Energy Efficient Strategies and Renewable Energy Utilization for Desalination

Joe Jacangelo, WateReuse Research Foundation

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PowerPoint Presentation **http://wrri.nmsu.edu/publish/watcon/proc56/Jacangelo.pdf**

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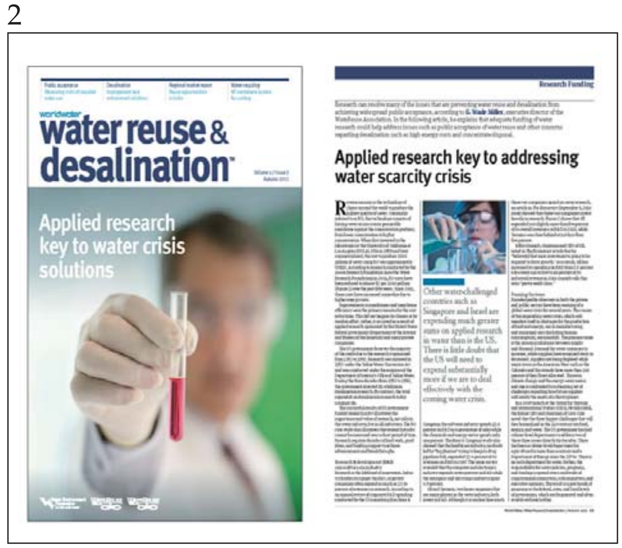

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Commitment to Research

$42 Million since 2001

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Energy Efficient Strategies and Renewable Energy Utilization for Desalination

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Background

- The generation of energy is the single largest source of green house gas (GHG) emissions.
- Optimizing the energy of desalination and reuse processes has become a critical component in addressing energy consumption.
- Increasing renewable energy resource (RES) utilization and reducing GHG emissions has become an important goal for water utilities and agencies.

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Study Goals

- To develop a comprehensive knowledge-base with the most updated developments in energy minimization and renewable energy techniques.
- Prepare a guidebook based on the relevant practical lessons learned by global researchers, organizations and utilities.

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Project Summary

Literature Review
- Collect information on energy minimization strategies, technological advancements and economic analyses (*Water Research* 45: 1907, 2011).

Utility Survey/ Case Studies
- Document information on process, implementation strategies, regulation and policy.

Guidebook Development
- Provide information to utility and policy makers.

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Promising New Desalination Technologies

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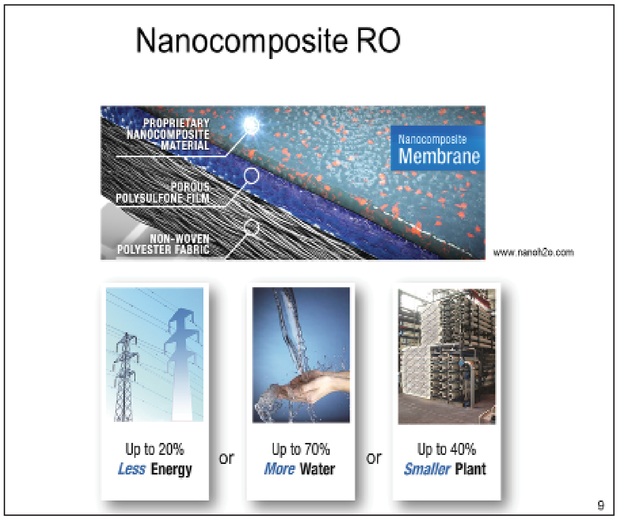

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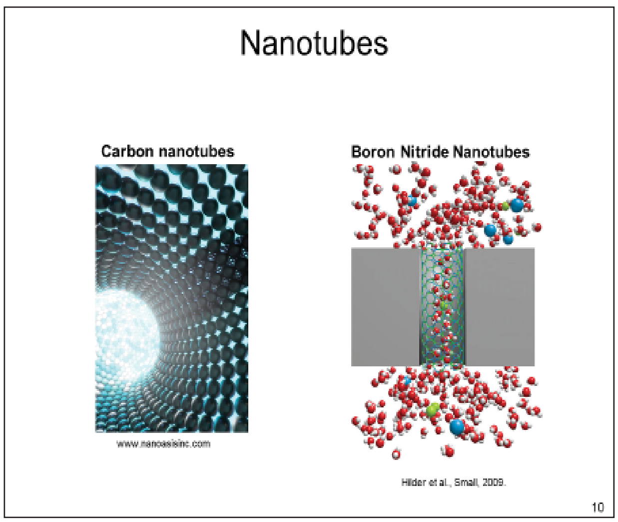

