Islands as references of Circular Economy Models: Potentials and Challenges

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CTO – R&D&I Director
Canary Islands Institute of Technology - ITC
ITC is a technology center specialized in

- Renewable Energies and Energy Efficiency
- Sustainable Water Technologies
- Algae Biotechnology
- Environmental Analysis (pollution prevention)
- Computing & ICTs
- Biomedical Engineering (customized implants)

- International Cooperation (above sectors; focus: West Africa)
- Innovation & Entrepreneurship
ITC: POZO IZQUIERDO facilities

Gran Canaria
The Canary Islands (Spain)

- 2.1 million inhabitants, 13 million tourists/year (fast economic growth)
- Energy dependence on external resources
- Electricity generation from fossil fuels (oil); low heat demand
- Isolated (insular) electrical systems
- Lack of water resources (extremely low rainfall)
- Insular dimension: strategic need to maximise the use of endogenous resources (energy+water for self-sufficiency)
- Importance of water-energy binomial (desalination)
Additional Challenges (apply to many islands worldwide)

- Biodiversity preservation (fragile land&sea ecosystems)
- Climate change
- Population density/growth
- Waste (removal, recycling, small scale biomass exploitation, etc.)
- Food Autarky
- Sustainable tourism
- Sustainable transport (land&sea)
- Difficulties for creation of new and sustainable economic sectors
  (potential: blue economy)
- Difficulties for the massive deployment of Renewable Energies
  (weak/isolated grids, lack of space for energy infrastructure
  placement, etc.)
- Etc.

Continental areas vs. Islands
  BaU solutions vs. Sustainable/Smart/Circular solutions
The Canary Islands

- Historically, the Canary Islands have suffered water scarcity associated to: low rainfall, high permeability of soils, over-exploitation of aquifer resources

- Conventional solutions applied:
  - Groundwater catchment by horizontal water tunnels ("galerías") and vertical wells
  - Rainwater catchment and storage
  - Construction and waterproofing of reservoirs
  - Efficient use of water
Canary Islands (non conventional) water resources (1)

Desalinated freshwater – European reference

- The first European seawater desalination plant was installed in Lanzarote island (1964)
- Currently, freshwater total demand is 200 hm³/year (more than 650,000 m³/day installed, approx. 2% world capacity)
- All desalination technologies installed (VC, MED, MSF, OI, EDR, SOLAR STILLS…..)

PRODUCTION CAPACITIES

<table>
<thead>
<tr>
<th></th>
<th>Capacity</th>
<th>Plants</th>
</tr>
</thead>
<tbody>
<tr>
<td>Seawater</td>
<td>430,000 m³/d</td>
<td>167</td>
</tr>
<tr>
<td>Brackish water</td>
<td>150,000 m³/d</td>
<td>146</td>
</tr>
<tr>
<td>Reclaimed wastewater</td>
<td>66,000 m³/d</td>
<td>12</td>
</tr>
</tbody>
</table>
Reclaimed wastewater

- Goal: to balance the hydric deficit of the islands and to promote a sustainable management of natural resources
- 20 years experience in wastewater treatment and reuse
- Recent normative and management challenges

**DEMAND**

<table>
<thead>
<tr>
<th></th>
<th>Demand (hm³/y)</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Irrigation</td>
<td>10.40</td>
<td>41%</td>
</tr>
<tr>
<td>Golf Public gardens</td>
<td>15.19</td>
<td>59%</td>
</tr>
</tbody>
</table>
15 years experience in non-conventional low energy consumption waste water treatment systems (< 2.000 inh.equiv.)

Gran Canaria

Temisas, Agüimes

Santa Lucía

Presa de Las Niñas

Campus de Tafira

La de la Naturaleza

La Laurisilva

Lomo Fregenal,

Arenales
Desalination has narrowed the gap between water demand and production for more than 20 years, thanks to a cheap energy supply.

But the age of “easy & cheap oil” is coming to an end and the link water–energy is critical.

