Energy for Water and Desalination

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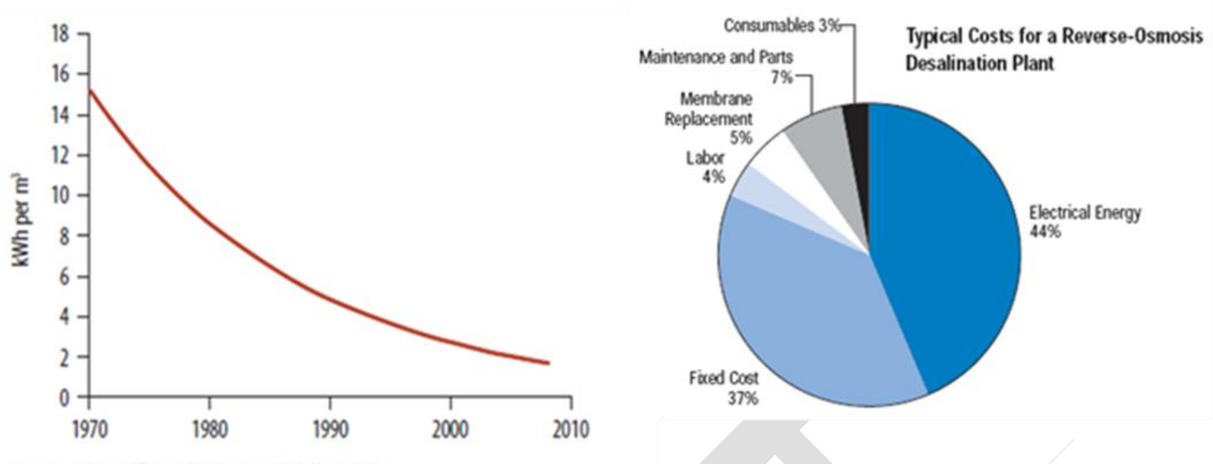
Introduction

Water does not simply appear out of our taps…Energy is needed to source, transport, treat, and condition the water that we use on a daily basis. This “hidden” energy use is significant. DOE reports that the energy used in water supply and wastewater treatment is 0.3 and 0.2 quads per year, respectively [1]. This energy creates a public supply of 44 billion gallons of water per day (bgd) while agriculture uses 137 bgd, consuming 116 bgd [1].

Stresses on our sources of “fresh” water continue to rise as our climate changes and as our extraction and use increases keeping pace with population growth along with agricultural and industrial demand. There is a critical need to develop ways of improving our use of all water sources, including saline, brackish, seawater, and wastewaters, to ease fresh water stress. However, the use of large amounts of energy to extract, transport, treat, and deliver water remains a stumbling block to this effort. Concurrent emissions of carbon, other pollutants, and the high costs associated with treatment and transport are also major challenges. Environmental damage may result from extracting and transporting saline water, and from disposing of the waste products from treatment.

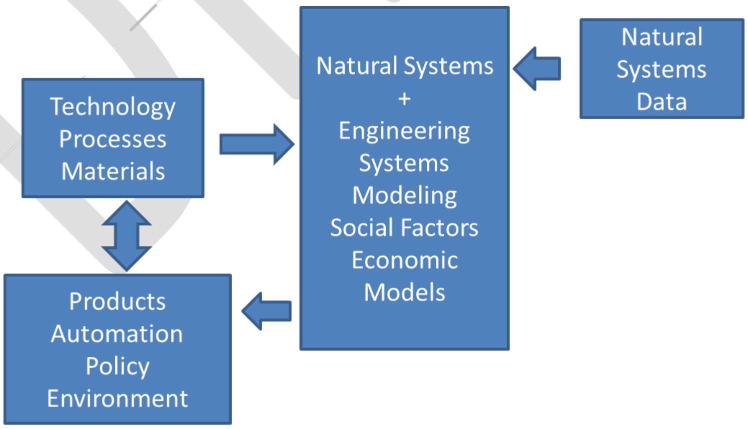
The amount of energy needed to desalinate water has decreased exponentially (see figure) over the last 40 years, a result of improvements in membrane technology and pressure energy capture. Even so, electrical energy can use as much as 50% of the costs for a reverse osmosis desalination plant [2-4]. As such, our opportunities to reduce costs, energy use, and emissions within the plant lie with improvements in capital investments and infrastructure, operations and maintenance (O&M), and labor costs. Automation, cost-benefit analysis, and optimization of water deliveries should be developed. Outside of the plant, there are other opportunities to reduce overall costs, energy use, and emissions.



Source: Adapted from Elimelech and Phillip 2011.

