis due to water scarcity will affect the global economy next 10 years.
Water scarcity effects on EU economy

- Water scarcity is an increasingly frequent and worrying phenomenon that affects at least 11% of the European population and 17% of EU territory.
- Since 1980, the number of droughts in Europe has increased, and they have become more severe, costing an estimated €100 billion over the past 30 years. One of the worst droughts occurred in 2003, when one-third of EU territory and over 100 million people were affected. Between 1976 and 2006, the number of people and areas hit by drought rose by almost 20%, and the yearly average cost has quadrupled.
Desalination—an answer to water scarcity

- During seawater desalination tons of brine are rejected back to sea.
- Brines are also produced by many industrial processes such as (chemical, food, extractive etc.)
- Tons of salts end in surface water bodies and sewage systems

*United Nations Environment Programme*

**Environmental Challenge**

‘Brine discharges is the major threat to the aquatic environment.’

Industry accounts **22% of the global water demand**
Innovative systems development to close the cycles of water

Steps to be followed

1. Definition of the materials that can be recovered from wastewater
2. Integration of new and older technologies to recover water and resources from the wastewater
3. Estimation of environmental footprint
4. Initiatives to improve social acceptance of systems and recovered materials
5. Overcome policy barriers and suggest solutions
6. Definition of existing and new markets for the products
7. Build/operate innovative systems

Initiatives to improve social acceptance of systems and recovered materials

Definition of existing and new markets for the products

Build/operate innovative systems
Circular economy among companies = Industrial symbiosis

+ Economic benefits
+ Environmental benefits
+ Social benefits

- Lack of cooperation among industries
- Lack of trust among industries
- Lack of information sharing
Policy review and assessment

- WFD
- REACH
- WFD + EoW
- Industrial Emissions Directive
- Other relevant to the final products
“Development of an advanced innovative energy autonomous system for the treatment of brine from seawater desalination plants”

Area of implementation: Tinos Island, Greece

- Project Budget: 1,209,689.00 €
- EC Funding (LIFE+): 604,844.00 €
- Duration: 39 months
- Start date: 01/10/2010
- End date: 31/12/2013

Municipality of Tinos Island (Project Coordinator)

National Technical University of Athens

Culligan Hellas S.A.
Sol Brine Objectives

- Zero Brine Discharge
- Water recovery 90%
- Marketable products
- Energy autonomy
- Innovative technologies use
Process flow diagram

Legend

A  Brine Treatment System
   a  Feed water tank
   b  MED Evaporator
   c  Crystallizer
   d  Dryer

B  Energy supply system
   e  Solar thermal collectors
   f  Photovoltaic generator
Total brine elimination: The system has been designed in line with the Zero Liquid Discharge principle

Water Recovery: (> 90%)

Production of useful end-products. (a) water of high quality and (b) dry salt. Products with market opportunities.

Energy autonomous operation: Solar thermal collectors are used for delivering hot water and a PV for electricity. All energy requirements are covered exclusively through the use of solar energy.

Use of state-of the art technology: Custom designed vacuum evaporation technology (evaporator and crystallizer) and solar dryer.
Sol Brine Pilot

[Image of Sol Brine Pilot equipment]

[Image of Crystallizer equipment]
Sol Brine Pilot
Sol Brine-EU Green Awards

The best Life Project of last 25 years
“Re-designing the value and supply chain of water and minerals: a circular economy approach for the recovery of resources from saline impaired effluent (brine) generated by process industries”

Area of implementation: The Netherlands, Spain, Poland, Turkey

Project Budget: 11,078,222 €

EC Funding: 9,992,209 €

Duration: 54 months

Start date: 01/06/2017

End date: 30/11/2021
Zero Brine Objectives

- Zero Brine Discharge
  - Water recovery 90% suitable for industrial use

- Use of waste heat
  - Marketable products, NaCl, Mg, Ca, Na₂SO₄

- Decrease of industry environmental footprint

Industrial sectors
- Desalination
- Extractive
- Textile
- Silica
“EVIDES produces tons of freshwater to the Rotterdam port and the surrounding industrial area. Tons of brine are rejected in the sea”
Process flow diagram