A promising option is desalination powered by renewable energies (RE), which are abundant, clean and endless resources.
The Canary Islands

- 3 GW installed power, approx. 9000 GWh total el. consumption
- 15% of electricity consumed in water cycle
- Abundant Renewable Energy Resources:
  - wind: \( \sim 4000 \text{ h.eq.}/\text{y} \); sun: \( \sim 2000 \text{ kWh/m}^2/\text{y} \)
- GOAL: 25% penetration in 2018

Structure of internal fossil fuels market

Electricity generation 55.6%

Road Transport 29.9%

Other (Industrial, Residential...) 12.1%

Combined water-electricity production 2.4%

Seawater desalination plants
ISLANDS are NATURAL LABORATORIES for developing, testing and demonstrating new technologies which will be implemented in continental regions (Europe and ROW), in insular regions worldwide, as well as in developing countries.

ISLANDS are the IDEAL PLATFORMS to showcase and transfer adapted technologies to regions of developing and emerging countries worldwide (and particularly of European neighbour regions).
Every island configurates one or several real laboratories for testing and demonstrating new technologies, especially emerging ones.

Biggest islands: 900,000 inhabitants; Smallest Islands <10,000 inhabitants
The Canary Islands are fully committed to the development and implementation of innovative energy, water and environmental protection technologies and policies, providing sound proof of concepts for the whole Europe and RoW.
The Canary Islands have been carrying out successful international cooperation projects (especially with West Africa and South America) for many years, developing and transferring adapted technology, for example in the energy, water, agriculture, fishing and public health sectors.

**RENEWABLE ENERGIES AND WATER TECHNOLOGIES**

The Canary Islands Government is deploying technology parks specialized in adapting technologies for the developing world.
Capacities and outstanding projects (2) - WATER


○ SDAWES project (Seawater Desalination with Autonomous Wind Energy System), connection of 3 different desalination systems to an off-grid wind farm.

2x230 kW off-grid wind farm.

EDR plant (from 3 to 7.9 m\(^3\)/h).

8 RO desalination plants (1 m\(^3\)/h each).

Synchronous machine (100 kW) & flywheel.

VVC plant (2 m\(^3\)/h).
Capacities and outstanding projects (3) - WATER

Case 2. Seawater - PV desalination unit (since 1999)

- Autonomous PV-RO system, designed to satisfy small water demands (up to 1,000 inhabitants) isolated from the electric grid. DESSOL® is an ITC patent.

RO unit - <3.5 kWh/m³.

PV field

Battery back-up system

Also tested a battery-less PV-RO system

Average operation 8 h/d (summer); 6 h/d (winter).
Case 3. Wind energy for high capacity desalination plant

- Grid-Wind-RO system, private initiatives

On-grid wind farm

SWRO plant with energy recovery - <3.0 kWh/m³

Irrigation
We have accumulated 20 years of experience in the development of solutions for the ENERGY and WATER supply to peri-urban/rural/remote areas.

We have carried out consulting and electrification/water desalination projects using RENEWABLE ENERGIES, as well as training and awareness activities in:

- Mauritania (since 1996)
- Morocco (since 1998)
- Tunisia
- Cape Verde
- Senegal
- ECOWAS
Technology transfer examples (I)

- Electrification of isolated communities with wind/solar energy

- Development and installation of small autonomous desalination plants, powered by renewable energies
Technology transfer examples (II)

- 4 seawater desalination plants, National Park Banc d’Arguin, Mauritania

- 4 brackish water desalination plants, powered by solar energy, Morocco

- Brackish water desalination plant powered by solar energy, Tunisia

- Consultancy in rural “microgeneration” (RES hybrid systems and micro/minigrids) (Cape Verde and ECOWAS)
Climate Change Study: Regional Approach
REUNIÓN DE SOCIOS

