Poster Abtracts

A Hybrid Photovoltaic/Thermal (PV/T) System for Water Desalination

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Poster Abstract 1

Photovoltaic System for Desalination (PV-T) is a system invented by UTEP that combines a special kind of photovoltaic system that is cooled by desalination feed water. El Paso and southern New Mexico are located in an area with high photovoltaic (PV) energy potential. According to NREL, the solar energy potential for a renewable energy project in this region is in the very high range of 6-6.8 kWh per m2 per day.

Water desalination is an energy-intensive process, due to the high water pressure needed to pump water through reverse osmosis membranes. A solar photovoltaic system could greatly contribute to the reduction of electrical costs during the period of highest time-of-use rates charged by electrical utilities. PV power can be used during the period of peak demand; grid power can be utilized during periods of low demand.

Conventional PV systems suffer from loss of efficiency when the PV cells heat up. PV cells absorb solar energy from both the infrared and the visible spectra, but only energy from a portion of the visible spectrum is converted to electrical energy. Heat is produced by the portion of incident solar energy that is not converted to electrical energy. Heating causes the efficiency of PV cells to drop typically about 0.5% per degree C. The loss in efficiency can be restored if the PV cells are cooled. Use of the recovered thermal energy from the PV cells to heat the desalination feed water is beneficial in reducing the power required for desalination.

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Culturing Microalgae from Desalination Concentrate Reusing Anaerobic Digested Sludge as Nutrient to Improve the Net Energy Ratio

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Poster Abstract 2

Biodiesel can be produced from microalgae; the net energy ratio for microalgae biodiesel is slightly positive as 0.93 MJ consumed/MJ produced by using fresh water, brackish groundwater and chemical nutrient. The objective of this article is to improve the net energy gain in microalgae biodiesel by reusing concentrate from desalination and anaerobic digested sludge (ADS) as water medium and nutrient suppliers. To ensure the right species, microalgae were seeded and cultured from desalination evaporation pond from brackish groundwater national desalination research facility, NM, USA. Two reactors (R1 and R4) were used. The initial conductivity of R1 and R4 were 19320 and 19120 μS/cm respectively. The initial volume of concentrate in R1 and R4 were 2.87 and 2.99 L respectively. 50 mL of ADS was fed into R1; 50 mL of Bold's Basal Medium (BBM) was fed into R4 every day. Reactors were brought outside to expose Sunlight from 9:30 am to 4:30 pm every day except public holidays. Microalgae growths were recorded in photographs, microscopic images, and dry weights. Experiments shown microalgae were growing well in desalination concentrate with both ADS and BBM. With our estimate, the net energy ratio is improved from 0.93 to 0.90 MJ consumed/MJ produced by reusing desalination concentrate and ADS into microalgae production by minimizing energy required for BBM and concentrate disposal; the concentrate disposal cost is 15% of total desalination cost for inland desalination which ranges from 1.18-10.04 $/m3.

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Solar Membrane Distillation

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Poster Abstract 3

Water scarcity is among the most serious, long-term challenges in the world. To an ever increasing degree, sustainable water supply depends on the utilization of water of impaired initial quality. This is particularly true in developing nations and in water-stressed areas such as the American Southwest. The most plentiful impaired water resources are brackish ground water and seawater. In both, salt is the primary contaminant of concern. Reverse osmosis (RO) is the most widely utilized membrane-based method for separating salt from water. RO treatment costs have become competitive with thermal desalination methods, even in seawater applications. However, both conventional thermal distillation and RO are energy intensive processes, exhibit economies of scale that discourage decentralized or rural implementation, require enhanced expertise for operation and maintenance, and are susceptible to scaling and fouling unless extensive feed pretreatment is employed. Membrane distillation (MD) processes, driven by low temperature thermal or vapor pressure gradients, can potentially overcome many of the drawbacks associated with conventional thermal distillation and RO desalination. This presentation describes the development and testing of a solar-driven, MD process. A prototype of the process, using only off-the-shelf components, has been successfully deployed in the field. MD can operate using low-grade, sub-boiling temperature heat sources. When it is driven by solar energy it does not require highly concentrating collection devices, non-aqueous working fluids, complex temperature control systems, nor extensive operational expertise.

