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PRELIMINARY MARKET CONSULTATION

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DESAL+ LIVING LAB
PCP Tech-challenges

Baltasar Peñate Suárez
ITC

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DESAL+ DESALINATION LIVING LAB

DESAL+LIVINGLAB

Supporting the Knowledge Economy in Desalination in the Canary Islands

Platform coordinated by:

itc INSTITUTO TECNOLÓGICO DE CANARIAS

Gobierno de Canarias

Members:

Gobierno de Canarias
Consejería de Economía, Industria, Comercio y Conocimiento
Agencia Canaria de Investigación, Innovación y Sociedad de la Información

ULPGC Universidad de Las Palmas de Gran Canaria

Universidad de La Laguna

MAC 2014-2020 Cooperación Territorial

Interreg

This R&D&i is promoted by the **DESAL + project,** co-funded by ERDF funds through the **INTERREG MAC 2014-2020 programme** (MAC/1.1a/094)

DESAL+ LIVING LAB - LOCATION

The Macaronesian Region comprises 4 archipelagos on the north of the Atlantic Ocean, in front of the coastline of the continents of Europe and Africa.

From north to south, this Region comprises:

- **Azores** (Portugal)
- **Madeira** (Portugal), including the Savage Islands
- **the Canary Islands** (Spain)
- **Cape Verde** (Africa)

DESALINATION IN THE MACARONESIAN AREA

Over 700,000 m^3/day (approx. 1% of the desalination capacity installed worldwide).

Largely dependent on fossil fuel imports

Over 350 desalination plants in operation

Over the 50% of the inhabitants and 14 million tourists supplied with desalinated water.

Also used for agricultural and recreational purposes.

The highest density of desalination plants in km^2 in the world

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DESALINATION LIVING LAB

OPPORTUNITIES FOR R&D&i IN DESALINATION

- +50 years of experience operating desalination plants
- Wide variety of plants, with a large array of technologies, design conditions and locations
- Availability of desalination infrastructure and pilot plants for testing purposes
- Excellent availability of natural resources: sun, wind and sea
- High number of researchers, engineers, technicians and qualified plant operators

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CANARY ISLANDS: SPECIAL TAX ZONE (ZEC)

Key advantage for foreign R&D companies, benefiting from the following tax advantages:

- Company Tax: the entities located in the ZEC area are subject to the Company Tax applicable in Spain **at a reduce rate of 4%.**

- **Non-residents are exempt from the Income Tax** (IRNR)

- Property Transfer Tax and Stamp Duty (ITP-AJD): the entities based in the ZEC area are **exempt from such taxes and duties in the following cases**:
  - Purchase of goods and rights for the development of the business activity of the ZEC entity within the geographic area of the ZEC.
  - Corporate transactions carried out by ZEC entities, except for the winding up.
  - Legally documented actions related to transactions performed by these entities within the geographic area of the ZEC.

- **VAT applicable in the Canary Islands** (IGIC): at the ZEC, the provision of goods and services within the entities based in the ZEC area, as well as the import of goods manufactured by such entities, are exempt from the value added tax applicable in the Canary Islands (IGIC).

DESAL+ LIVING LAB DESCRIPTION

DESAL + LIVING LAB is **an open research ecosystem** with both experimental and real-world environments mainly located in the Canary Islands. This platform has also collaborators in Cape Verde, Madeira y Mauritania.

Tests, experiments and demonstrations can be carried out in order to promote and mature the commercial potential of a technology, product and/or service.

DESAL + LIVING LAB has established the **conditions, infrastructure and protocols required to gain access to desalination plants,** enabling the collaboration and cooperation of universities, research centres, manufacturers, companies, operators and end-users by using all the resources available within the ecosystem.

R&D&i PRIORITY LINES
(2018-2025) (1/3)

SL1. **Advance** (predictive and preventative) maintenance of the facilities to ensure efficiency across their useful life

SL2. **Automation**, **big data processing**and the implementation of**artificial intelligence** to improve efficiency and control the process costs

SL3. **Pre-treatments**: Actions intended to maintain and/or improve the water quality at the entrance of the reverse osmosis membranes

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R&D&i PRIORITY LINES
(2018-2025) (2/3)

SL4. **Membranes 4.0**: Testing and operations with critical elements to maximise the useful life of reverse osmosis membranes

SL5. **Desalinated water-energy nexus**: Improvement of the energy efficiency of the desalination process and direct use of renewable energies

SL6. **Desalinated water quality**: Improvement of the quality of desalinated water for multiple objectives, especially for agricultural purposes

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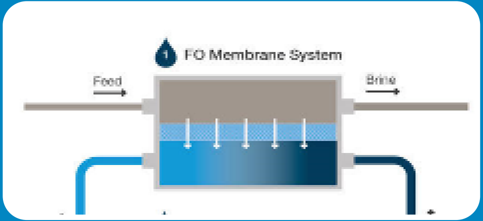
R&D&i PRIORITY LINES
(2018-2025) (3/3)

SL7. Brine and the circular economy: Solutions and process intended to increase the value of brine and/or the path to minimise the discharge of brine as much as possible

SL8. Green chemistry. New processes, developments or operational approaches to reduce the use of chemicals in desalination or to replace them with more sustainable chemicals



SL9. Emerging desalination technologies: New desalination technologies alternative or supplementary to reverse osmosis

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DESALINATION INFRASTRUCTURE FOR R&D

The platform provides desalination infrastructure (+10 facilities) and testing areas unique in the world (+3) for desalination R&D purposes in a real environment as a test bench to do research, develop, test and validate water desalination solutions, the use of renewable energies and the water-energy nexus.