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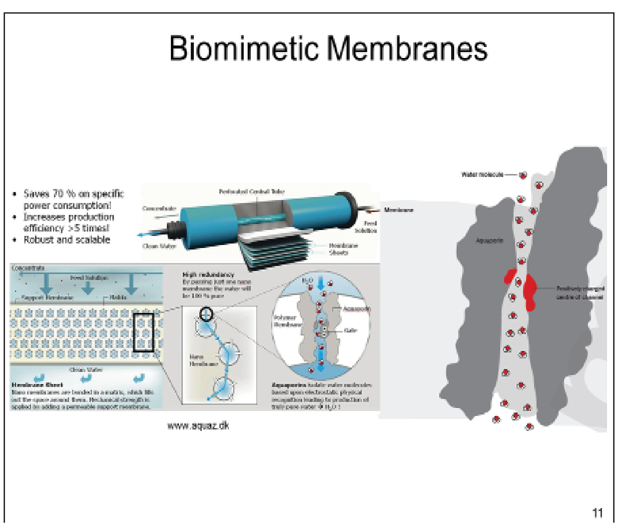

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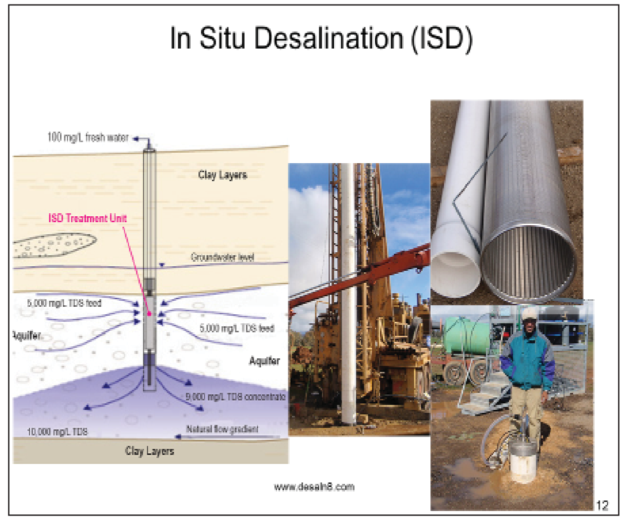

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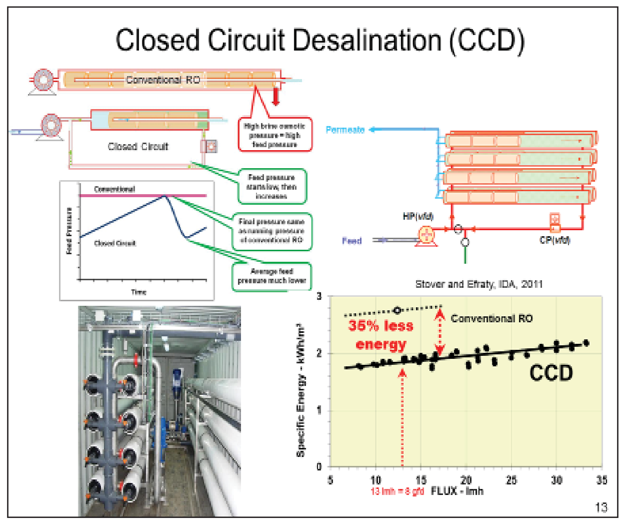

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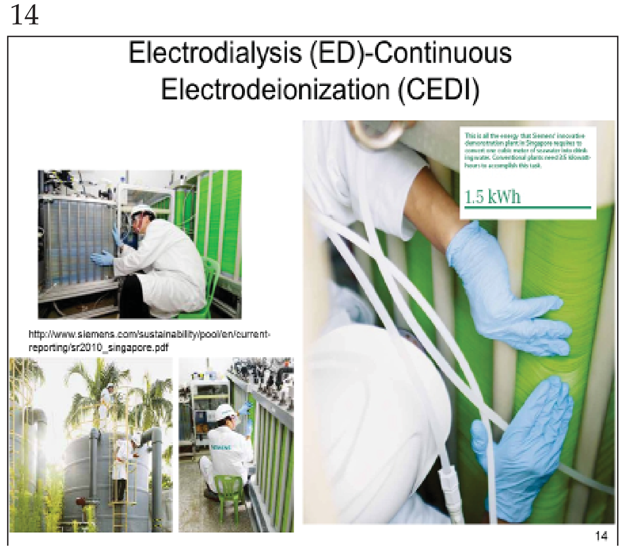

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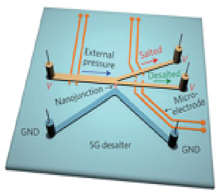
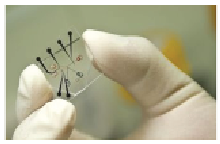
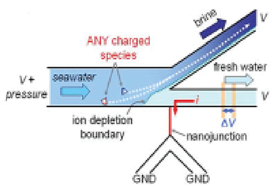
Ion Concentration Polarization







- **Ion concentration polarization**:
  - Absence of membrane and applied pressure.
  - Specific energy consumption similar to RO ~ 3.5 kWh/m^3 (Kim et al., *Nature Nanotechnology*, 2010).
  - 1,600 units fabricated on 8-inch wafer – 15 LPH of desalted water.

