U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

Breakout Sessions Report

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Advanced Manufacturing Office

www.manufacturing.energy.gov

Breakout Session 1: Membrane-based Technologies
Group 1: Water Purification

Targets

- Fouling resistance/Anti-fouling- process to discourage fouling, surface modification of membranes for anti-fouling, anti-fouling coating,
- Membranes with higher selectivity and recovery to reduce waste stream
- Tunable membranes based on water input
- Self-cleaning membranes; manufacturing membranes in situ
- Tolerance to temperature, oxidants(chlorine), pH, organics
- Can you make at any scale at any costs? High-quality membranes vs. low-quality membranes

Technology Barriers/Challenges

- Manufacturing Complexity
- Multiple Foulants and foulant modes
- Biofilm (organic carbon biomass)
- Multifunctional systems- organic versus analytical TDS
- Uniformity control of mass production
- Misaligned incentives between academic innovators and industry
- Fundamental understanding of transport in comp

R&D Needs

- Collaboration between materials experts, process experts, testing experts
- Collaboration between industry and academia
- New Materials- multi-functional and multi-scale
- High-throughput membrane testing and prep

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Breakout Session 1: Sensors and Controls
Group 2: Water Systems Integration

Future Opportunities/ Technical Barriers and Challenges

- Sensor durability, sensitivity, drift, fouling, detection range
- Sensor material and design applicable for measuring range of contaminants
- Real-time, reliable, can pinpoint failure
- Development of and ability to manufacture sensors with advanced materials and scale-up at low cost
- Techno-economic analysis, supply chain concerns,
- Operator training with new monitoring and control software/program
- Detection of polysaccharide and organic materials for fouling monitoring
- Cyber security issue. Utilities are not encouraged to cloud sourcing.
- Data fusion challenge (data analytical), integrated to enable using of delivered data in water system
- Sensor cleaning, self cleaning capability
- Non-ideal conditions – variability of water quality/mixed streams and interference to the detection

R&D Needs

- Need to develop distributed in-situ data and analysis sensing platforms
- Need strategies for preventing process performance degradation that are caused by many mechanisms (fouling/biofouling, precipitation/scaling, clogging, etc.)
- Advanced synthesis technique to enable advanced material manufacturing; conversion of batch process to continuous or R2R process for low cost advanced material manufacturing
- Need integrated multiscale strategies for fouling prevention

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Breakout Session 1: Process Intensification
Group 3: Cross-Cutting Water Processing

Future Capabilities and Opportunities

- High thermal conductivity materials for high temperature and hybrid water processing systems (>100 deg C) to efficiently utilize thermal energy and waste heat recovery
- Hybrid systems (NF-RO-ED-CDI) and combined technologies/treatment methods to reduce CAPEX of multi-effect systems through manufacturing innovation
- Modularization of multiple water treatment operations and off-grid or micro/modular systems
- Brine waste recovery opportunities including handling and disposal (environmental impact)
- Water supply security including distributed treatment for water system resilience and hardening

Targets and Metrics

- Dynamic capacity and rate (volume/energy per unit time)
- Fully renewable energy cost (solar) of <$0.30 per cubic meter
- 80% lower greenhouse gas emissions – net zero energy
- Use of exergy coefficient of performance (ECOP)
- $/sustainability (regional deployment)

Breakout Session 1: Process Intensification
Group 3: Cross-Cutting Water Processing

Technology Barriers/Challenges

- Material cost/lifecycle, appropriate predictive models, degradation due to fouling and side reactions
- Lack of multi-technology systems integration
- Large scale testing facilities are scarce and scale-up for manufacturing across the technology spectrum
- High volume/low total dissolved solids treatment is expensive
- Grid integration with electro-kinetic desalination

R&D Needs, Pathways, and Approaches

- More large scale test facilities needed including test beds for evaluation at scale with data sharing
- Fundamental materials design and development including computational materials design and optimization with rigorous validation
- Renewable energy storage integration with desalination - concentrate on solar power technologies and pair with modular desalination (photochemical/photothermal)
- Organism solutions for brine management and use of bio-solids as an energy source

