- Depth of water resource
- Brine disposal options

3. Develop typical project profiles
4. Case examples
5. Project budgeting guidance

Estimated Project Budget and Schedule

$250,000; 12 months

Proposed Partners

[none provided]

Known Prior Research on This Topic

1. National Resource Council, 2008. Desalination: A National Perspective. Washington DC: National Academy Press.
2. European Renewable Energy Council. Key Issues for Renewable Heat in Europe (K4RES-H). Key Issue 5: Innovative Applications: Geothermal Utilization for Seawater Desalination
3. UNESCO-EOLSS Integrated Power and Desalination Plants Project: Encyclopedia of Desalination and Water Resources DESWARE
4. W. Teplitz-Sembitzky. Sept. 2000. The Use of Renewable Energies for Seawater Desalination – A Brief Assessment
5. K. Bourouni, R. Martin, L. Tadrist, M.T. Chaib. Heat transfer and evaporation in geothermal desalination units. 1999. Applied Energy, Vol 64, Issues 1-4.
6. (Funded by KFW)

INFRASTRUCTURE

Infrastructure Project 1

Title

Technical and economic comparison of reverse osmosis (RO) and electrodialysis (ED) brackish water desalination units powered by hybrid wind/photovoltaic (PV) systems

Needs the Project Meets

The demand for fresh water is increasing due to population growth, change of life style, and industrial growth. As a result, there is a reduction in the volume of available fresh water resources, requiring the use of impaired water supplies. In order to meet the increasing demand for fresh water resources, we need a better balance of water management (including water conservation and recycling) and sustainable development of new water resources. This project utilizes an integrate hybrid renewable energy-desalination system designed for sustainable development of new water resources by the following approach:

- Suitable desalination technologies to treat brackish water resources. Both pressure driven (RO) or nanofiltration (NF) and electrically driven (ED or EDR) technologies are good candidates.
- A hybrid wind/PV system provides more consistent daily and year round performance and reduces the need for back-up fossil fuel generation.
- Characterize the efficiency and cost effectiveness of RO compared to ED.

Benefits of Project and Expected Outcomes

The novel aspect of this project is the use of both wind and solar energy in a hybrid renewable energy generation system. The major advantages of a solar/wind hybrid system are the following:

- Different and opposite patterns in terms of wind and solar resources (wind common at night when solar energy is not available), making solar/wind complimentary solutions
- Less reliance on one method of power production
- More consistent power generation
- Reduces the need for high cost energy storage technologies, resulting in a cost-effective power supply

Unlike other renewable energy resources, the combined solar/wind system is that it allows for the use of either RO or ED, which are the most energy efficient technologies available for brackish water desalination.

Another important outcome of this project is that both RO and ED units are major technology and currently used in brackish water desalination, but there is no availability of sufficient information about the economic comparison of these two processes when they are powered by hybrid renewable system.

Expected Outcomes Includes

- Knowledge of how to integrate a system consisting of two renewable energy sources and a desalination technology
- A detailed understanding of the technical aspects of both desalination and renewable energy (wind and solar) technologies.
- Quantify the economic benefits of the wind/ photovoltaic/reverse osmosis system and wind/ photovoltaic/electrodialysis system including: advantages, limitations, power consumption, and the cost of fresh water produced.
- The above information will help in choosing the suitable system for the available site and water condition.

Research Objectives

The goal of this project is to study the technical feasibility and suitability of hybrid integrations of wind and solar renewable energy resources with desalination processes. The objectives of the project can be summarized as follows:

- Review the state of the art of wind and solar technologies and development trends.
- Review of RO and ED/EDR desalting systems for integration with wind/solar hybrid.
- Evaluation of the feasibility and benefits of the utilization of RE for power supply to stand-alone water desalination units through the reduction of fossil fuel consumption.
- Study the performance of RO and ED desalination units when they are coupled to renewable energy resources.