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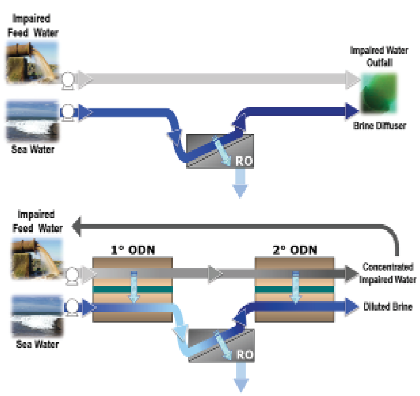
FO/RO Hybrid: Osmotic Dilution of Seawater



Cath et al., WateReuse Research Foundation, 2009.

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Renewable Energy Utilization

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Benefits of Renewable Energy Sources

- Renewable energy is carbon neutral
- Abundant resources
- Underutilized
- Decentralized facilities
- Ability to create new employment

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Challenges of Renewable Energy Sources

- High capital costs
- Local/region dependent
- Often require new infrastructure
- Requires funding and incentives
- Large footprint requirement
- Return-on-investment (ROI)

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Established Renewable Energy Technologies

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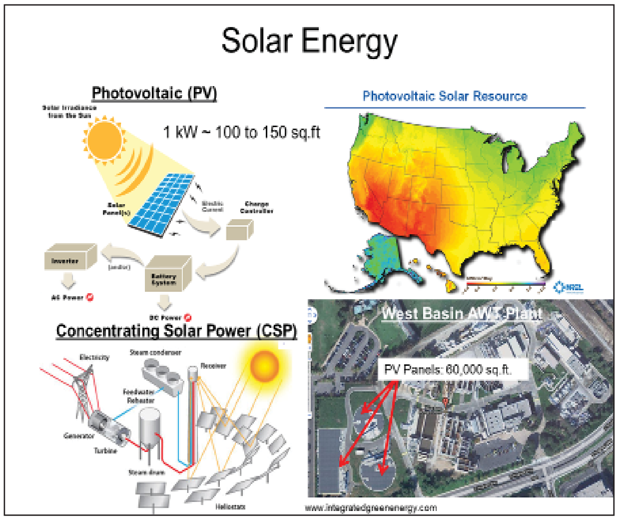

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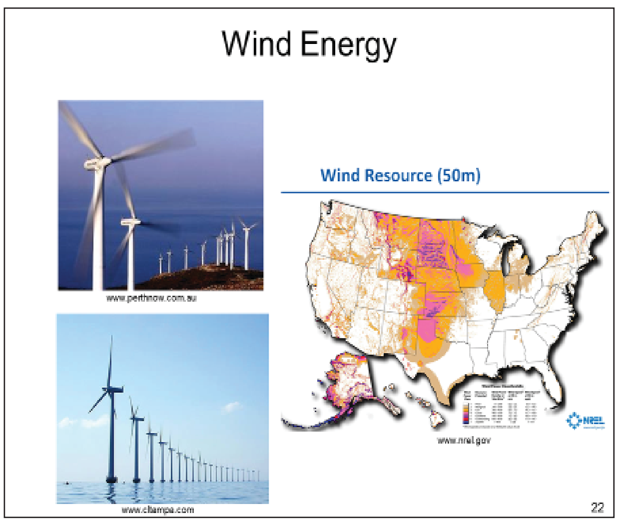

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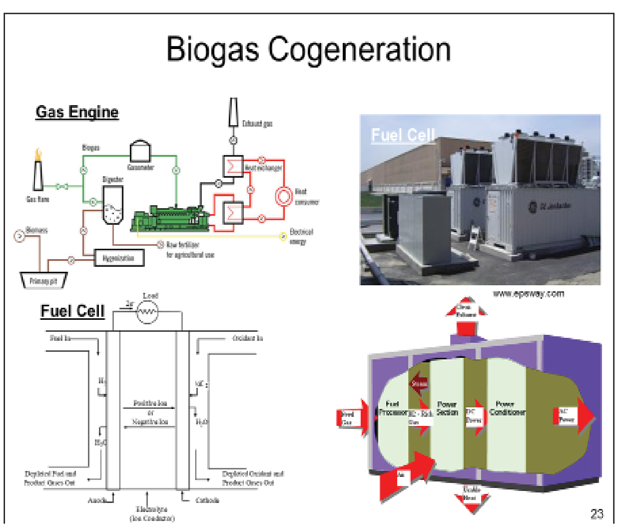