–

CIERRE DEL PROYECTO

(Lunes 16

–

Junio

2014)

http://climatique.itccanarias.org
The CLIMATIQUE project

- 2 years project lead by ITC, carried out by Canary Islands’ and Moroccan Institutions (Sous Massa Draa Region)

- “New” approaches:
  - Projections below the meso-scale (“regional” level)
  - Monitoring of bird migration patterns (deviations) as potential Climate Change indicator
Regionalization improvements

ERA-Interim 2-metre Maximum Temperature in Celsius Degrees

CRU-TS 3.10 2-metre Monthly Minimum Temperature in Celsius Degrees

TRMM 3B42 Daily Precipitation in mm

WRF 2-metre Maximum Temperature in Celsius Degrees
Domains definition
WRF model configuration

WRF 2-metre Maximum Temperature

Quarzazate (30.930N, -6.909W)
Agadir Al-Massira (30.316N, -9.383W)
Sidi-Ifrni (29.368N, -10.180W)

Resolution 15 km

Atlantic Ocean

Canary Islands

Souss-Massa-Draa

Madeira

ULL Universidad de La Laguna

Cooperación Transfronteriza

UNION EUROPEA

Fondo Europeo de Desarrollo Regional
Projections: annual mean changes, 2090-2100
Projections: seasonal changes, Precip., 2090-2100
Conclusions

• Maximum and minimum temperatures increase:
  • Up to 2.5ºC (2045-55) and up to 6 ºC (2090-2100)
  • The changes will be more important at elevated zones
  • During summer, the changes will be more significant

• Precipitations decrease:
  • Most important changes will occur at high altitude areas
  • During winter, the changes will be more significant
  • The largest changes appear for the period 2090-2100 and the RCP8.5 scenario

• Winds:
  • No significant changes during 2045-55 were appreciated
  • For 2090-2100 decade and for the scenario RCP8.5, important changes are observed at high altitude areas with an increase in the East component
  • At the south part of the domain, an increase in the NE component is observed

Call H2020-WATER-2015; Topic: “Integrated approaches to food security, low-carbon energy, sustainable water management and climate change mitigation”
THE ISSUES OF THE CALL

- Increased understanding of how water management, food and biodiversity policies are linked together and to climate and sustainability goals.

- Reduction of the uncertainties about the opportunities and limitations of low-carbon options, such as bioenergy technologies and resource efficiency measures, in view of relevant near-term policy initiatives.

- Contribution to future assessments, including those of the IPCC, with multidisciplinary and integrated tools.
BLUE Growth / BLUE Economy
Implementation of RIS3 Priorities in Blue Growth

Las Palmas de Gran Canaria (Canary Islands)

Canary Islands

BLUE GROWTH IN REGIONAL RIS 3

8-9 October 2015

Organised by:

Local partners:
Pilot projects (1)

- Blue Economy / Algae Technology / Business Incubation:

  Algalimento S.L. (microalgae production), incubated at ITC Pozo Izquierdo facilities

Support to Biotech start-ups
Pilot projects (2)

- **Coastal Water Quality / Protection of Marine Biodiversity:**
  - Monitoring of discharges / Risk prevention
  - Venturi (desalination plants´) Brine Diffuser (International Patent)

- **Marine Renewable Energies:**
  - Arinaga (Gran Canaria) Multimegawatt Wind Test Platform:
    - First spanish off-shore wind turbine tested/certified 2014/2015

**Europe in my region|city**
September|October|November 2015
GOAL: 100 % Renewable Energy Supply
Technical Solutions (I)  HV/MV: Pumped Hydro (where possible)

- Upper Reservoir
- Lower Reservoir
- Hydro Power Station
- Pumping Station
- Control
- Desalination Plant
- Wind Farm
Technical Solutions (II)

- **HV/MV:**
  - Subsea electrical interconnections

**Refuerzo del enlace submarino entre Lanzarote y Fuerteventura**
Technical Solutions (III)

- **MV/LV:**
  - Distributed Generation, esp.:
  - Mini- & Microgrids with high renewable energy penetration, incl. energy storage, management of critical loads (e.g. seawater desalination) and electrical mobility
DEMAND MANAGEMENT: water desalination

15% of energy production goes to water desalination and water distribution.