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Monitoring and Modeling the Hydrologic Connectivity Between Headwaters and Their Snow-Melt Driven IR

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Poster Abstract 4

The hydrologic connectivity between upland water sources, floodplain valleys downstream, and groundwater may be an important determinant of hydrologic resilience in the face of climate variability. The objective of this study is to characterize the hydrologic interactions occurring in three watersheds of northern New Mexico. These watersheds are characterized by the use of traditionally-irrigated systems driven by snow-melt runoff. In order to better understand the hydrologic interactions between uplands and associated valleys, we are using a combined field data collection and multi-modeling approach to characterize the hydrologic connectivity of the study sites. We are monitoring different components of the water budget including precipitation, soil moisture and temperature, river and canal flow, groundwater levels, and different climate variables. Field data collected are being used to calculate water budgets at the field, valley, and watershed scales. Also, field data collected are being used to parameterize different physically-based models. For instance, the Root Zone Water Quality Model is being used to simulate crop irrigation – deep percolation relationships at the field scale. Observed and simulated deep percolation results are being related to shallow-groundwater level fluctuations observed at the field and valley scales. A system dynamics approach is being taken to integrate results obtained at the field and valley scales into a watershed scale model. Preliminary results suggest that there is a strong hydrologic connectivity between snow-melt driven runoff in the headwaters and the recharge of the shallow aquifer in the valleys, mainly driven by the use of traditionally-irrigated agriculture systems.

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Effects of Operating Conditions on the Efficiency of EDR Systems

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Poster Abstract 5

Water supply all over the world is being stressed due to increased demand and limited availability. The overall use of water in agricultural, industrial, and domestic areas, coupled with the need for water to produce energy, makes it difficult to evaluate various options and prepare additional sources of clean water. Hence, working on this field in order to provide potable water from saline and brackish water is worthwhile. Electrodialysis Reversal (EDR) is one of the technologies used for desalinating brackish and saline waters. EDR uses electrical fields to transport ions through ion exchange membranes. In the recent years due to the higher recovery rate of EDR compared to Reverse Osmosis, interest in EDR has increased. The focus of this study is to develop a model to predict the effects of various operating conditions, such as temperature, pressure, conductivity, voltage, and current density, on the efficiency of EDR. A huge database collected from a pilot-scale system, located at the Brackish Groundwater National Desalination Research Facility (BGNDRF) in Alamogordo, NM, will be analyzed. The planned method will keep all conditions constant except the condition whose effect is under study. By using this technique, the relationship between each parameter and the efficiency will become clear. Among all operating conditions, the two most important factors are voltage and current density. Since it is desired to have the highest efficiency at the lowest cost, knowing about optimum voltage and optimum current and the relationship between them is of higher importance in comparison with other factors.

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Mathematical Models Explaining Ion Selectivity in Electro-Separation Processes

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Poster Abstract 6

Researchers have always been looking for different methods for brackish water treatment using desalination processes. Electrodialysis (ED) is an electrochemical separation processes that have proven its capability in desalination. This technique is based on ion transport through ion exchange membranes under the effect of an electrical field. Since most brackish water sources do not have drinking water standards due to excess amount of one or some species, it is worthwhile to study selective removal of some target ions. Because of this purpose it is needed to know that which parameters affect removing monovalent or divalent ions selectively. In this research, selective removal of different ions in the ED process is studied using an appropriate mathematical model. The irreversible thermodynamic (IT) is used as an approach for ion transport model which can explain the transport of ions and water through the membrane. The IT theory explains a mathematical mean for relating the flux of species through the membrane to the interfacial concentrations of these species, as well as the external driving forces. In addition, during this study the Maxwell-Stefan equation is used for multicomponent diffusion. Using these tools, the selectivity for different ions is determined. By studying the effective factors in selective removal of different ionic species, the optimized selectivity conditions can be verified. Determining the most important factors in selectively separating of the monovalent ions from multivalent ions or vice versa is essential in different industries such as food, chemical, and pharmaceutical industries.