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INITIATIVES AND PROJECTS

The DESAL+ Living Lab platform is developing projects and services related to:

- Technical studies and reports
- Laboratory analysis and tests
- Testing in pilot plants
- Development of prototypes
- Implementation in real environment
- Software development
- Training
- Technical consulting and planning
- **Pre-commercial public procurement - R&D services**

MAC 2014-2020 Cooperación Territorial

Interreg

Fondo Europeo de Desarrollo Regional

Interreg Atlantic Area

European Regional Development Fund

EUROPEAN UNION

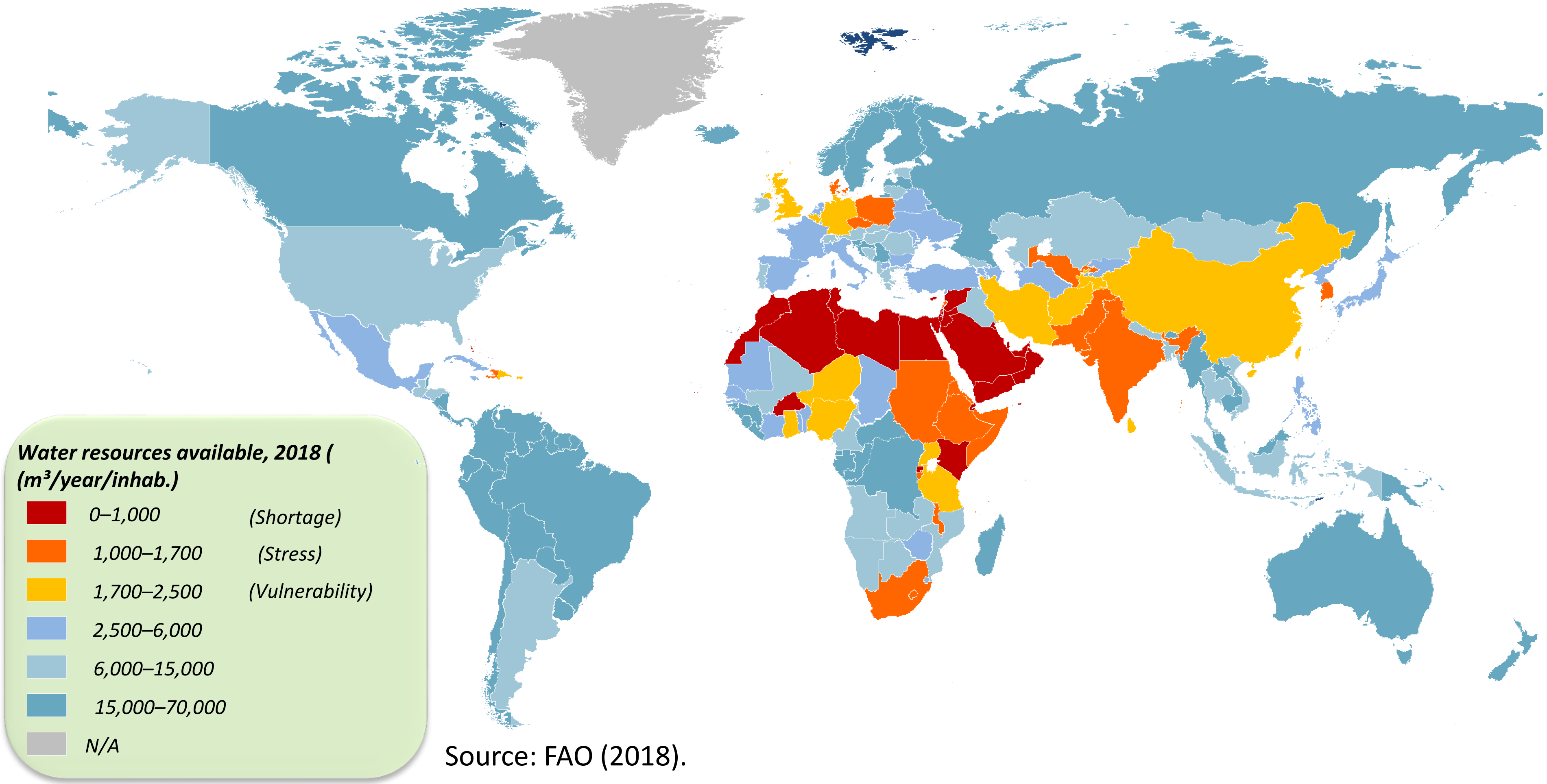
Cabildo de Gran Canaria

spegc

Shortage of drinking water

The population growth and the changes in the water consumption trends turn desalination into one of the most appropriate alternatives to ensure the supply of water for different purposes (urban areas, agriculture, tourism and industries).

Natural resources available, 2018 ((m^3/year/inhab.)



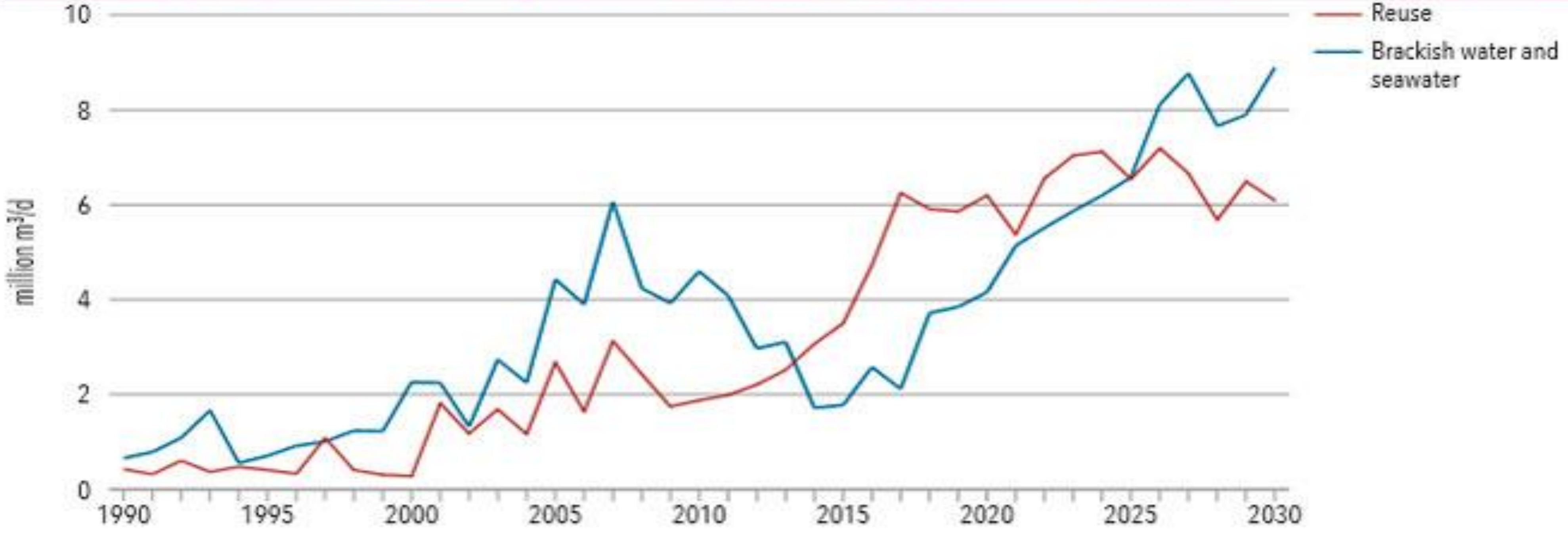
Source: FAO (2018).