- Study the quality and cost of the fresh water produced from each process.
- Assessment of the effectiveness, reliability, operational and maintenance (O&M) requirement, and cost of the RE technologies.
- Study the environmental benefits resulting from using renewable energy as power source for desalination units.
- Understand variable desalination operation based on availability of wind/solar

Research Approach (numbered by task)

1. Overview of wind and solar technologies
   - Overview of wind technology with emphasis on the types wind turbines, turbine designs, available sizes, power production, limitations, market, applications and environmental advantages and disadvantages.
   - Overview of solar PV with emphasis on PV theory, solar cell types, PV systems types, market and environmental benefits.
   - Overview of the hybrid RE systems with emphasis on the reliability of power production.
2. Overview of desalination processes
   - Overview of reverse osmosis (RO) desalination systems with emphasis on theory, system components, performance and market.
   - Overview of electrodialysis/electrodialysis reversal (ED/EDR) desalination systems with emphasis on theory, system components, performance, and market.
3. Overview of brackish water with emphasis on characteristics, habitats, total dissolved solids (TDS) content, and geographical availability of wind and solar energy.
4. Compare RO vs ED technologies as functions of feed water chemistry and product quality requirements.
5. Design conceptual, integrated hybrid renewable energy-desalination system design based on the suggested desalination system capacity, water chemistry, product water requirements, and availability of wind/solar and resulting power generation.
6. Conduct a feasibility study using available software to predict system performance and fresh water production cost and environmental benefits for a range of operating conditions (i.e. availability of wind/solar).
7. Submit recommendations for pilot or demonstration of integrated RE-desalination system.

Estimated Project Budget and Schedule

We anticipate this will be approximately a one-year effort, with a project budget approximately equal to the billable rate for one full-time researcher, $200,000.

Proposed Partners

National Renewable Energy Laboratory, Reclamation, General Electric

Known Prior Research on This Topic

Carta, J.A., González, J., Subiela V. 2003. Operational analysis of an innovative wind powered reverse osmosis system installed in the Canary Islands. Solar Energy 75:2003:153.

Subiela, Carta, González. 2004. The SDAWES project: lessons learnt from an innovative project. Desalination 168:2004:39–47.

ADU -RES Project 2005. (INCO -CT -2004-509093) Coordination Action for Autonomous Desalination Units based on Renewable Energy Systems, "Report on the status of autonomous desalination units based on renewable energy systems."

Peñate, B., Castellano, F. Ramírez, P. 2007. PV-RO Desalination Stand-Alone System in the Village of Ksar Ghilène (Tunisia). Proceedings of the IDA Conference, Maspalomas (Gran Canaria Island) October 2007

Essam Sh. Mohamed, G. Papadakis, E. Mathioulakis and V. Belessiotis. (2008) A direct coupled photovoltaic seawater reverse osmosis desalination system toward battery based systems – a technical and economical experimental comparative study; Desalination, Volume 221, Issues 1–3, 1 March 2008, Pages 17–22

E. Brauns, Salinity gradient power by reverse electrodialysis: effect of model parameters on electrical power output, Desalination 237 (2009) 378–391

Enercon. Enercon desalination systems – sustainable solutions for drinking water production. http://www.enercon. de/www/en/broschueren.nsf/vwwebAnzeige/1008C1

E9AED 7CAA 5C1256FC 7003776B9/$FILE /DesalinationSystems_Booklet_English.pdf, downloaded the 1.12.2009

INSTITUTIONAL CONSIDERATIONS

Institutional Considerations Project 1

Title

Guidance manual on financial implementation of renewable energy (RE) - desalination projects - options and implementation

Needs the Project Meets

1. Identifies sources of public financing for an RE-desalination project.
2. Identifies potential sources of private financing
3. Identifies tax and other incentives available to these types of projects
4. Identifies opportunities for exporting power/heat energy from oversized RE segments of a project as a co-generation project.

Benefits of Project and Expected Outcomes

Provides a clear road map for the project planners to identify and involve potential sources of financial assistance, tax incentives and commercial opportunities at the start of the project. This will enable the planners to fashion the project from the start of fully exploit all avenues of financing and particularly to start incorporating the technical features of the project necessary to meet the requirements of the financial stakeholders, particularly if commercial power sales are expected.