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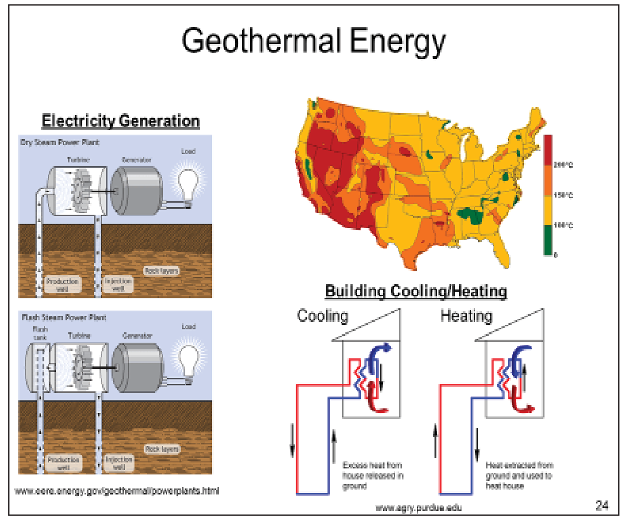

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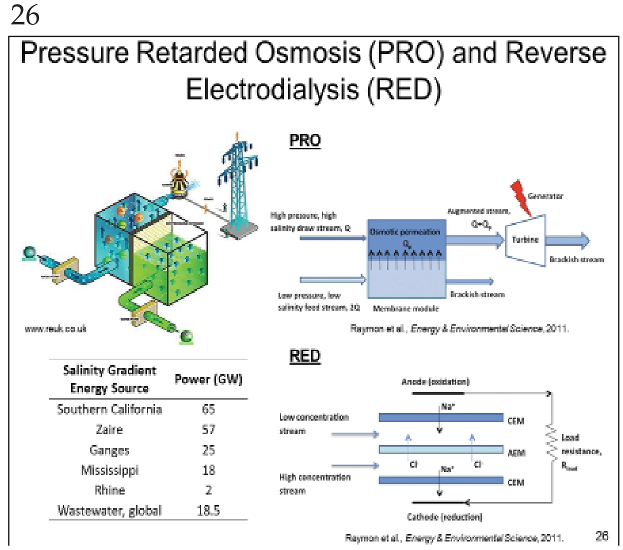

Salinity Gradient Energy Source	Power (GW)
Southern California	65
Zaire	57
Ganges	25
Mississippi	18
Rhine	2
Wastewater, global	18.5

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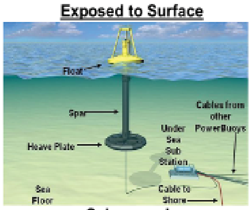
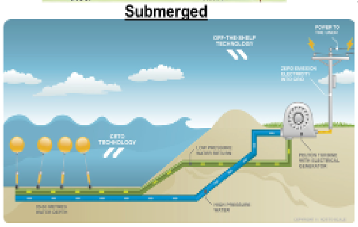
Wave Energy

Exposed to Surface



Submerged



Wave Energy Levels (kW/m of Wave Front)
www.oceanpowertechnologies.com

Carnegie Water Energy Limited

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Utility Case Studies

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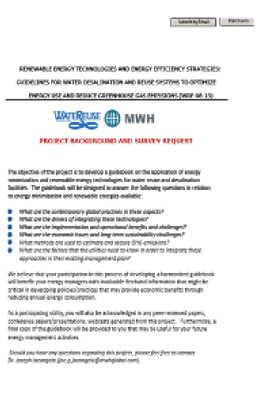
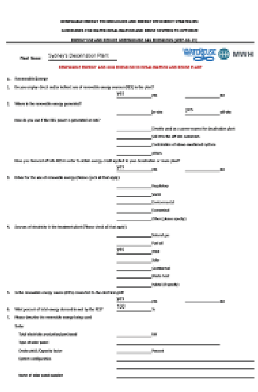
Survey Questionnaire





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Questionnaire Objectives

- Treatment process description
- Energy consumption for utilities using conventional energy source
- Energy consumption for utilities using renewable energy
- GHG emissions and tools used for quantification
- Economic evaluation for integrating renewable energy and implementation of energy efficient strategies
- Regulation and policy for energy management

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Utilities Participating in Study

Type of Plant	Capacity MGD	End Use	Feed TDS, mg/L	Permeate TDS, mg/L	Energy Consumption, kWh/m³
Reuse 1	30	GWR, IPR	850	30	NA
Reuse 2	11	IPR, Industrial	552	26	0.98
Seawater Desalination 1	38	DW	37,000 - 40,000	< 200	3.6
Seawater Desalination 2	66	DW	36,700	275	3.3
Seawater Desalination 3	88	DW	40,500	< 80	3.5
Seawater Desalination 4	36	DW	35,000	< 270	3.5 – 3.9
Seawater Desalination 5	25	DW	< 28,500	< 360	3.9
Brackish Desalination 1	3.5	DW	2,300	< 320	0.94
Brackish Desalination 2	8	DW	2,000	< 150	1

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Energy Consumption of Various Components of a Seawater Desalination Plant Participating in Study

Component	Energy Consumption, kWh/m³
Raw Water Pumping	0.39
Pretreatment & Desalination	2.865
Post Treatment	0.012
High service pump station	0.3
General (Buildings, heating, cooling)	0.04
Total Energy Consumption	3.607

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Reported Energy Minimization Strategies

- Energy efficiency of pumps monitored (pump efficiency curves) to determine if the pumps and motors are operating close to the best efficiency point (BEP).
- Older pumps and motors replaced with newer premium efficiency models.
- VFDs installed to control motor speed.
- Smaller RO trains and larger high pressure pumps utilized for seawater desalination.
- ERDs (pelton wheel, pressure exchangers) for seawater desalination were installed in the first pass.
- ERDs (turbochargers) for brackish water desalination were installed between the first and second stage to operate as a booster pump.