Water desalination on a global scale

The global installed desalination capacity stands at 80.9 million m^3/d (GWI, 2019).

According to the estimates, this figure may reach 100 million m^3/d by 2025 (IDA).

Figure 2.73 New contracted capacity of municipal water reuse vs brackish/seawater desalination, 1990-2030

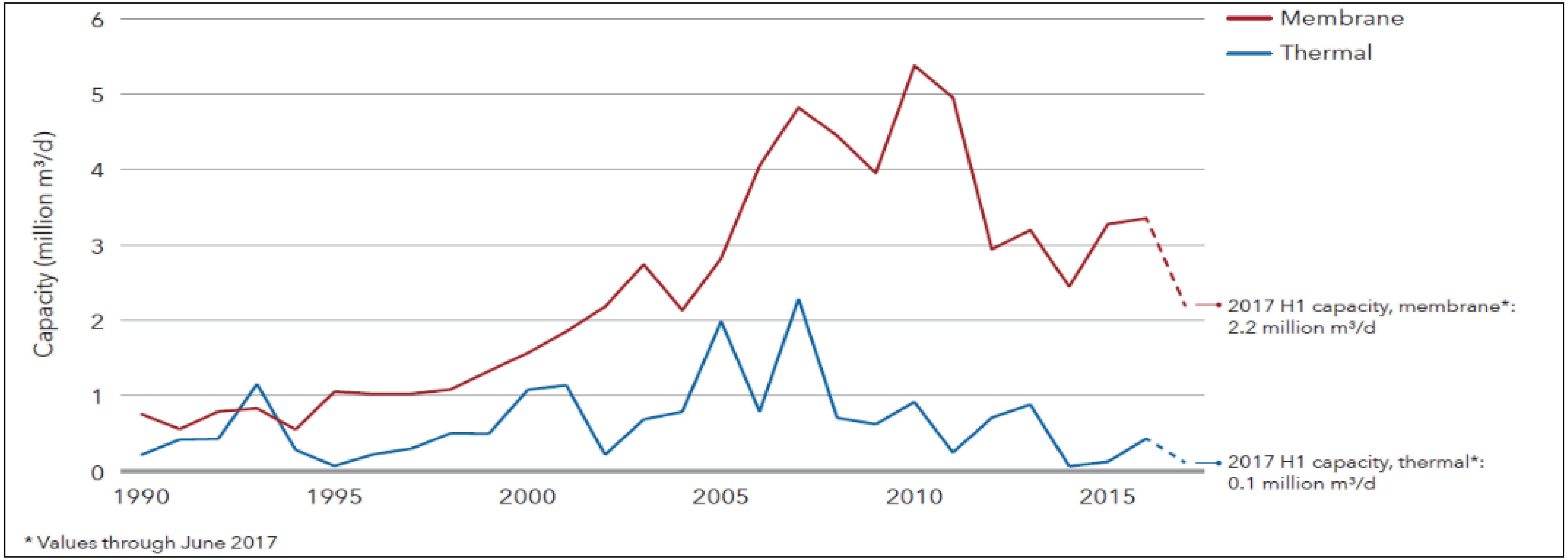


Note: Due to the difficulty in distinguishing spending on reuse from spending on wastewater treatment, it is not possible to realistically estimate spending on reuse in monetary terms. Instead, we have estimated the market by contracted capacity.