Use of desalinated water

<table>
<thead>
<tr>
<th></th>
<th>Residential &amp; touristic</th>
<th>374,000 m³/day</th>
<th>153 plants</th>
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</thead>
<tbody>
<tr>
<td>Agriculture</td>
<td></td>
<td>146,000 m³/day</td>
<td>100 plants</td>
</tr>
</tbody>
</table>

Energy consumption for water desalination:

- 1Kgr fuel/ m³ of desalinated water.
  - For 522,000 m³/day
  - Import 150,000 Ton fuel /year.
DEMAND MANAGEMENT: Electric cars

30% of oil consumed in the internal market goes to the road transport sector.

Peak shaving: More than 1 million vehicles could charge at valley hours of the electric demand curve.
Maximizing PV/RES Penetration in islands

- Governance
- Operation

Enhancing Effective Implementation of Sustainable Energy Action Plans in European islands through Reinforcement of Smart Multilevel Governance

www.sustainableislands.eu
www.smilegov.eu

- Distributed Generation (Microgrids)
  - La Graciosa
  - TILOS
  - West Africa
SiNGULAR Project (FP7)

**R&D:** effects of large-scale integration of renewable energy sources (RES) and demand side management (DSM) on the planning and operation of insular (non-interconnected) grids.

**Emerging issues:** grid-connected RES, large scale distributed generation (DG), informed or active consumers with real-time pricing, energy efficiency, demand response, energy storage, forecasting: Towards a Smart and Sustainable Grid!

Financed by EC FP7: 5.5 M€ (Dec. 2012- Dec. 2015)

Pilot sites for testing and validation:
- S. Miguel Island, Azores – Portugal
- La Graciosa, Canary Islands – Spain
- El Hierro, Canary Islands - Spain
- Island of Pantelleria – Italy
- Crete Island – Greece
- Great Island of Brailla – Romania

Objectives:
- Reduce CoE
- Communicate to the Operator the status of the EES and forecast of the energy flow
- Receive emergency orders from the Grid Operator
- Ensure that the energy flow at the PCC is within the forecasted limits
TILOS Project (H2020)

**INDUSTRIAL PARTNERS**
- EUNICE Laboratories SA (EL)
- FIAMM Energy Storage Solutions SRL (IT)
- Open Energi (UK)
- SMA Solar Technology AG (DE)
- Younicos AG (DE)

**ISLAND GRID OPERATORS**
- Hellenic Electricity Distribution Network Operator S.A. (EL)
- Schleswig-Holstein Netz AG (DE)

**RESEARCH / ACADEMIC PARTNERS**
- Commissariat à l’Energie Atomique et aux Energies Alternatives (FR)
- Instituto Tecnológico de Canarias S.A. (ES)
- Kungliga Technica Hogskolan (SE)
- Rheinisch-Westfälische Technische Hochschule Aachen (DE)
- Technological Educational Institute of Piraeus (EL)
- Universite de Corse (FR)
- University of East Anglia - Business School (UK)

**NGOs**
- WWF World Wide Fund for Nature – Greece (EL)
Existing Expertise/Capacities (Energy & Water)

- Energetic optimization of the Water Cycle

- Water desalination and treatment/reuse technologies, powered by Renewable Energies (+ experience in Africa)

- Water quality (focus: coastal waters)

- Design of innovative & sustainable energy generation systems (microgrids, hybrid systems, etc.)