Breakout Session 2: Non-Membrane Technologies
Group 1: Water Purification

Targets

- Selective and reusable sorbents
- Ion Exchange
- Electrokinetic separation
- Membrane distillation
- Bio-derived organism treatment
- Evaporation and subsets
- Freeze separation
- Brine Management
- Supercritical processes
- Metric Examples:
  - Cost- Capex/Opex, levelized cost of water purification
  - Performance- kWh/m3, m3/hr/$, low and high salinity capability
  - Environmental impacts, human health impacts

Technology Barriers/Challenges

- Techno-economic analysis
- Scale-up
- Fouling and pretreatment of feedwater
- CDI- material barrier
- Materials resistant to harsh conditions

R&D Needs

- Brine Management
- System models and fundamental understanding of interfaces
- Scaled prototypes
- Data collection, benchmarking, and data sharing

Breakout Session 2: Water Technologies in the Energy System
Group 2: Water Systems Integration

Future Opportunities/ Technical Barriers and Challenges

- Can you have both high efficiency and low cost in one separation system
- Modularized/distributed vs. centralized systems – cost considerations and economies of scales
- New multi-functional material for desalination membrane (to address issues like biofouling)
- Operational and political barriers for energy/water system integration, including scale issues (local vs. state), temperature/pressure, no regional coordination
- Barriers/challenges in manufacturing: ROI, system life, adaptability; challenges to manufacturing and deploy to materials and surface textures cost effectively.

Breakout Session 2: Water Technologies in the Energy System
Group 2: Water Systems Integration

R&D Needs

- Scalable manufacturing approaches for new material testing/performance evaluation
- Non-membrane technologies for separation from solvents and others, must be cost effective.
- Improve resilience to fouling in filters, pipes, and pumps in water and energy systems
- Multi-functional material design based on fluid-solid interactions for fouling /scaling prevention to improve durability
- Design experiments and test at relevant scale, even for low TRL
- Develop modeling and analysis framework that integrates surface chemistry/interaction model, unit operation model, process level model, and system level models, to find opportunities to optimize the performance.
- Develop system level analysis for performance, cost, TEA, LCA, water resource, energy use, at regional scale, and factoring temporal considerations for multiple applications and multiple resource qualities. Decision support tool.
- Increase performance and cost of auxiliary system
- Membrane modules, smart and smaller systems.
- User friendly softwares

Breakout Session 2: Integration of Renewable Energy with Desalination
Group 3: Cross-Cutting Water Processing

Future Capabilities and Opportunities

- More use of thermal solar for RO feed and customizable and flexible, low-temperature (<100°C) solar collectors for desalination
- Use of waste heat for low temperature water purification operations and technologies for using low-grade heat sources (e.g., cooling towers)
- Integrated solar PV / thermal desalination systems and renewable energy technologies
- Fresh water/desalination concentrate integrated with grid stabilization
- Use of alternative energy sources (photo-catalysis for peroxide and ozone for pre-treatment, biosolids, etc.)
- Water storage vs electricity storage

Targets and Metrics

- Capacity value and demand response potential of water infrastructure (in MWh)
- Water production 100% focused on below average energy costs
- Thermal storage density approaching 40 MJ/kg
- Water at pipe parity

Breakout Session 2: Integration of Renewable Energy with Desalination
Group 3: Cross-Cutting Water Processing

Technology Barriers/Challenges

- Renewable energy capacity factors and grid stability challenges
- Lack of robust and effective in-situ photo-catalysis oxidant production
- Lack of automation of water technology operations
- Low power density of low and intermediate temperature thermal storage
- Modeling of renewables and water management to identify technical and economic drivers

R&D Needs, Pathways, and Approaches

- New thermo-chemical storage cycles
- System models that include a renewable energy technology portfolio for integrated process synthesis
- Heat-to-cold desalination / pretreatment technologies
- Water treatment technologies that can robustly ramp up and down
- Metrics-driven modeling for optimization and technology selection

Breakout Session 3: Technologies for Variable Water Quality
Group 1: Water Purification

Targets

- SMART
  - Sensor Technology: rapid online sensing methods; technology for automatic adjustment; distributed, variable controls
    - Metrics: longevity, need for calibration, accuracy, drift
  - Computer Control: predictive
  - Cyber Security
- Process Control Improvements: rapid response, treatment cascade, variable flow
  - Metrics: meet regulations and standards, process intensification at great than 95%, continuous process control
- Differentiation of Specifications
  - Efficient of classification of water quality
- Design Strategies- specialized vs flexible