Source: GWI

Water desalination on a global scale

Year capacity hired per technology between 1990 and 2017

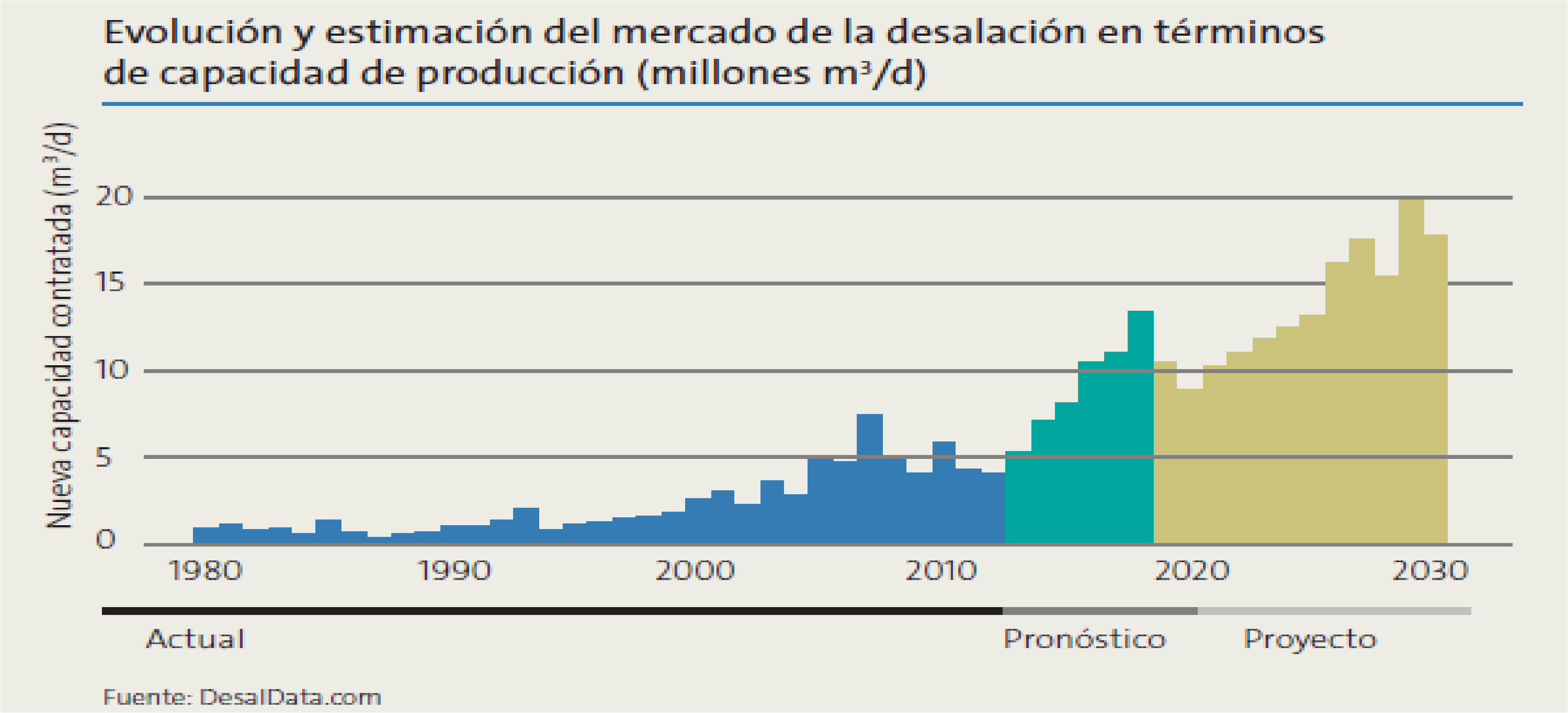


Source: IDA (2017). Desalination Yearbook, Global Data Report DesalData 2017-2018.

Water desalination on a global scale

Over 66 million m^3/day of desalinated water is current produced worldwide, which equals the consumption of over 250 million people.

Only the 5% of the world demand of drinking water and the 3% (+20% in Spain) of the demand of agricultural water are covered



Desalination technologies

WITH PHASE CHANGE

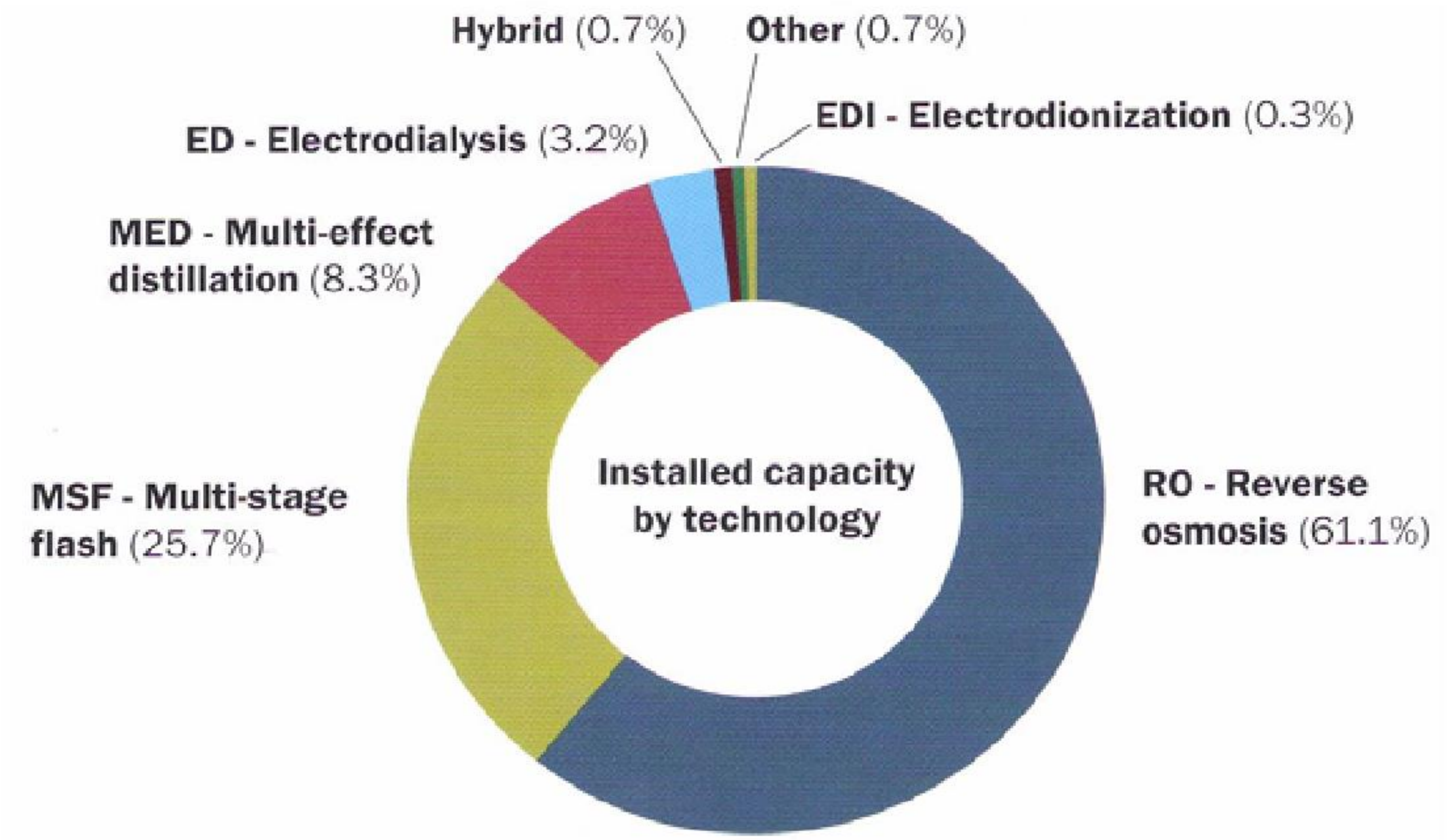
- **MSF** (Multi-Stage Flash Distillation)
- **MED** (Multiple-Effect Distillation)
- **MVC** (Mechanical Vapour Compression)
- **TVC** (Thermal Vapour Compression)
- **ABHP** (Absorption Heat Pump)
- **ADHP** (Adsorption Heat Pump)
- **HDH** (Humidification – Dehumidification)
- **PVD** (Passive Vacuum Desalination)
- **MD** (Membrane Distillation)
- **SD** (Solar Distillation).
- **FM** (Freezing – Melting).
- Pervaporation

Desalination technologies

WITHOUT PHASE CHANGE

- RO **(Reverse Osmosis)**
- NF (Nanofiltration)
- FO (Forward Osmosis)
- ED **(Electro-Dialysis)**
- IE (Ion Exchange)
- CDI (Capacitive Deionization)
- Adsorption

Desalination technologies



Source: IDA (2017). Desalination Yearbook, Global Data Report DesalData 2017-2018.

Sea water desalination in Spain and the Canary Islands

Desalination reference with many milestones reached throughout the history of desalination, featuring over 800 desalination plants (AEDYR, 2018). Canary Islands, Community of Valencia, Balearic Islands, Andalusía, Catalonia, Murcia….

