Energy Optimized Desalination Technology Development Workshop

Dr. Mark Johnson
Director, Advanced Manufacturing Office
U.S. Department of Energy
November 5-6, 2015
San Francisco
Energy-Water Nexus: DOE’s Role

- DOE has strong expertise in technology, modeling, analysis, and data and can contribute to understanding the issues and pursuing solutions across the entire nexus.

- This work has broad and deep implications
  - User-driven analytic tools for national decision-making supporting energy resilience with initial focus on the water-energy nexus
  - Solutions through technology RDD&D, policy analysis, and stakeholder engagement

- We can approach the diffuse water area strongly from the energy side
  - Focus on our technical strengths and mission
  - Leverage strategic interagency connections

Download the full report at energy.gov
Energy-Optimized Treatment, Management, and Beneficial Use of Nontraditional Water

- Projections suggest desalination is most promising current technology with sufficient potential capacity to prevent reservoir depletion in western states over the coming decades
- There are a number of promising treatment technologies that could lead to optimized systems
- Systems level solutions, such as dynamic control, and off-peak optimization, bring increasing opportunities for lower cost and lower carbon footprint.

Sustainable Low-Energy Water Utilities

- Over 3% of US electricity used for water infrastructure (treatment and pumping)
- Water utilities identify energy as largest operating cost
- Energy needs increase with treatment regulatory requirements (e.g. nutrients), growing inter-basin transfers
- Process innovation (e.g. microbial fuel cells), and manufacturing advance (e.g. 3-d printing of pump impellers) enable energy efficiency and energy extraction.

Water-Efficient Cooling

- About 40% of US water withdrawals and 4% of consumption are for thermoelectric cooling
- Scalable cooling technologies can also reduce water requirements in industry and commercial buildings
- In FY15, there were significant investments by FE, ARPA-E ARID, and in CERC
- In FY17, we will pursue increased efficiency in heat exchangers and cooling systems, while monitoring significant recent tech investment
- In FY18, we will demo promising technology
Clean Energy Manufacturing
Making Products which Reduce Impact on Environment

Advanced Manufacturing
Making Products with Technology as Competitive Difference
The Imperative
Energy-Water Nexus: Critical National Needs

- Energy and water are interdependent.
- Water scarcity, variability, and uncertainty are becoming more prominent.
  - This is leading to vulnerabilities in the U.S. energy system.
- Climate Change and Technology Change: We are already in a Race
- Updating aging infrastructure brings an opportunity.
- The nexus is regional heterogeneous, has dynamically complex systems dynamics, has large uncertainties, and many potential options.
- Energy and water issues are internationally prominent.
Nature’s Timely Reminder!

- California drought is cited as the worst recorded in 1200 years*

- California recently passed Italy and the Russian Federation to become the world’s 8th-largest economy.

Context for E-W Dynamics in Water-Stressed Regions

Water Stress in the U.S.

Projected Changes in Seasonal Precipitation
- Winter
- Spring
- Summer
- Fall

Groundwater Depletion

Present

Future

Example: Energy growth for Inter-basin pumping
Context for the Nexus and Connected Infrastructure Vulnerabilities

- **Electricity**
- **Water**
- **Natural Gas**
- **Population**
- **Land**

**Legend**
- Interstate Pipelines
- Intrastate Pipelines

Source: Energy Information Administration, Office of Oil & Gas, Natural Gas Division, Gas Transportation Information System.

Major Land Resource Area (MLRA) Boundaries
Water flows in the United States

A Water problem is an **Energy** problem


Energy (Quads/year)
- Petroleum 35
- Natural Gas 10
- Coal 20
- Nuclear 8
- Geothermal 1.2
- Hydro 3
- Wind/Solar 1

Water (Billion gallons/day)
- Fresh Surface 264
- Saline Surface 57
- Fresh Ground 82
- Saline Ground 2

Energy reported in Quads/year. Water reported in Billion Gallons/Day.
What is ‘Pipe Parity’ for Water

• Deliver Water with equivalent Economic & Energy / Carbon cost
  
  – Price: Approximate $0.50 / m³ (tonne)
    • Ranges from $0.10 to $1.00 nationally
  
  – Energy: Approximate: 1kWh / m³ (tonne)
    • 0.65 kWh (corresponding to 235m elevation change)
  
  – Carbon: Approximate: 1lb / m³ (tonne)
    • Based on 0.69kg CO₂/kWh
  
  – Quality: 500 ppm TDS
  
  – Complimentary Cases: Produced Water and Grey Water
Framework Cost break down for Desalination

Goal = $0.50/m³

Cost Decreases for Desalination

What are the technology pathways that get us there?
Some Possible Areas for Opportunity

- **Operating Costs**: Chemical additives (anti-bacterial, longer lasting membranes), Disposal / Post-processing of saline brines

- **Capital Costs**: Low-cost heat exchangers for thermal processes, Cost Effective membranes, Balance of Plant Equipment

- **Energy**: Improve pressure energy recovery, utilize low-cost thermal energy

- **System Integration**: Intelligent design of water networks to minimize connection costs, Real-time Control and Sensor Systems

- **Soft Costs**: Workforce, Supply Chain, Permitting Expertise and Environmental Considerations
Where are the gaps?

Technical Challenge Framework
Multi-disciplinary and Translational

Applications
- Fresh Water
- Waste Water
- Produced Water

System Test-Beds
- Forward Osmosis
- Membrane Distillation
- Advanced RO
- Capacitive Separation
- Dew-vaporation

Enabling Technologies
- Resistant Materials
- Process Models
- Separation Membranes
- Control Systems
- Ionic Liquids & Sorbents
- Flow/Heat Exchangers

Scientific Foundation
- Multi-scale Simulation
- Data / System Optimization
- New Materials Discovery

Technical Requirements
Qualified New Technologies
Technical Insight & Understanding

Knowledge Gaps
Goals for workshop

• What are the technology advancements needed to hit our cost target?

• What ancillary and associated technologies (membranes, pumps/valves, etc.) are needed to make desalination pipe-parity competitive?

• Identify the most effective role for DOE in advancing these technologies.

• Discuss pathways to accelerate RD&D of promising desalination approaches for fresh-water at lower energetic, economic, and environmental costs relative to existing technologies.
Thank You!