Technology Barriers/Challenges

- Development of Analytical Methods for continuous sensing, i.e. trace levels
  - Sensor response at 1 – 10 seconds
- Foulants: many types, challenging contaminants, variety of contaminants and reactions
  - Reduce down cycle time and maintenance costs
- Lack of investment for retro-fitting and infrastructure
  - $1T
- Data Handling and Storage – 1TB per day of storage and analysis
- Sensing at membrane levels
- Stimuli responsive systems
  - Sensor response at 1 – 10 seconds
- Easy swap modular systems
- Cyber-security: need to protect for smart sensing systems

Breakout Session 3: Water Purification Plant Design and O&M
Group 2: Water Systems Integration

Opportunities and Targets/Candidate Metrics

- For pilot plants, candidate metrics will be different than full scale – e.g., Lab scale should be 1-4 GPM, pilot 10-40 GPM; pilot goal target should be the current U.S. cost of water (in energy and $) but will vary depending upon application/location
- Energy efficiency or % of energy coming from renewables (or other sources)
- Capital provided directly from municipalities vs. grants
- Mean time for system function failure: > 20 years
- Quantifying design capacity vs. operational load, including peaking
- ROI: will be different for industry (1-2 years) and municipalities (?)
- Developed cost model for water plants and systems (update old ones, create new)
- Co-location with facilities/industries that have excess waste heat (e.g., servers at data centers)
- Fit-for-purpose systems: utilize a “one water approach” where the plant design considers the community being served and other factors
- Eliminated pre-treatment for RO if possible (through improved membranes, chlorine, etc.)
- Smart manufacturing and 3D printing for skids with 50% reduced material costs

Breakout Session 3: Water Purification Plant Design and O&M
Group 2: Water Systems Integration

Technology Barriers/Challenges

- Centralized model limits use – building large plants that may not be needed
- Size of plant and projections on water availability/demand, population causes uncertainty and affects capital costs
- Computational modeling at different levels is not being done today
- Plants have to pay for pilot tests (in the several million $); and regulations differ between states
- Perceived and actual risk of using alternative water sources (e.g., water from waste sources)

R&D Needs

- Utilized system analysis to inform the system integration approach, to determine research needs (before you start experimenting)
- Better mid-scale, Aspen level process models
- Validation of design parameters (TDS, T) for technologies, in test beds
- Better models for future projections (water availability/demand) that include climate changes
- Overall computational model that connects the entire plant design

Breakout Session 3: Materials and Minerals Co-Production
Group 3: Cross-Cutting Water Processing

Future Capabilities, Opportunities

- Need for highly selective materials and technologies for recovery of target elements (e.g. lithium, manganese oxide, rare earths)
- New recovery methods for Li/Mg for battery materials, nitrates/phosphates/carbon compounds from agriculture, short chain fatty acids in digestion, and low concentrations of rare earths
- More data and a national resource characterization database
- Other areas for future opportunities; incinerator ash, mixed metal oxide production, brackish sources, etc.

Targets and Metrics

- Reduce cost of mineral recovery form co-produced brine by 10X
- Technology to recover critical materials and other minerals from brine concentrate up to 15 wt. % salt
- Product metal purity greater than 90% to the customer
- Performance ratio of integrated thermal systems greater than 20 per dollar of capital invested per daily gallon produced
- Minerals/metal production with internal ROI at least 20 percent
- Seawater desalination provides all uranium for reactors

Breakout Session 3: Materials and Minerals Co-Production
Group 3: Cross-Cutting Water Processing

Technology Barriers/Challenges

- Existing technologies not sufficiently selective given low concentration of target species
- Lack of fundamental understanding on metal interactions with surface
- Low concentration, large variety of chemicals and variation over time and location
- Environmental impacts of concentrating contaminants (e.g., selenium in Calif. Central Valley)
- Scalability of extraction approaches

R&D Needs, Pathways, and Approaches

- Selective separation of materials and processes based upon oxidation state with 90% separation efficiency
- New low energy and low water use in primary metals production processes
- Surface functionalization for selective separation in preprocessing
- Optimal control for flexible operations with dynamic feed properties that are source specific
- More large-scale and better testing facilities