Almost the 85% desalinates sea water, with reserve osmosis (RO) being the mostly used technology, followed by EDR.

Spain, ranking 5th in installed capacity.
Spain features leading desalination companies and engineering entities worldwide

Desalination in the Canary Islands – *Europe's spearhead*

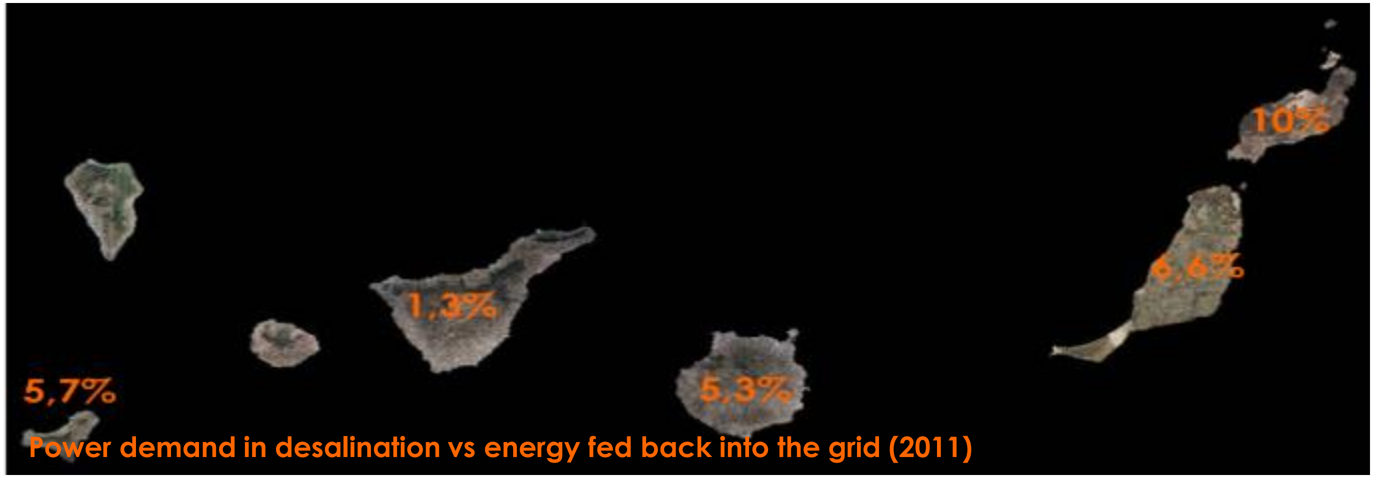
Since 1964, with over 50 of experience, all the commercial desalination technologies have been installed in the Canary Islands.

319 desalination plants (90% RO) and an output capacity above **600,000 m^3/d**

Brine discharge of 570,000 m3/d (approx.)

Energy dependency in the Canary Islands of around the 10% of the energy fed back into the grid (ITC, 2018).

Several facilities with **wind, solar and PV farm** linked to the desalination, in order to reduce the use of fossil fuels.



Priority: two technological challenges:

- Sea water desalination with a lower consumption of energy per m3
- Valorisation of brine (*on-site*; new industrial activity).

PRESENTATION OF THE TECHNOLOGICAL CHALLENGES

CHALLENGE No.1: **Exploitation of brine from the desalination plants** within the framework of the circular economy strategy: solutions and processes to increase the value brine on the path to minimising the discharge of brine as much as possible

CHALLENGE No.2: **Emerging desalination**: new desalination technologies, alternative or supplementary technologies to reverse osmosis, including new sub-processes or non-commercial changes of the current technology improving the energy efficiency of the desalination process

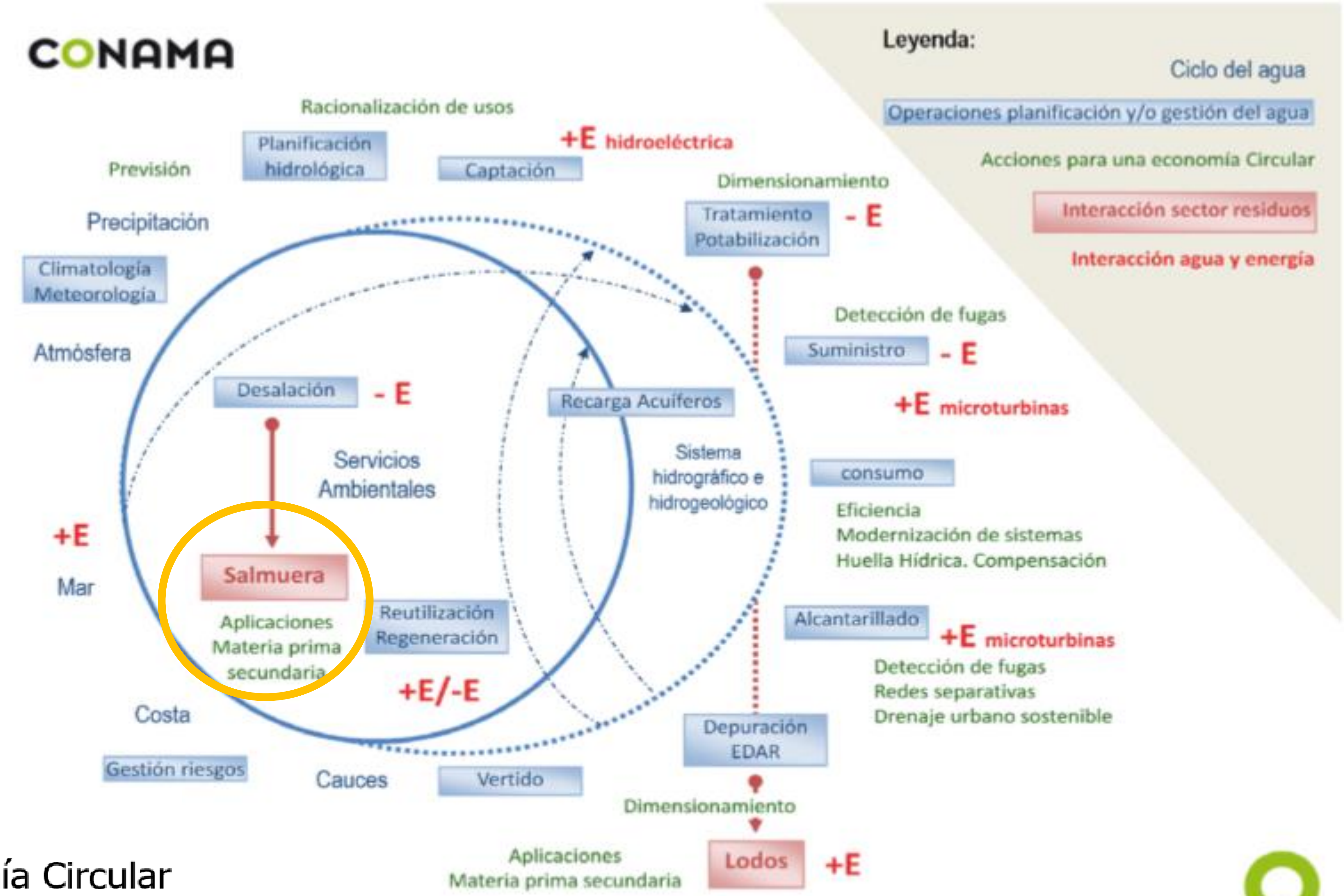
Challenge No.1 – Valorisation of brine from desalination plants

