

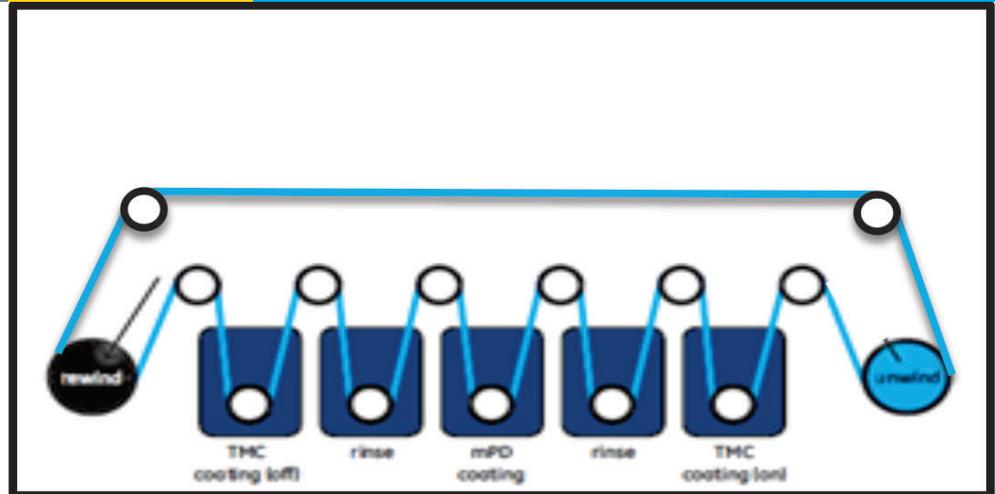
## Novel Membranes and Systems for Industrial and Municipal Water Purification and Reuse

Decreasing energy consumption of reverse osmosis membrane separation processes

Water is essential for life and critical to economic activity. It impacts a wide range of U.S. industries, including power generation, oil and gas production, mining, food processing, and chemical production. In 2010, the U.S. Geological Survey estimated the United States used 355 billion gallons of water daily, more than 51% of which was used by the manufacturing, power generation, and mining industries. Climate concerns, population growth, and increasing water scarcity are leading to greater consideration of industrial and municipal wastewater reuse and desalination of brackish water and seawater to meet anticipated future water supply needs. Global water demand is also expected to grow significantly in the next 20 years.

Reverse osmosis (RO) membrane-based processes are used worldwide for water treatment and industrial and municipal wastewater reuse. Today, RO membranes are the leading technology for new desalination installations, and they are applied to a variety of seawater, brackish water, and wastewater sources. However, current membrane performance is less than optimal, resulting in inefficient, energy-intensive separation processes.

Innovations in membrane materials, manufacturing methods and system designs that result in significantly increased membrane water permeance, improved



GE's proposed modular R2R pilot line for fabricating solution phase molecular layer-by-layer synthesis (mLbLS) reverse osmosis (RO) membranes. *Photo courtesy of GE Global Research*

fouling resistance, and enhanced rejection of contaminants are critically needed to reduce the cost and energy requirement of water production by RO processes. Operating the RO process at lower hydraulic pressure while maintaining similar water throughput is the key to reducing energy consumption for membrane-based water purification.

This project aims to develop technology capable of decreasing the energy consumption of RO membrane separation processes by 50%, while also decreasing the cost of water purification and reducing environmental impacts. This will be accomplished through the development of nano-engineered, high permeance membrane materials with more than double the permeance of current conventional RO membranes, as well as manufacturing technologies for large-scale and cost-effective production of the novel materials.

### Benefits for Our Industry and Our Nation

Advanced membrane technology could improve U.S. manufacturing energy productivity while at the same time reducing its environmental footprint.

Additionally, water scarcity issues facing the United States could lead to periodic shutdowns in manufacturing industries requiring large amounts of cooling tower, boiler, or process water. The membranes and systems developed here could help prevent such shutdowns by improving the economics of new and alternative water sources for manufacturing industries, allowing the sustainability of existing manufacturing infrastructure. In addition, the technology could open new opportunities for economic development in water-stressed areas.

### Applications in Our Nation's Industry

U.S. manufacturing industries requiring large amounts of cooling tower, boiler, or process water will benefit from more energy-efficient RO membrane processes. In addition, RO-purified water could also be used in the food and beverage industries, as well as for municipal water sources.

### Project Description

The project has three main objectives to be achieved: (1) develop and optimize novel nano-engineered RO membranes with at least three times the permeance of

current conventional RO membranes, (2) design and build pilot scale manufacturing processes for promising materials, and (3) design and simulate an RO system to maximize energy savings of high permeance membranes and validate 50% energy savings potential.

### Barriers

- Ensuring molecular layer-by-layer synthesis (mLbLS) RO membrane materials and process are robust.
- Developing a nanocomposite membrane fabrication process that can be scaled up from lab to pilot.
- Avoiding mLbLS membrane fabrication steps that are too complex to meet process economic goals.
- Creating an RO system design that can take full advantage of high permeance membranes.

### Pathways

Project partners will first develop, optimize, and characterize nano-engineered RO membrane materials using lab scale mLbLS (solution phase and gas phase) RO membrane approaches. Next, RO membrane pilot manufacturing processes will be developed for the mLbLS RO membranes that meet performance specifications. Subsequent efforts will focus on membrane module fabrication, module testing, and system design and optimization. Finally, energy savings will be calculated over a range of feed water salinities and compared with thermodynamic minimums and the targeted 50% energy reduction to be enabled by the new membrane manufacturing processes.

### Milestones

This three year project began in December 2014.

- Develop nano-engineered membranes with both solution phase molecular layer-by-layer synthesis (mLbLS) and gas phase mLbLS approaches and demonstrate >2x permeance enhancement over currently available RO membranes while maintaining 98% or higher salt rejection (Completed).
- Design, build, and optimize pilot scale membrane manufacturing process for the most promising technology approach (2017).
- Fabricate membrane modules, perform extensive membrane module testing, and design and simulate an optimal RO system (2017).

### Commercialization

Successful development of this technology would provide high permeance membranes and systems with greatly reduced energy consumption, and would be well positioned to capture significant market share in the rapidly expanding desalination and water reuse membrane element and equipment markets. Because the technology is modular and scalable, GE expects to leverage its extensive experience in the water technology arena to target a broad range of commercial market segments, from lower production single skid systems to large-scale industrial and municipal water facilities.

### Project Partners

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