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Renewable Energy Employed by Utility Participants

Type of Plant	Renewable Energy	% Use of Renewable	Onsite/Offsite	Funding/Incentives
Reuse 1	Solar PV	20%	Onsite - Grid Connected	*Southern California Edison*
Reuse 2	Cogeneration	20%	Onsite - Grid Connected	*Energy Saving Fund (NSW Dept. of Env. and Climate Change)*
Seawater Desalination 1	Wind	100%	Offsite - Grid Connected	*Government*
Seawater Desalination 2	Wind	100%	Offsite - Grid Connected	*Energy Saving Fund (NSW Dept. of Env. and Climate Change)*
Seawater Desalination 3	None	0%	-	-
Seawater Desalination 4	None	0%	-	-
Seawater Desalination 5	None	0%	-	-
Brackish Desalination 1	Future Consideration	0%	Considering Onsite Solar PV/CSP	*Not Determined*
Brackish Desalination 2	Future Consideration	0%	Considering Onsite Solar PV	*Not Determined*

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Challenges for Utility Participants

Plant Type	ROI	Funding	Footprint	Integration	Permitting
Reuse 1	_	+	_	_	+
Reuse 2	_	+	+	_	+
Seawater Desalination 1	_	+	+	+	+
Seawater Desalination 2	_	+	+	+	+
Seawater Desalination 3	NO RENEWABLES UTILIZED				
Seawater Desalination 4	NO RENEWABLES UTILIZED				
Seawater Desalination 5	NO RENEWABLES UTILIZED				
Brackish Desalination 1	_	?	?	?	_
Brackish Desalination 2	_	_	+	?	?

"+" indicates "favorable condition"
" - " indicates " NOT favorable condition"
"?" indicates "NOT evaluated"

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Reported Renewable Energy Utilization Lessons

- Feasibility study essential before implementation at the utility scale.
- Footprint requirements for installation of solar PV reduced by installing solar panels on existing concrete tanks.
- Grid integration for solar PV panels improved by utilizing several inverters in parallel to provide continuous power supply.
- Government funding and support from utility board was key in the implementation of renewable energy resources.
- Risk shared in delivery of renewable energy: third party utilized to provide independent risk assessment.
- Specialized staff required within utility during the design and implementation phase.

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Guidebook

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The Purpose of the Guidebook is to Answer the Following Questions

- What resources are available as a utility manager to reduce energy consumption and implement renewable energy resources?
- What are the strategies available to reduce energy consumption in an existing or newly proposed plant?
- How are energy efficiency and GHG emissions monitored?
- What are the steps required for implementing renewable energy?
- What are the renewable energy technologies available for implementation at a large scale?
- What are the funding options available?
- What are the challenges involved during implementation of renewable energy resources?

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Components of the Guidebook

- Chapter 1: Introduction
- Chapter 2: Planning
- Chapter 3: Implementation of Efficient Energy Strategies
- Chapter 4: Utilization of Renewable Resources
- Appendices – Utility Surveys and Literature Review

Important information

Further resources and tools

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Implementation of Energy Efficient Strategies (Contents of Chapter 3)

- Distribution of energy consumption through treatment processes.
- Design strategies for energy minimization during design of seawater/brackish water/advanced water treatment processes.
- Pumping strategies for energy efficiency.
- Selection of energy minimization components for treatment processes.
- Strategies to reduce energy consumption with HVAC and lighting.
- Implementation of energy efficient strategies.

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Example: What you need to know while selecting ERDs (Contents of Chapter 3)

Criterion/Device	Pelton Wheel Turbine	Reverse Running Turbine Pump	Turbo Booster Pump	Pressure or Work Exchanger
Commercial Availability	Yes	Yes	Yes	Yes
Proven Technology for high salinity applications	Yes	Yes	Yes	Yes
Potential Energy Savings (Relative to each other)	Medium	Low to Medium	Low	High
Capital Cost (Relative to each other)	Low to Medium	Low to Medium	Low	High
O&M Costs (Relative to each other)	Low	Low	Low	Medium to High
Efficiency (Relative to each other)	Medium (84% to 90%)	Low to Medium (75% to 85%)	Low (55% to 60%)	High (95% to 97%)
Efficiency Curve Shape	Varies	Varies	Slopes downward at low flows	Flat
Efficiency at Changing Process Conditions (Effect of deviation from design point)	Efficiency reduces when flow rate changes from design point	Efficiency reduces when flow rate changes from design point	Efficiency reduces when flow rate changes from design point	Moderate impact on performance
Brine Mixing with Feed Water	None	None	None	About 2 - 3%
System Complexity	Low	Low	Low	High

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Implementation of Renewable Energy Resources (Contents of Chapter 4)

- Determination of resource availability.
- Available options for financing and incentives.
- Commercial technologies available.
- Leading renewable energy providers.
- Integration challenges and methods, consideration for grid integration.
- Handling resource variability.
- Permitting approach and requirements.