Discharge of brine in the Canary Islands: 570,000 m3/d (approx.)

In Gran Canaria alone 145,000 m3/d
(Plan Hidrológico Gran Canaria, 2º ciclo)

Environmental objectives in connection with brine management:

- Incorporate circular economy concepts into the industry.
- Need to reduce the impact on the marine environment.
- Support the incorporation of processes and technologies to add value to brine.



CONAMA
Leyenda:
Ciclo del agua
Operaciones planificación y/o gestión del agua
Acciones para una economía Circular
Interacción sector residuos
Interacción agua y energía
Racionalización de usos
Planificación hidrológica
Previsión
Captación
+E hidroeléctrica
Dimensionamiento
Tratamiento Potabilización
- E
Precipitación
Climatología Meteorología
Detección de fugas
Suministro
- E
Atmósfera
Desalación
- E
Recarga Acuíferos
+E microturbinas
Servicios Ambientales
Sistema hidrográfico e hidrogeológico
consumo
Eficiencia
Modernización de sistemas
Huella Hídrica. Compensación
+E
Mar
Salmuera
Aplicaciones Materia prima secundaria
Reutilización Regeneración
Alcantarillado
+E microturbinas
Detección de fugas
Redes separativas
Drenaje urbano sostenible
+E/-E
Costa
Depuración EDAR
Gestión riesgos
Cauces
Vertido
Dimensionamiento
Aplicaciones Materia prima secundaria
Lodos
+E

Challenge No.1 – Valorisation of brine from desalination plants

- Many technological-scientific centres and companies are working on solutions to **fully or partially increase the value of brine and to obtain added-value compounds or by-products**.

- Several emerging valorisation initiatives are currently at a developmental stage.

  - Extraction of chemicals to use them on-site in desalination plants or as a supply for other industries.

  - Exploitation of the energy produced by brine, using technologies that take advantage of the osmotic gradient between brine and a low-saline solution .

  - Capture and use of CO2.

- The key is **to generate a high efficiency of extraction/production, provided that this is sustainable and financially feasible**.

Challenge No.1 – Valorisation of brine from desalination plants

- The main referenced uses brine that may result in the marketing of products or by-products are the following:
  - Obtaining/recovery of salts and high-value by-products (evaporation, selective precipitation, etc.)
  - Production of acids and bases (electrolysis/electrodialysis using bipolar membranes)
  - Industry (e.g., chlor-alkali, CO_2 capture, etc.)
  - Exploitation of energy (forward osmosis, pressure-retarded osmosis, etc.)
  - Aquaculture and microalgae production.
  - Environmental applications (e.g., regeneration of wetlands)
  - Other (frost protection, hydrotherapy, etc.)
  - Hydroponics.

Challenge No.1 – Valorisation of brine from desalination plants

- Different potentially applicable technologies:
  - Forward osmosis (FO)
  - Pressure-retarded osmosis (PRO)
  - Pervaporation
  - Membrane distillation
  - Capacitive deionisation
  - New membrane materials: Graphene nanopores
    Biomimetics
    Aquaporins
  - Electrodialysis metathesis and electrodyalisis using bipolar membranes

Challenge No.1 – Valorisation of brine from desalination plants

- The subject matter of the Preliminary Market Consultation is:
  - Identify innovative solutions using non-commercial technologies or processes to increase the value of the brine coming from sea water desalination plants
  - Understand the scope of the solution: partial valorisation of brine, obtain added-value resources coming or generated from brine or reduce the volume discharged into the sea
  - Needs for the procurement and manufacture of equipment, creation of prototypes and pilot technologies to be initially validated in a simulated environment with real brine.
  - Assess the current technology readiness level (at least TRL 2). The approach, the objectives necessary for the validation in the lab, the technical-economic feasibility, the scalability (to reach at least a TRL 6 within 18 months) will be assessed.
  - Participants' need for feasibility, market and business mentoring studies.

Challenge No.1 – Valorisation of brine from desalination plants

- Cornerstones of the solutions to be submitted:
  - **Circular economy**: reduce discharge, generate new products to be directly or indirectly used as reagents for another process, exploitation of waste from another industry: synergies, minimisation of waste generation
  - **Solutions** in desalination plants: increase the value of brine directly in the very desalination plant, providing components to be directly used in these facilities. Technology capable of recovering energy by the use of brine.
  - **Green chemistry**: decline or elimination of the use of harmful chemicals in the idea/project, due to either a shift to a more sustainable product or the full avoidance or elimination of harmful chemicals in the process.
  - **Added-value products and diversification of the industrial activity**: connection with the local needs, alternatives to the dependency on the foreign market.
  - **Industry 4.0** Digitalisation of the processes, fostering a higher automatisation, connectivity and globalisation of the system.
  - **Increase of the produced water conversion:** Any process that directly or indirectly involved an increase of the conversion factor of the plant in comparison to the initial feed, whether generating desalinated water with the necessary quality or brine with favourable conditions to be redirected to the feed flow of the reverse osmosis plant.
  - Avoid solution proposals with **regulatory gaps** or without a clear regulatory framework.