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Determination of Limiting Current in Full-Scale Electrodialysis Reversal

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Poster Abstract 7

The empirical determination of the limiting current density (LCD) for an electrodialysis reversal (EDR) system is based upon generally accepted equations relating current density to the concentration of the diluate stream and the mass transfer coefficient, where specific membrane and system-flow properties influence the empirically determined correlations. Thus far, researchers have focused primarily on identifying the LCD of benchtop-scale EDR systems using single-solute solutions. However, in the treatment of brackish waters, the concentration and chemical makeup of the feed water will vary significantly from source to source, requiring site-specific evaluation of the limiting current density. In full-scale field operations, the hydrodynamics and feed water compositions are much less ideal than lab-scale, and their determination may require improved methods.

Results from full-pilot scale EDR research on natural brackish waters in Alamogordo, New Mexico, indicate significant differences from the generally published results concerning the LCD's dependence on diluate concentration, composition and flow velocity. Understanding the basis of these variations could reap large benefits, as the LCD determines the efficient use of electrical current, and the required membrane are for a desired product water quality. These two factors, membrane area and electrical input, are the largest contributors to the capital and operating costs of an EDR system.

Developing the methods to accurately determine the LCD of a full-scale EDR system will allow for the optimization of parameters to reduce the total cost of inland brackish-water desalination, making brackish water a feasible water resource in the years to come.

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Vegetation Dynamics in a Chihuahuan Desert Shrubland Receiving Saline-Sodic Industrial Effluent

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Poster Abstract 8

Land application of treated, saline-sodic wastewater is potentially a low-cost desalination process that could mitigate environmental degradation of surface waters such as the Rio Grande. However, impact of this anthropogenic disturbance on soils and native flora are not adequately known. Lagoon-treated saline-sodic industrial effluent was land-applied from 2002-2005 to a Chihuahuan Desert shrubland to assess the changes in soil quality and subsequent growth of seven indigenous intershrub space herbaceous plant species, vis-à-vis an adjacent non-irrigated area. After four years, effluent irrigation increased soil saturation extract salinity (electrical conductivity), but not above 4 dS/m required for a saline soil. However, effluent irrigation resulted in sodic soil conditions (sodium adsorption ratio > 13). On the irrigated plot, the sodium adsorption ratio was 10 to 15 times higher than on the non-irrigated plot, and reached a maximum of 35 at a soil depth of 7.5 cm. There was a decline in plant species diversity under highly sodic irrigated conditions, and Lepidium virginicum produced the highest biomass of all species. Similar aggressiveness of other Lepidium sp. in high-Na or alkali conditions reported in other studies suggests that L. virginicum was able to exploit an edaphic niche not useable or tolerated by the other herbaceous species. While invasiveness of the apparently natrophilic L. virginicum may lead to a loss of native biodiversity, potential ecological value of this species must be considered in the overall management objectives of land application of saline-sodic wastewater to Chihuahuan Desert vegetation communities.

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Evaluating Salt Quality Requirements in Electrodialysis Metathesis

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Poster Abstract 9

Electrodialysis metathesis (EDM) is a component in the zero discharge desalination (ZDD) process that maximizes water production and salt recovery. EDM is used to treat reverse osmosis (RO) and nanofiltration (NF) concentrates from brackish water. EDM has four-compartment repeating cells for circulation of a feed-diluate stream of depleted salt, a concentrated stream of mixed-sodium anion salts, a concentrated stream of mixed-chloride cation salts, and sodium chloride. The concentrated solutions are formed when an electrical potential is applied to the cell. Typical cations present in an EDM system for brackish water treatment include sodium, magnesium and calcium. Typical anions are chloride, sulfate and bicarbonate.