Figure 2. Left: Energy input required for reverse osmosis processes since 1970. Right: A pie-chart representing the costs associated with a modern reverse osmosis facility.

We need to look at the “full picture” surrounding desalination. Not only energy reduction in the primary salt-water separation step, but in overall plant costs (including pre- and post-treatment), capital and O&M costs, labor costs, automation needs, environmental costs, and the economics surrounding location and transportation costs associated with acquisition of water, disposal of waste, and utilization of coproducts. This means that there are important linkages between the engineered systems and the natural systems involved. Water sources require widely varying amounts of energy to acquire. For example, in California, the energy intensity of water supply and conveyance can vary from 0 to 14,000 kWh/MG, drinking water distribution varies from 700-1200 kWh/MG, and supplying groundwater for agriculture uses from 500-1500 kWh/MG [5, 6]. Policy communications/development, the economics behind plant construction and the costs to supply water, and social factors (regulations, water rights, utilization patterns, risk perception) are a critical part of the analysis from beginning to end.



1. Key Challenges/Research Questions

Topics include water sourcing, transportation, treatment, and delivery to the consumer.

- Challenges
    - Identifying “new” water resources
    - High costs
    - Intensive energy demand
    - Environmental impact related to intake, concentrate disposal, and transportation
    - Membrane fouling and scaling
    - Rural and small communities need cost-effective desalination technologies
    - How to tailor pre- and post-treatment to specific scenarios?
- Research Questions
    - Can we identify new resources in optimal locations that require less energy to source/treat/deliver?
    - Can new technologies reduce treatment costs and energy consumption?
    - How can the pretreatment be improved to reduce membrane fouling and scaling?
    - How can we reduce the costs for concentrate minimization and resources recovery?
    - What is the relative importance of (hindered) convection, diffusion, and electromigration on contaminant transport and fouling in membranes?
    - What are the fundamental electrolysis reactions and destabilization mechanisms during electro- and chemical coagulation of impaired waters (e.g. high salinity brackish water, oil-field wastewater, etc.)?
    - How can we recover the maximum energy from treatment, desalination and conditioning processes?
    - What waters are available in optimal locations for use? What is the best intersection of location, needs, acquisition energy use, treatment energy use, and transportation energy use?
    - Who will pay for new, advanced systems for sourcing, treatment, and delivery? How much will they be willing to pay? How do we bridge the gap between research discoveries and affordable supply?

2. Data/Knowledge Gaps

- Currently there are many existing processes and new technologies under development. There is a need for a comprehensive database and evaluation of the technical, economic, and practicability of these technologies. The research team at NMSU and CSM has evaluated over 60 technologies and processes for produced water treatment. The database and decision support tool can be updated with new technologies, and develop into a roadmap to estimate short-term and long-term solutions.
- New technologies need to be demonstrated at pilot- and full-scale, and evaluated from a life cycle standpoint.

- Mechanisms of contaminant removal and optimization of membrane and pretreatment operational parameters are needed. Calls for optimization of membrane selectivity [7] over membrane flux are one example of optimization.

3. Potential Transformative Solutions Needing More Research

- New materials and innovative desalination technologies need more research, such as membranes, draw solutions for forward osmosis, and highly conductive and porous electrode materials for capacitive deionization.
- Nanotechnologies have developed rapidly and can be transformative solutions for water treatment processes, such as graphene membranes. Nanomaterials can also be used to modify commercially available membranes, which could be a short-term solutions to enhance desalination efficiency.
- * The appropriate implementation of technologies for treatment of impaired waters need to be rigorously evaluated. For example, nanofiltration is a low-pressure alternative to reverse osmosis, which is feasible when divalent (or trivalent) ions and organic matter are predominant contaminants that need to be removed. Another treatment technique that is well-suited for small, on-site applications is (electro)coagulation. Electrolytic oxidation of elemental aluminum or iron releases coagulant precursors that can effectively purify several classes of impaired waters. However, their application to brackish water, flowback/produced water, and wastewater reclamation needs to be established along with developing a mechanistic understanding of associated transport phenomena including fouling and passivation.
- Development of linked natural-engineered systems to optimize sourcing, treatment, and delivery while minimizing energy use, waste creation (including carbon emissions), and disposal costs. Minimize the cost to the user while improving the total delivery system

4. Impacts on Science and Society

Our ability to utilize low-quality water supplies is becoming a necessity, and reality, due to pressures on existing freshwater supplies and drought conditions thought to be induced by a changing climate. The proposed research address the development and effective implementation of energy-efficient, advanced technologies to source, purify, and deliver what were highly impaired waters as clean water resources for multiple uses.

References Section

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