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Example: What you need to know while selecting solar PV cells (Contents of Chapter 4)

Parameter	Description
Cell efficiency	Percentage of solar energy falling on PV cells that is converted into electrical energy
Module efficiency	Combination of cell efficiency placed into a module
Energy yield	Output in kilowatt hours (kWh) over time
Typical module size	175 – 200 Watt: 3 feet by 5 feet
Common types of modules	Poly Crystalline, Mono Crystalline, Amorphous Silicon (thin film)
Module lifetime	Poly Crystalline ~ 40 years; Mono Crystalline ~ 50 years; Amorphous Silicon ~ 20 years

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Example: What you need to know about financing options available (Contents of Chapter 4)

- Third-party ownership with a power purchase agreement (PPA):
  - Provides utilities with the ability to benefit from renewable energy service contracts while avoiding the risks associated with ownership.
  - The utility enters into a contract with the vendor/electric company to install a renewable energy system.
  - The vendor/electric company deliver a set amount of power at an agreed price.
  - The third-party (vendor/electric company) is responsible for operation and maintenance of renewable energy system.

www.epa.gov/greenpower/buygp/solarpower.htm

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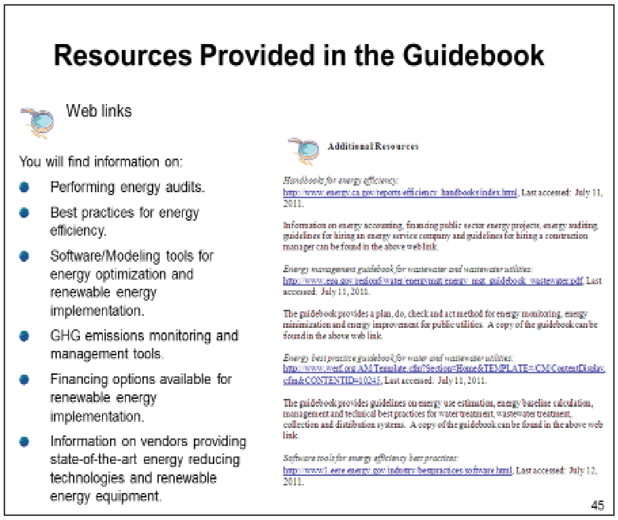

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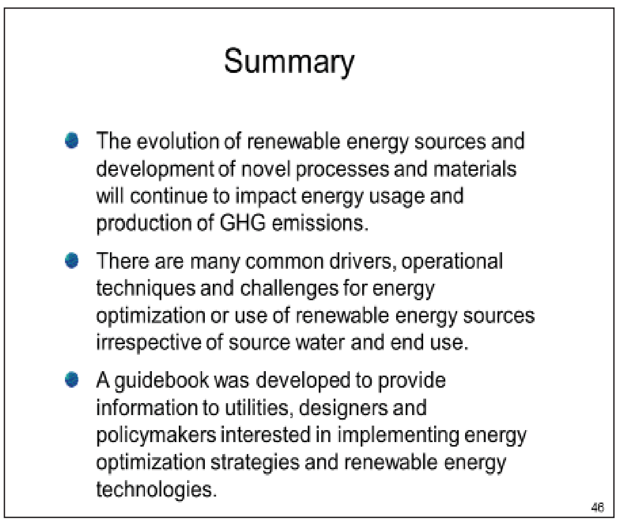

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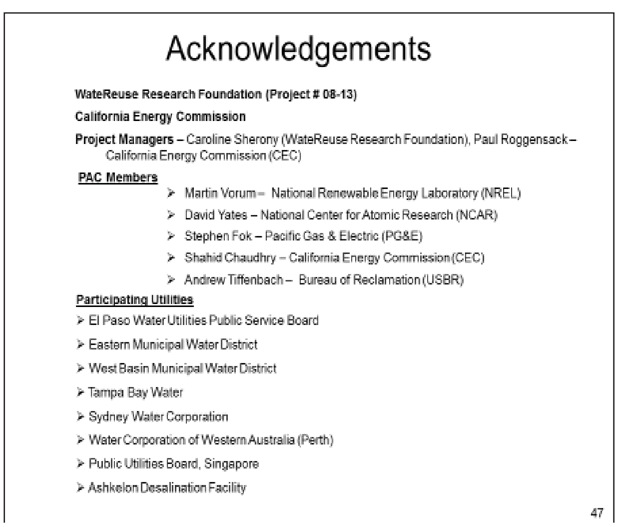