Regeneration Effluent from IEX

Nanofiltration 1 → Nanofiltration 2 → Evaporator

MF-PFR

Mg(OH)₂ → Ca(OH)₂

Water

Concentrate brine for IEX regeneration
Pilot in EVIDES
EVIDES Pilot results

• Ca and Mg removal of around 93%
• Purity of recovered Mg crystals is 84-90% and Ca crystals is 93-99%
• Water recovery of about 90%
• Quality improvement of end products → a positive impact on annual revenues (3,000,000-8,000,000 €/year)
• Avoiding environmental penalties due to brine discharge
• Internal valorization of NaCl solution
Industrial Symbiosis

- Brine Analyses, Design of Brine Treatment Systems.
- Tools for the Estimation of CAPEX and OPEX
- Consultancy about the recovered material and their market
Brine Mining-General Information

“Demonstration of an advanced technique for eliminating coal mine wastewater (brines) combined with resource recovery”

Area of implementation: Poland

Project Budget: 6,383,847 €

Duration: 54 months

Start date: 01/10/2019

End date: 1/03/2024

EC Funding (LIFE+): 3,508,365 €
Brine Mining Partners

Coordinating beneficiary
National Technical University of Athens

Beneficiaries
GLOWNY INSTYTUT GORNICTWA
LENNTech
NEVIS-NOVEL Environmental Solutions S.A.
SEALEAU B.V.

Silesian University of Technology
POLSKA GRUPA GORNICZA
THERMOSSOL STEAMBOILERS S.A.
Titan Salt B.V.
Importance of coal in Europe

- In 2019, 44% 244 (tonnes) of EU’s total lignite production was covered by Germany.

- Europe’s total hard coal production was 57 million tonnes. Poland has a leading role in hard coal production - 95% of the EU hard coal is produced in Poland.
The problem

• Poland is the dominant coal producer in Europe
• Coal mines produce huge amounts of brines
• Direct or indirect brine discharge to water bodies:
  □ Quality Degradation of river water
    □ Vistula: 55% of fresh water in Poland (Ecological Status: Moderate)
    □ Cost from Vistula salinization: $150-200 million per year (transport services, industry, agriculture)
The project target area: The Golawiecki Stream and the Small Vistula River

The 2 national monitoring points of the area

The 3 artificial ponds in the Ziemowit mine. In each pond, coal mine brine from different depth of the mine is discharged

Source of Golawiecki Stream

Estuary of the Stream to the Small Vistula River
Coal mine brine discharge in the project target area

- High content of chlorides, sodium ions and sulfates
- The Gołowiecki Stream’s conductivity reaches the level of seawater
- High water hardness in the Gołowiecki Stream’s source
- High level of $K^+$, $Br^-$, $Sr$, $Mn^{+2}$, $B$, $HCO_3^-$ all these ions are associated with produced wastewater from coal mine operations
Brine Mining Objectives

1. >90% recovery of salts and water
2. >95% salts purity
3. Marketable products (e.g. MgOH)
4. WFD and Circular Economy Package Implementation
5. Decrease of energy consumption in comparison with the Debiensko system
Brine Mining process flow diagram

\[ Q_{12} = 2 \text{ m}^3 \]
\[ \text{TDS} = 6.9\% \]

\[ Q_{16} = 0.75 - 0.94 \text{ m}^3 \]
\[ \text{TDS} = 14 - 17.2\% \]

\[ Q_{17} = 2.2 - 2.6 \text{ m}^3 \]
\[ \text{TDS} = 3 - 3.1\% \]

\[ Q_{18} = 1,152 - 1,358 \text{ m}^3 \]
\[ \text{TDS} = 5.7 - 5.8\% \]
Brine Mining – Circular Economy Diagram

- Brine
- Coal Mine
- Innovative Prototype Desalination System: Filtration, Precipitation, Electrodialysis, Evaporation
- Salts
- Clean water
- Revenues
- Industry
- Municipal purposes
- Agriculture
Brine Mining – Expected Results (1/2)

1. Prevention of brine discharge
   Avoid discharge of 7,000 m³ brine per year into surface water

2. Recovery of clean water
   Recovery of 5,782 t of clean water per year

3. Production of minerals/salts
   432 t of minerals/salts will be produced per year
4. Purity of the minerals/salts

- Mg(OH)$_2$: 91% purity
- CaCO$_3$: 98% purity
- CaSO$_4$: 91% purity
- NaCl: 98% purity