- Dynamic grid stability studies (using advanced software)

- Reversible pumped hydro power systems and design of energy storage solutions

- Integration of Renewable Energies in electricity grids; design of power electronics devices

- Energy Planning strategies (focus: insular systems & remote areas)

- Test of RES system components (both electrical (focus: PV) and thermal (solar heaters)); modeling of thermal loads in buildings using advanced software; bioclimatic design of buildings
The paradigms of our vision:
La Graciosa & El Hierro
La Graciosa 100% RES

La Graciosa:
650 inhabitants
0.7 MW peak
2 GWh/y demand

Smart Microgrid with high RES penetration, energy storage (incl. desalination) and electric vehicles fleet
Electric power supply through a submarine cable
- Cable capacity = 1.030 kW
- Max electric demand = 668 kW
- Electric consumption 1.6 GWh/year
- Diesel genset for emergencies

Water supply through a submarine water pipe

High wind and solar resources
- Solar radiation = 4.9 kWh/m²-d
- Wind speed = 5.7 m/s

La Graciosa

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<table>
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<tr>
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<tbody>
<tr>
<td>Permanent residents</td>
<td>658</td>
</tr>
<tr>
<td>Residents coming on</td>
<td></td>
</tr>
<tr>
<td>weekends</td>
<td>200</td>
</tr>
<tr>
<td>Residents coming in</td>
<td></td>
</tr>
<tr>
<td>summer</td>
<td>600</td>
</tr>
<tr>
<td>Touristic beds</td>
<td>400</td>
</tr>
<tr>
<td>Houses</td>
<td></td>
</tr>
<tr>
<td>Electric consumption</td>
<td>1.6 GWh/y</td>
</tr>
<tr>
<td>Energy for Water</td>
<td>175,200 kWh/y</td>
</tr>
<tr>
<td>consumption</td>
<td></td>
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</table>

La Graciosa: The perfect object to illustrate one of the pillars of the new energy paradigm: distributed generation / RES micro-mini grids
Microgrid in La Graciosa Island

- Technical works on-going (coordination between ENDESA and ITC with the Insular Authority)
Microgrid in La Graciosa Island

- Insular authority is investing in:
  - Installation of PV systems
  - Installation of charging station for electric vehicles
- Technological Industrial partners (ENDESA, ENEL, ITC) are working together to raise funds for:
  - Installation of batteries
  - Finalisation of technical studies to maximize RES penetration
SMART METERS (already installed) + electric vehicles (planning phase)

smartmetering is more
more intelligent
more flexible
more efficient
more endesa
El Hierro: first 100% RES Island

- 278 km²
- 10,500 inhabitants
- 7 MW peak
- 40 GWh/y demand (Diesel)
EL HIERRO
Sustainable Development Plan (1997)
Biosphere Reserve Declaration (2000)
BIOSPHERE RESERVE – UNESCO - JANUARY 2000

Sustainable Development Program
SDP
Sustainable Development Program

Start 1995
Updated 2006

- Architecture
- Tourism
- Agriculture
- Employment
- Fisheries
- Energy
- Water
- Culture
- Transportation
- Commercialization
- Wastes
- Livestock
- Industry
- Etc.
Sustainable Development Program

6 CRITERIA

1. People as the Main Target
2. Clean Production and Technologies
3. Systems Design
4. Creating Cycles
5. Economical System / Local Economy
6. Social Development and Citizens Participation
¿What have we done until now towards sustainability?

Organic Agriculture
Waste Recycling
Marine Reserve
El Hierro, UNESCO Biosphere Reserve
Primary Sector Products Processing
Sustainable Water Management
Sustainable Tourism
Renewable Energies
100% renewable energy supply

- Design and construction of a Wind-Pumped Hydro Power Station
- Installation of solar collectors & PV systems
- Evaluation of biomass exploitation possibilities
- Transport. Sustainable Mobility
- Environmental Education
Wind-Hydro Power Station
El Hierro: 100% RES Island

In operation since 2014

Wind – Pumped Hydro Power Station
## Wind-Hydro Power Station

<table>
<thead>
<tr>
<th>Component</th>
<th>Capacity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wind Farm</td>
<td>11.5 MW</td>
</tr>
<tr>
<td>Hydroelectric Substation</td>
<td>11.3 MW</td>
</tr>
<tr>
<td>Pumping Station</td>
<td>6 MW</td>
</tr>
<tr>
<td>Upper Reservoir</td>
<td>400,000 m³</td>
</tr>
<tr>
<td>Lower Reservoir</td>
<td>150,000 m³</td>
</tr>
</tbody>
</table>
Upper Reservoir
Conductions

3 km.