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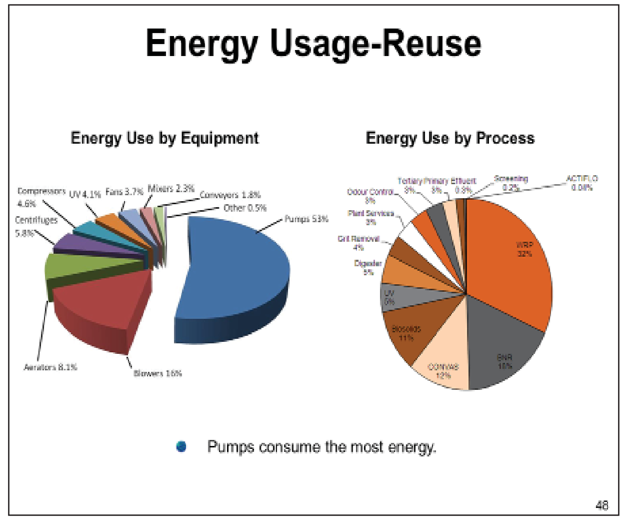

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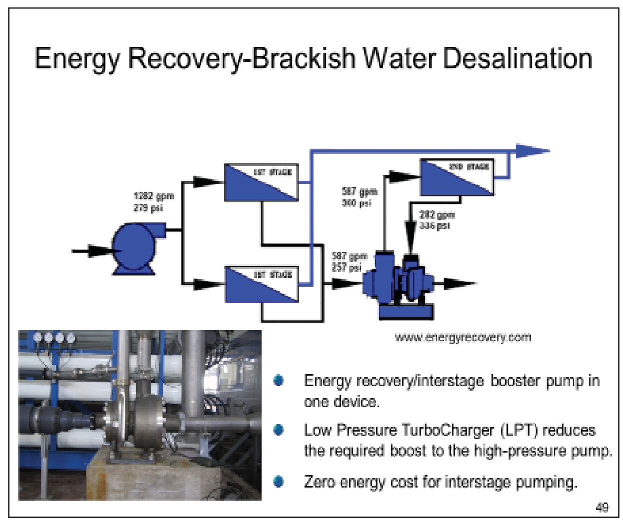

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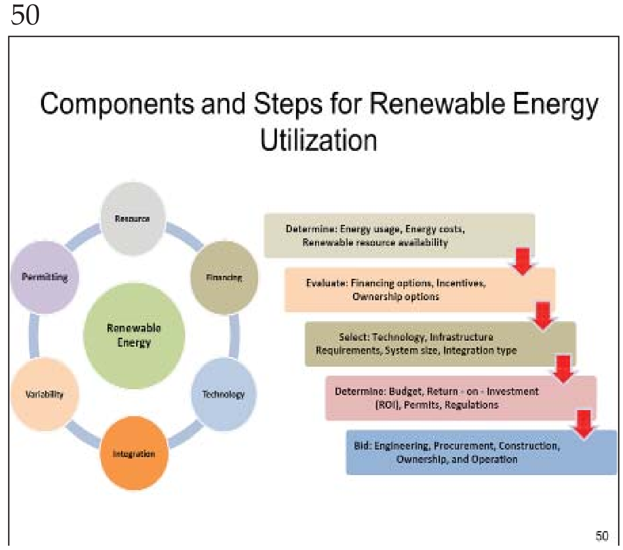

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Energy Usage and Minimization Strategies

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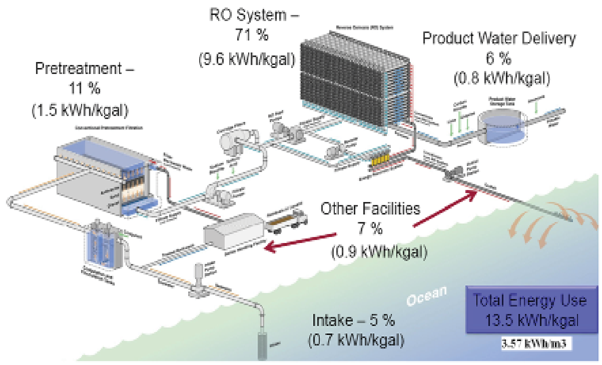
Energy Consumption – 50 MGD Seawater Desalination



Voutchkov, IDA Energy Conference, 2010.

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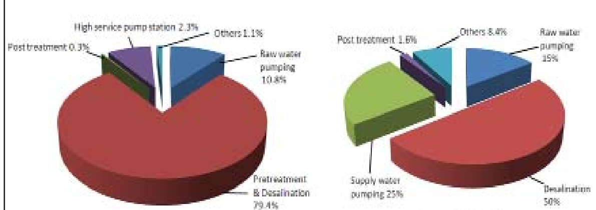
Energy Usage-Desalination



- High Pressure pumps consume the most energy.