5. Prevention of CO$_2$ emissions

407 t of CO$_2$ emissions savings
4. Purity of the minerals/salts
- Mg(OH)$_2$: 91% purity
- CaCO$_3$: 98% purity
- CaSO$_4$: 91% purity
- NaCl: 98% purity

5. Prevention of CO$_2$ emissions
407 t of CO$_2$ emissions savings
“Next generation water-smart management systems: large scale demonstrations for a circular economy and society”

Area of implementation: The Netherlands, Italy, Spain, Cyprus

Project Budget: 19,097,946 €

EU Funding: 16,876,959 €

Duration: 48 months

Start date: 01/09/2020

End date: 31/08/2024
Larnaca WWTP with numbers

Person Equivalent 100,000

Average Inflow 10,000 m³/day

Maximum Inflow 18,000 m³/day

3.500.000 m³ of water/year

5.000 m³ of sludge/year

100% water and sludge reuse in agriculture
## The problem

<table>
<thead>
<tr>
<th>Element</th>
<th>Symbol</th>
<th>MW</th>
<th>Unit</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sodium</td>
<td>Na</td>
<td>23</td>
<td>mg/L</td>
<td>490</td>
</tr>
<tr>
<td>Magnesium</td>
<td>Mg</td>
<td>24</td>
<td>mg/L</td>
<td>61</td>
</tr>
<tr>
<td>Calcium</td>
<td>Ca</td>
<td>40</td>
<td>mg/L</td>
<td>149</td>
</tr>
<tr>
<td>Chloride</td>
<td>Cl</td>
<td>35</td>
<td>mg/L</td>
<td>890</td>
</tr>
<tr>
<td>Tot. Phosphorous</td>
<td>P</td>
<td>31</td>
<td>mg/L</td>
<td>1.52</td>
</tr>
<tr>
<td>Elec. conductivity</td>
<td>EC</td>
<td></td>
<td>mS/cm</td>
<td>4.2</td>
</tr>
</tbody>
</table>

High salinity impacts to the soil (salinization-degradation), not appropriate for sensitive crops irrigation.
Water Mining Objectives

- >90% recovery of salts and water
- >95% salts purity, marketable products
- Anaerobic digestion for biogas production
- >50% of energy from renewable Energy Sources

Policy gaps/suggestions
- Social acceptance of products

Industrial sector
- Desalination
- Chemical Industry
- Urban Wastewater
Larnaca pilot process flow diagram

Larnaka WWTP effluent

- Biophree
  - Phosphorus
    - Agricultural Application
  - Industrial Application

- Nanofiltration

- Low Temperature Evaporator
  - SALTS

- Reverse Osmosis
  - Multi-Effect Distillation
    - Crystallizer

- Water as a resource

WATER

WATER
Pilot in Larnaca WWTP
Water Mining Platform
Walnut-General Information

“Closing waste water cycles for nutrient recovery”

Area of Implementation:
Belgium, Hungary, Spain, Greece

Project Budget:
5 949 628,75 €

EU Funding:
5 949 628,75 €

Duration:
54 months

Start Date:
01/09/2021

End Date:
28/02/2026
Walnut Partners
Walnut-Objective

WalNUT aims to develop the necessary concepts and technological solutions to re-design the value and supply chains of nutrients from wastewater and brine.

✔ 15 partners
✔ 5 pilots
✔ Implementation in 4 countries
✔ Input: industrial, urban wastewater and sludge, brines
NTUA role in Walnut

Pilot
- System for the recovery of Mg and K to be used in Bio-Based Fertilizers

Platform
- To help matching among wastewater owners, technology providers/consultants and end-users of nutrients

Policy
- Review of European and National Policy
- Gaps and barriers definition
- Policy suggestions for the adoption of Bio-Based Fertilizers and the proposed by the project systems
NTUA pilot process flow diagram

Brine from Desalination Unit 0.5 m³/d

Mg precipitation tank

- NaOH

- Mg(OH)₂

- Mg Recovery >98%

Ca precipitation tank

- Na₂CO₃

- CaCO₃

- Ca Recovery >98%

NF

- Concentrated Na₂SO₄ solution

- solar dryer

- Na₂SO₄

MED evaporator

Crystallizer

- NaCl, KCl

Distillate water

Flotation tank

- NaCl

- KCl

Distillate water

NaCl, KCl
Thank you for your attention!