NSF Nanosystems Engineering Research Center for Nantechnology Enabled Water Treatment Systems (NEWT)

Rice University (lead institution)

NEWT is applying nanotechnology to develop transformative and off-grid water treatment systems that both protect human lives and support sustainable economic development.

A National Science Foundation Engineering Research Center since 2015

Partner Institutions:

- *Arizona State University*
- *University of Texas at El Paso*
- *Yale University*

No other resource is as necessary for life as is water, and providing it safely and universally is a grand challenge inextricably linked to public health and sustainable development. Yet, affordable and reliable access to clean water is still a significant challenge for millions of Americans and a major limiting factor to hundreds of millions more around the world. We have identified three major problems that nanotechnology can help solve:

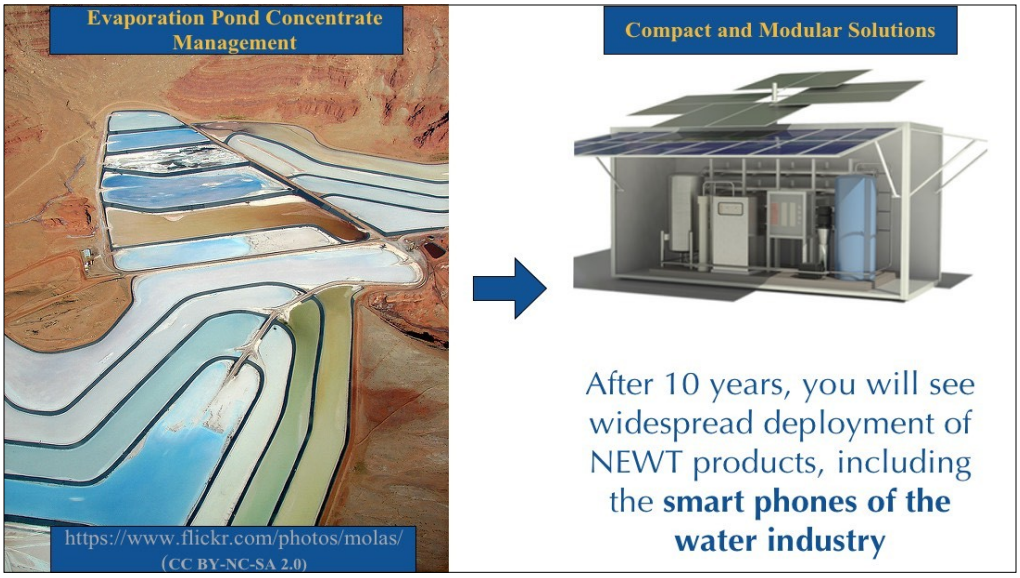
- Millions of people lack access to municipal water and need decentralized (distributed) water treatment.
- Desalination—which is increasingly required due to insufficient or impaired source waters—is energy intensive and thus prohibitively expensive for many stakeholders.
- Industrial wastewater treatment needs highly efficient and targeted technologies that can be deployed rapidly and treat according to specific desired end use, while enabling water reuse.

These problems inform our three high-level research questions:

- Which novel nano-scale properties can be exploited to significantly improve water and industrial wastewater treatment?
- How can we harness light energy directly to enhance treatment efficiency, reduce costs, and reduce chemical usage/sludge production?
- How can nanomaterials be reliably attached to surfaces or embedded into scaffolding without losing their unique functionality or selectivity to remove priority pollutants?

Our education program is driven by two underlying factors:

- Providing affordable and clean water is a compelling challenge that attracts students and teachers into science, technology, engineering, and mathematics (STEM) fields.
- Those most affected by lack of reliable and affordable access to clean water tend to be parts of the population that are minorities underrepresented in STEM fields.



Early NEWT technologies are changing the way industry is thinking about concentrate management. On the left you see evaporation ponds (which are being phased out in China) and on the right you see what a scaled-up version of NEWTSkid could look like.

Research Strategy

Thrust	Projects	NEWT Systems		
		POU drinking water	Solar Desalination	Industrial wastewater reuse
1. Priority Contaminant Removal by Multifunctional Materials	1.1: Sorbents	■		
	1.2: Magnetic	■		■
	1.3: Photocatalytic	■	■	
2. Low-energy Desalination	2.4: Light-Management	■	■	
	2.2: Membrane Distillation	■	■	■
	2.3: Mixed Matrix Membranes	■	■	■
3. Removal of Interfering Species; Scaling, and Fouling Control	3.1: Assisted Nucleation	■	■	■
	3.2: Electrosorption	■		■
	3.3: Anti-Fouling Surfaces	■	■	■
Theme: Safety & Sustainability	Lifecycle, Safety & Economics	■	■	■
	Social Acceptance	■	■	
Testbeds	MobileNEWT	■	■	
	NEWTSkid		■	■

Therefore, key pieces of our education program include:

- Pre-college programs that target teachers who will be able to leverage the STEM challenges of water to attract students who would otherwise forego these types of careers.
- University-level programs that focus students on problem-based learning in water treatment and a Research Experiences for Undergraduates (REU) program that recruits from community colleges exclusively.