1 m./diam.
0,8 m./diam.
Lower Reservoir
Hydro-Station
Pumping-Station
Edificio Central: Subestación Hidroeólica y Sala de Bombas
Five E-70 energy-self-sufficient El Hierro

ENERCON WIND TURBINES WORK IN COMBINATION WITH A PUMPED STORAGE SYSTEM. THE PROJECT MAKES POWER GENERATION ON EL HIERRO COMPLETELY INDEPENDENT OF FOSSIL FUELS.

El Hierro has set itself ambitious goals for power production. The smallest of the Canary Islands now wants to meet its electricity demand using one hundred percent renewable energies. The electrical energy will be produced directly on the island to make El Hierro self-sufficient in electricity. The project is funded with a grant from the Spanish Government and the European Union. The project was realised on the west coast near the island’s main settlement of Valverde. Enercon supplied the wind energy converters and the wind farm control unit FICOS. Five E-760.3 MB wind turbines

Upper reservoir at El Hierro's hybrid power plant. In the background to the right the wind farm.
Inauguración de Corona del Viento. La Isla del Meridiano comienza a producir energía 100% renovable
El arranque del parque eólico marca el punto de partida para el autoabastecimiento energético y de agua

**EL HIERRRO ENCIENDE LA LUZ LIMPIA**

El arranque ayer de la Central Hidroeléctrica de El Hierro convierte a la Isla y a Canarias en referente mundial en energías renovables. Su inauguración, en medio del debate de las proyecciones petrolíferas que el Estado ha autorizado frente a Lanzarote y Fuerteventura, se aprovechó para pedir una Canarias «verde y azul, no negra».

Siete minutos tardaron ayer en aparcar a bordo los cinco aerogeneradores del parque eléctrico de la Central Hidroeléctrica de El Hierro. A las 16:40 de la mañana se inició el proceso con la celebración de las argas según la delegación a su altura. La Central, cuatro turbogeneradores, con energía 100% limpia y para demostrar que las energías renovables y la demanda son compatibles, dijo José Antonio Armis, que no recordará que la Isla tiene el último modelo de transformación energética que daría a otros territorios del mundo.

Su inauguración, por su parte, no desaprovechó la ocasión para insistir en que Canarias quiere un futuro verde y azul, pero no marrón, en claro alineación con la propuesta que el Gobierno de la Nación ha autorizado a buscar frente a Lanzarote y Fuerteventura.

El derrumbe fue irónico, pero no perjudicial para la Isla, del que se acordaba que «la tenencia de la energía del futuro, el futuro verde de Canarias, el futuro de Canarias, el futuro de Canarias, el futuro de Canarias, el futuro de Canarias, el futuro de Canarias, el futuro de Canarias, el futuro de Canarias, el futuro de Canarias».

Inauguración de Corona del Viento. El evento reunió en El Hierro a más de 200 personas. Media docena de invitados portaban pegatinas en contra del petróleo. Una cápsula del tiempo recordará el arranque de la central

**ENERGÍAS RENOVABLES: PUESTA EN MARCHA DE LA CENTRAL HIDROELÉCTRICA HERREÑA**

Corona del Viento ahorrará a la atmósfera 18.700 toneladas anuales de CO2

La central hidroeléctrica pone sobre el Hierro el foco mundial en energías limpias. Paulino Ríos y Hernández Bento ajustan cuentas por el crudo
Thank you very much!
Gonzalo Piernavieja
gpiernavieja@itccanarias.org