The early precipitation of calcium sulfate in one of the concentrate compartments can adversely affect the potential recovery of other useful salts, such as Na2SO4, MgCl2, and MgSO4, from the EDM process. This can be prevented by selecting optimum parameter conditions and good quality salt. The amount of impurities such as calcium and sulfate ions present in the salt can increase the potential for calcium sulfate formation in the EDM concentrate compartments. On the other hand, a specification for high purity salt can adversely increase the energy footprint and cost of brackish water treatment by the ZDD process. This paper presents preliminary results on the evaluation of salt quality requirements for EDM treatment of RO/NF concentrates from brackish water.

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Solar Powered Desalination

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Poster Abstract 10

The world's supply of water is enormous, about 97% is found in oceans and is too salty to drink, the remaining 3%, 2.997% is locked up as ice at the poles and glaciers or in groundwater. Sunpower Systems Corporation has invented a solar collector called "SMARTROF" which is patented worldwide generates steam using solar energy to the invented GREEN PUMP. It uses an overhead cable sun-tracking system that provides rigidity to the trough structure so that the structure itself can be much less expensive than other solar trough systems. The parabolic reflector in the SMARTROF collector focuses sunlight at high intensity upon a heat receiver tube in which water is passed that produces steam at high temperature and pressure. The steam is piped to the Kinetic Pump, which is patented worldwide. The Pump is simple but effective. It has no turbines, gearboxes, standard hydraulic pistons or rotating shafts. It uses a principle that was overlooked by previous researchers in the field. It can efficiently pump water to a pressure that is considerably higher than the applied steam pressure. The diagram below schematically shows the layout of the components. DESAL combines the Smartrof, the Green Pump and proven reverse-osmosis (RO) technology to allow the economic production of fresh water from seawater or brackish water using solar energy. This is accomplished by using Smartrof concentrated solar energy to produce steam, which can be used to directly pump high-pressure seawater into RO desalination units using the green Pump.

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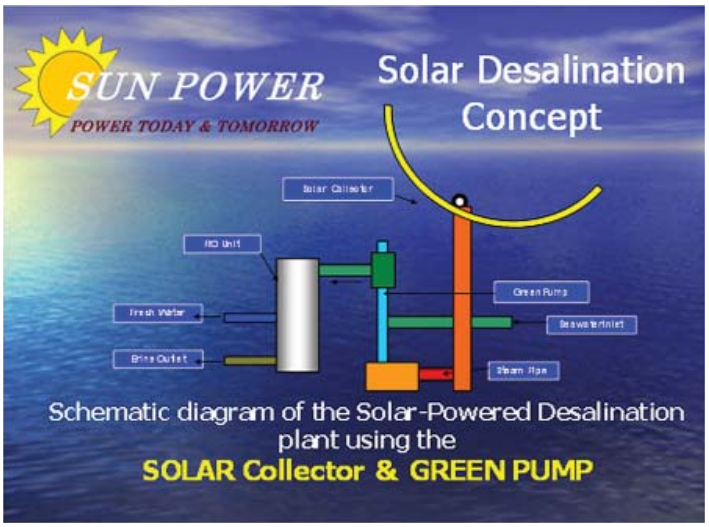

Energy and Mass Flow in Solar Membrane Water Purification

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Poster Abstract 11

The objective of the research is to identify and simulate key optimization parameters controlling energy usage and production rate of purified water in a solar membrane distillation system. We have built bench-scale, small pilot-scale and a full pilot-scale units as testing and validation platforms for the theoretical work. Lab-scale has been used to determine the membrane distillation mass transfer coefficient, k, related to the water flux through the membrane. This coefficient allows for predictive, theoretical modeling of the mass flux. On the small-pilot system, heat exchangers are implemented to recycle heat to the incoming air, thus lowering system energy use. The incoming air is heated by the hot brine and hot wet air. At this scale, the primary goal is to determine the efficiency gains provided by using the heat exchangers so it can be applied to the full pilot-scale system deployed at our Marana (Arizona) field site. The Marana system includes an automated system that operates circulating pumps in the system's loops to adjust to heat availability and optimal use. Determining the time to turn the module pumps on allows the feed temperature to the module to be decoupled from the solar insolation variation. In addition, the data from the Marana site provides the data on which to build a simulation model to identify the limiting processes for final scale-up to commercial implementation.