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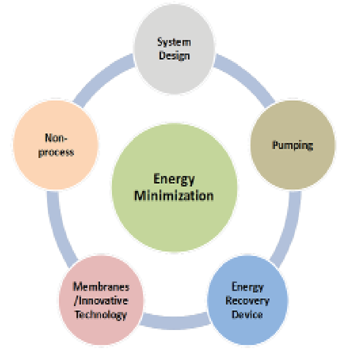
Components of Energy Minimization



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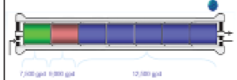
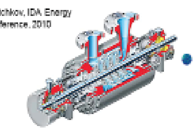
Established Energy Minimization Techniques



Voutchkov, IDA Energy Conference, 2010



www.flowserve.com

www.energyrecovery.com

- **Enhanced system design**: Use of hybrid elements (nanofiltration, brackish, seawater), interstage boosting, use of permeate from front-end elements to feed second pass. Reduced energy consumption ~ 5 – 12%.
- **High efficiency pumping**: Use of variable frequency drive (VFD), premium efficiency motor, larger capacity pumps, operation at BEP, regular energy monitoring and maintenance.
- **Energy recovery device**: Use of turbo-chargers and pressure exchangers. Reduced energy consumption ~ 30 – 50% (combining with high efficiency pumping).

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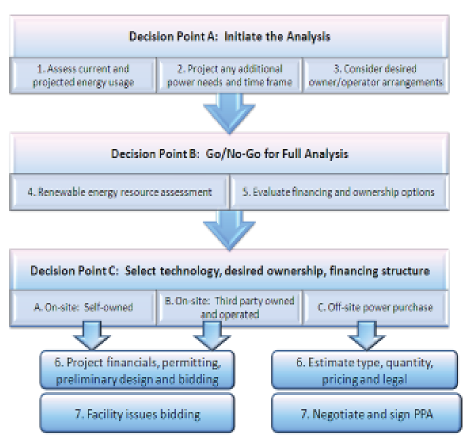
Process for Developing a Renewable Energy Project



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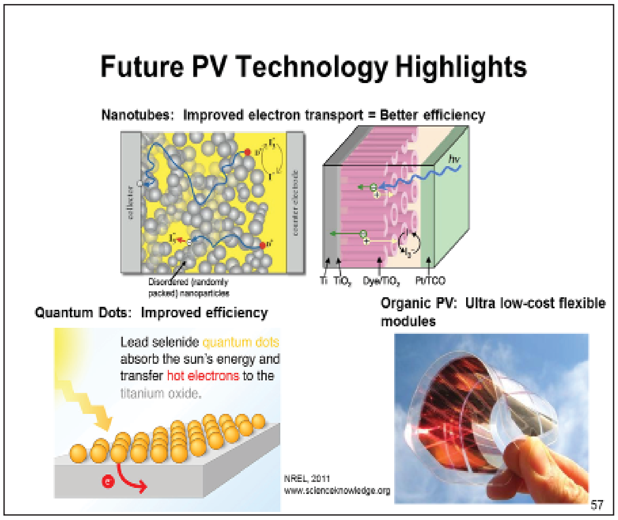
Future PV Technology Highlights
Nanotubes: Improved electron transport = Better efficiency
Disordered (randomly packed) nanoparticles
Ti TiO2 Dye/TiO2 Pt/TCO
Quantum Dots: Improved efficiency
Lead selenide quantum dots absorb the sun's energy and transfer hot electrons to the titanium oxide.
Organic PV: Ultra low-cost flexible modules
NREL, 2011
www.scienceknowledge.org
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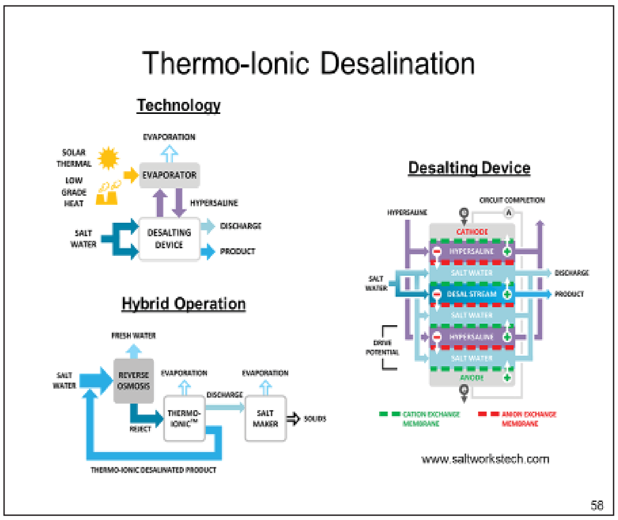
Thermo-Ionic Desalination
Technology
EVAPORATION
SOLAR THERMAL
LOW GRADE HEAT
EVAPORATOR
HYPERSALINE
SALT WATER
DESALTING DEVICE
DISCHARGE
PRODUCT
Hybrid Operation
FRESH WATER
SALT WATER
REVERSE OSMOSIS
EVAPORATION
DISCHARGE
REJECT
THERMO-IONIC
SALT MAKER
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CIRCUIT COMPLETION
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