Challenge No.1 – Valorisation of brine from desalination plants

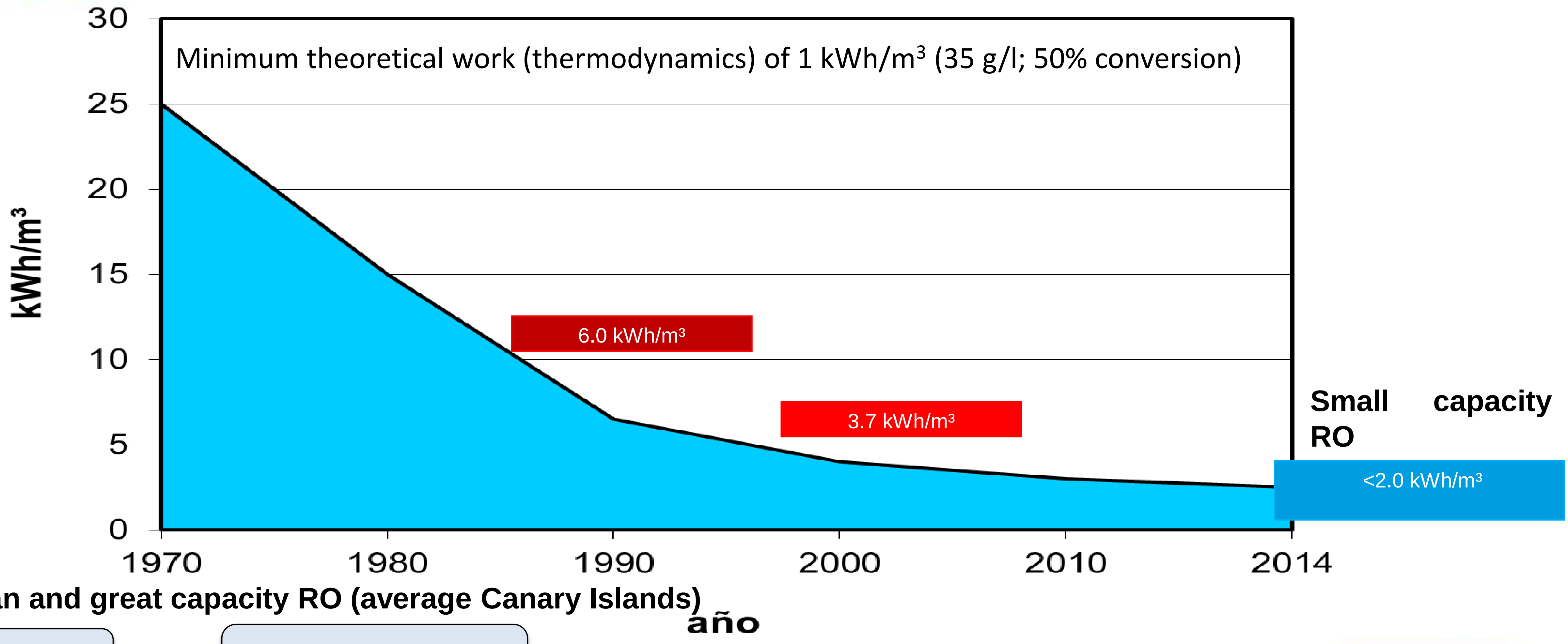
- Impact indicators to be considered
  - Economic profit generated from brine.
  - Cost reduction as a result of a decline in the import of chemicals.
  - Reduction of the flow/concentration of brine disposal in the case that the solution is provided *on-site*.
  - Reduction of the desalination plant's carbon footprint in case of energy solutions.
  - Employment creation.

PRESENTATION OF THE TECHNOLOGICAL CHALLENGES

CHALLENGES No.1: **Exploitation of brine from the desalination plants** within the framework of the circular economy strategy: solutions and processes to increase the value brine on the path to minimising the discharge of brine as much as possible

CHALLENGE No.2: **Emerging desalination**: new desalination technologies, alternative or supplementary technologies to reverse osmosis, including new sub-processes or non-commercial changes of the current technology improving the energy efficiency of the desalination process

Challenge No.2 – Emerging desalination - energy efficiency



Median and great capacity RO (average Canary Islands)

2020 → **3.25 kWh/m³**

Challenge No.2 – Emerging desalination - energy efficiency

- EXPLOITATION COSTS - ENERGY CONSUMPTION

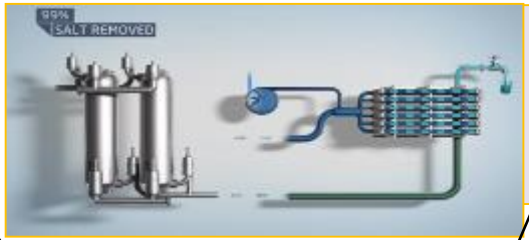
RO improvements (over the last 25 years):
- **High surface and low fouling membranes**
- **Energy recovery systems**
- **Variable frequency drives**
- **Pumping equipment efficiency**

The real minimisation of the specific energy consumption of reverse osmosis to desalinate sea water can be addressed from different perspectives:

- improvement of the efficiency of the electromechanical equipment used
- improvement of the membranes
- hybridisation with other processes or change in the mode of operation
- development of emerging technology