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ZDD – Achieving Maximum Water Recovery

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Poster Abstract 12

Increasing population, decreasing water supply, and droughts are leading to increased competition between users of freshwater. The Zero Discharge Desalination (ZDD) process maximizes the volume of product water from a brackish source while minimizing impacts to the environment caused by waste disposal. ZDD has been evaluated at several locations including New Mexico, Texas, California and Florida. ZDD technology utilizes a combination of Electrodialysis Metathesis (EDM), a variant of electrodialysis, and reverse osmosis (RO) or nanofiltration (NF), as well as various forms of pre-treatment techniques. Previous pilot studies have demonstrated overall water efficiencies of 95-98% on brackish ground water with sparingly soluble calcium sulfate and moderate silica levels. The University of Texas at El Paso's Center for Inland Desalination Systems (CIDS) was awarded funding from the US Bureau of Reclamation's DWPR program. This effort is a collaborative project between CIDS and Veolia Water Solutions and Technologies and the project is located at the Brackish Groundwater National Desalination Research Facility. During Year 1, the team successfully demonstrated a new ZDD design that utilized NF instead of RO membranes to eliminate a silica removal system. The feed water had about 3,000 mg/L TDS and the treated water was below 800 mg/L TDS. The recovery by NF and EDM was 98% compared to 75% recovery by conventional RO. A larger ZDD system was designed for Years 1 and 2. In Years 2 and 3 the team will operate the larger system, evaluate waste stream optimization, and evaluate the potential for incorporation of renewable energy.

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Decentralized, Autonomous Water Treatment in the Navajo Nation

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Poster Abstract 13

The Navajo Nation covers 27,000 square miles, mainly in northeastern Arizona, but also in New Mexico and Utah. This vast area has a population of 174,000 inhabitants, which translates to a density of only 6 inhabitants per square mile. Low population density coupled with water scarcity and impairment makes providing access to adequate supply a daunting challenge. The population relies primarily on groundwater which is often in deep aquifers and of brackish quality.

Consequently, a large fraction of the population hauls water from remote wells at high cost. In addition, the lack of grid-delivered electricity in many areas further complicates delivery of basic water and power services. This paper discusses a large project undertaken by the Bureau of Reclamation in collaboration with the University of Arizona and the Navajo Nation to investigate and deploy autonomous (off-grid) systems to pump and treat brackish groundwater using solar energy. The process utilizes a membrane distillation technology to potentially supply both livestock and potable water in small volume, remote installations. An analysis of the economic efficiency of the desalination unit was conducted to assess the viability of sustainable financial support from the community for the system. The study also surveyed water haulers in the region to determine the distance traveled to secure potable water and water for livestock to establish a baseline for comparison of water hauling methods versus local desalination system deployment.

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Interannual Snowpack Variability in the Upper Rio Grande Basin and its Relation to Warm and Cool Episodes of the El Niño-Southern Oscillation

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Poster Abstract 14

Meltwater from mountain snowpack in the Upper Rio Grande Basin is a vital source of surface water for irrigated agriculture in New Mexico. Over the last decade, there has been large interannual variation in snow cover and snow water equivalent (SWE), which has resulted in years of severe water shortages (e.g., 2002 and 2011) and years of relative abundance (e.g., 2010). Understanding how warm and cool episodes of the El Niño-Southern Oscillation (ENSO) impact snow cover and SWE can help water managers and farmers prepare ahead for a productive or unproductive snow year. Using data from the Moderate resolution Imaging Spectrometer (MODIS) sensor onboard the Terra and Aqua satellites, we show the variability in snow cover over the Upper Rio Grande on the anniversary date, April 1st, from 1999 to 2011 and relate this to annual streamflow from 23 high elevation sub-basins. For this same 12 year period, we compare snow cover and peak streamflow to cold (La Niña) and warm (El Niño) ENSO episodes. Results indicate that unproductive snow years are associated with La Niña episodes while productive snow years are associated with El Niño episodes. Historical records of SWE data can be also be used to compare productive/unproductive years with ENSO episodes. We present preliminary data from this analysis for the last 50 years.

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