Challenge No.2 – Emerging desalination - energy efficiency

PELTON = 4.14 kWh/m³
<u>Desalination Plant:</u>
Las Palmas III

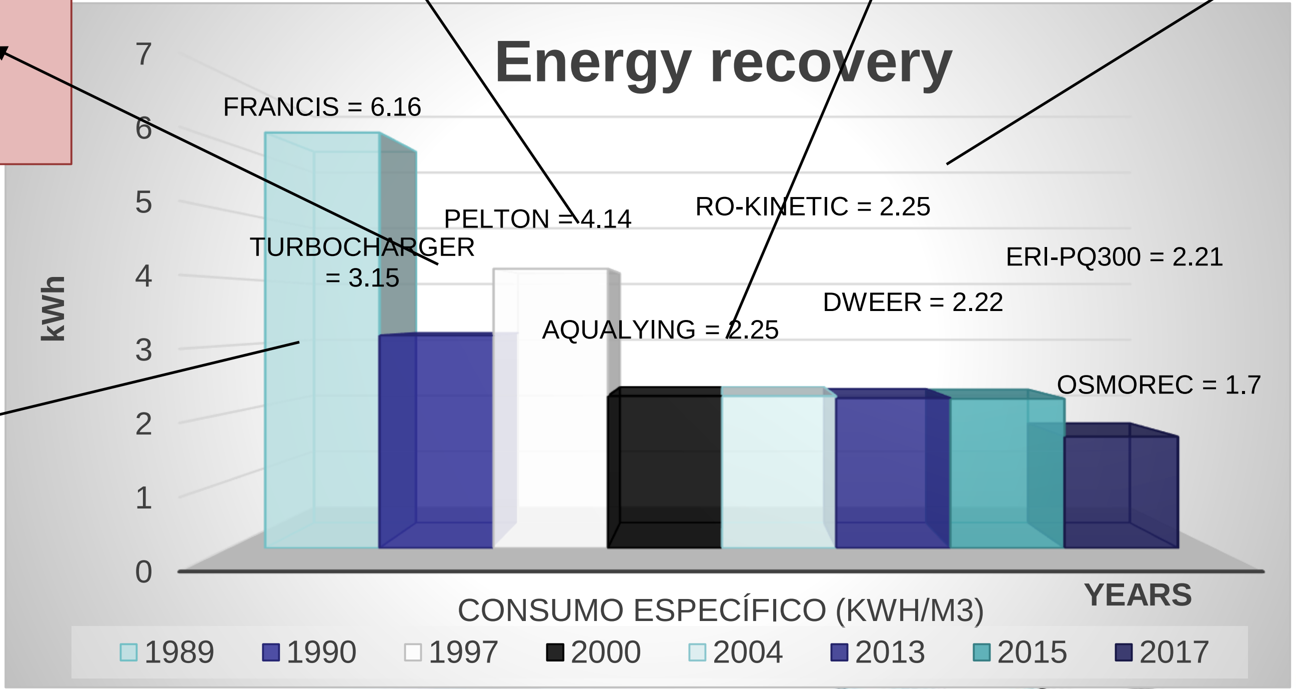


AQUALYNG = 2.25 kWh/m³
<u>Desalination Plant:</u>
Tauro

RO-KINETIC = 2.25 kWh/m³
<u>Desalination Plant:</u>
El Confital

TURBOCHARGER = 3.15 kWh/m³
<u>Desalination Plant:</u>
Bonny

FRANCIS = 6.16 kWh/m³
<u>Desalination Plant:</u>
Las Palmas III



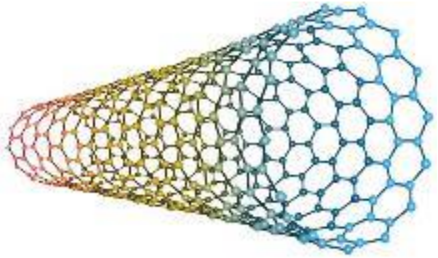
SALINNO® 1.98 kWh/m³
Pozo Izquierdo
2019

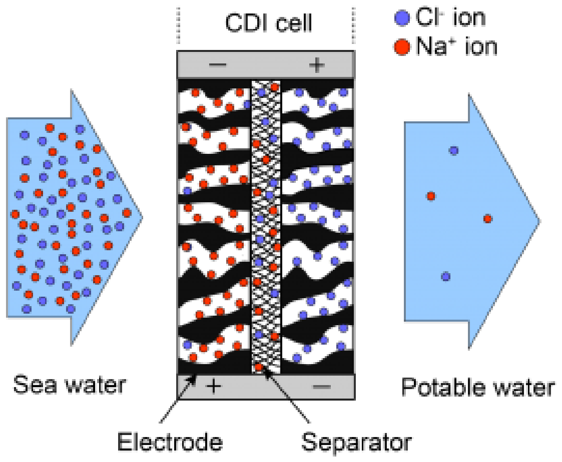
Source: Gómez-Gotor, A., Del Río-Gamero, B., Prado, I. P. & Casañas, A. (2018). The history of desalination in the Canary Islands. Desalination, 428, 86-107.

Challenge No.2 – Emerging desalination - energy efficiency

The main referenced disruption technologies or changes of RO in desalination are:

- FO (Forward Osmosis)
- Pressure-retarded osmosis (PRO)
- CDI (Capacitive Deionization)
- Carbon nanotubes (CNT) - graphene
- Biomimetic membranes - Aquaporin proteins (AQP)
- Electrodialysis metathesis (EDM) - bipolar membranes
- Membrane distillation (MD)
- Adsorption
- Pervaporation
- Latent heat...





Challenge No.2 – Emerging desalination - energy efficiency

- The subject matter of the Preliminary Market Consultation is:
  - Identify new sea water desalination processes or non-commercial changes of RO extrapolating **at mid or large scale a consumption projection below 2.0 kWh/m3 (desalination only)**.
  - Assess the current technology readiness level (at least TRL 2). The approach, the objectives necessary for the validation in the lab, the technical-economic feasibility, the scalability (to reach at least a TRL 6 within 18 months) will be assessed.
  - Understand the implications of the solution: simulations, expected feasibility, expected impact.
  - Needs for the procurement and manufacture of equipment, creation of prototypes and pilot technologies to be initially validated in a simulated environment with real brine.
  - Participants' need for feasibility, market and business mentoring studies.

Challenge No.2 – Emerging desalination - energy efficiency

- Cornerstones of the solutions to be submitted:
  - **Energy efficiency, circular economy and green chemistry**: the lowest energy consumption possible to desalinate sea water, reduce the discharge, free-chemical desalination, ZLD combinations.
  - **Industry 4.0** Digitalisation of the processes, fostering a higher automatisation, connectivity and globalisation of the system.
  - **Increase of the produced water conversion:** Any process that directly or indirectly involved an increase of the conversion factor of the plant in comparison to the initial feed, whether generating desalinated water with the necessary quality or brine with favourable conditions to be redirected to the feed flow of the reverse osmosis plant.
  - Hybridisation with **energy generation** taking advantage of the salinity gradient.
  - Avoid solution proposals with **regulatory gaps** or without a clear regulatory framework (drinking water).

Challenge No.2 – Emerging desalination - energy efficiency

- Impact indicators to be considered
  - Reduction of the carbon footprint in the desalination process through a decline in the energy consumption of the process.
  - Reduction of the volume or flow of the discharge of brine (zero liquid discharge (ZLD) technologies).
  - Environmental benefit as a result of the impact caused by the disposal or discharge of brine.
  - Decline in the exploitation costs, also resulting from the lower use of chemicals.
  - Increase of the efficiency of the desalination process through improvements of the membrane properties (higher flow, lower fouling).
  - Generation of valuable byproducts, apart from desalinated water.

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Thank you very much!

Thank you!

desal+@desalinationlab.com