Research

NEWT is applying nanotechnology to develop next-generation modular treatment systems that are relatively small and easy to deploy, and that have superior treatment capacity to utilize nearly any water source to protect human lives and support sustainable development. The planning and execution of NEWT's research activities are driven and guided by our three systems-level goals, to develop: (1) off-grid point-of-use (POU) and point-of-entry (POE) drinking water supply, (2) on-site industrial wastewater treatment and reuse, and (3) solar desalination processes that could provide drinking water or allow for water reuse. This ensures that the research activities are well integrated throughout the Center. The table summarizes how the research pieces of NEWT come together to achieve these three outcomes: (1) POU drinking water treatment, (2) direct solar desalination, and (3) fit-for-purpose industrial wastewater treatment and reuse.

Our strategy is to match the treated water quality to the intended use (fit-for-purpose treatment) —which could be, for example, drinking water, landscape or peri-urban irrigation, or industrial use— and to preferentially remove priority pollutants. This avoids wasting treatment capacity and decreases treatment costs. Due to variability in source water quality and treatment requirements, our strategy requires considerable versatility. Thus, we rely on modular treatment systems that can be integrated into treatment trains as needed. Each Thrust contributes a combination of fundamental knowledge and enabling technologies to develop advanced materials and treatment modules. NEWT's three research Thrusts are grouped according to the challenges they aim to solve, and collaborate to share knowledge and best practices. See the figure below, where each Thrust is represented by a boxed group.

Our Safety & Sustainability Theme is interwoven throughout all of the work done in the Center. This cross-cutting Theme ensures that we select our materials wisely, overcome important social barriers to technology dissemination, and avoid unintended consequences.

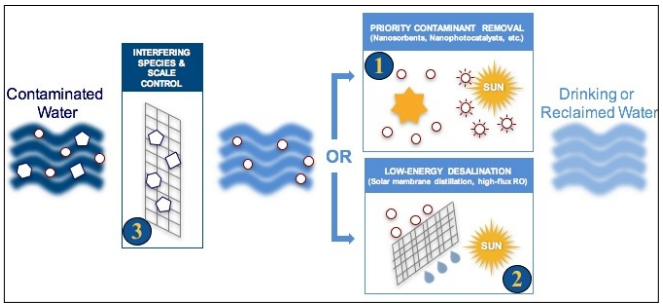
The two Testbeds in NEWT are focused on drinking water applications (MobileNEWT) and industrial wastewater treatment and reuse (NEWTSkid), respectively. These platforms provide important feedback loops to the teams working at the laboratory scale. When something becomes a roadblock at the Testbed scale, we can run experiments at the fundamental scale to solve the problem.

Education

The Center's Education Program is rooted in NEWT's vision to enable access to treated water almost anywhere in the world by developing nanotechnology-based treatment systems that protect human lives and support sustainable development.

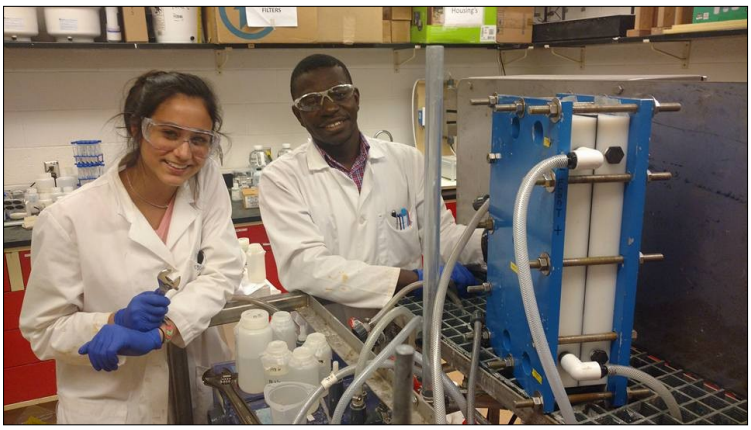
With this vision in mind, we set five general desired outcomes for our **graduate education program**: NEWT graduate students will (1) have strong interdisciplinary technical expertise in areas related to nanotechnology-enabled water treatment, (2) display an increased understanding of global water issues and their complexity, (3) be familiar with industrial and entrepreneurship practice and experiences, (4) be committed to sustainability and safety, and (5) become ethical and successful faculty members, industry or community leaders, or entrepreneurs.

We expect our graduate students to achieve these outcomes by conducting research that is relevant to the objectives of NEWT, taking part in the NEWT core course, mentoring undergraduate students and high school teachers, serving in the Student Leadership Council, and participating in a series of professional development activities. The core course is a two-semester-long seminar designed to develop a basic understanding of key concepts at the core of NEWT's mission and a common language for NEWT students, and to foster the creation of a NEWT culture. The course is taught by NEWT faculty members from



The figure depicts the "flow" of water treatment via NEWT research thrusts.

Professor Rafael Verduzco providing a lab tour to NEET program participants.



Sophia Grossweiler (REU intern) with her mentor, Oluwaseye Owoseni (PhD student), in Dr Shane Walker's lab at UTEP.

all partner institutions. Professional development activities range from career panels and internships with industry partners to courses on Engineering Management and Leadership and Evidence-based STEM Teaching.

In our **undergraduate education program**, students are exposed to NEWT-related research and to sustainability and nanotechnology-based water treatment concepts through undergraduate courses incorporating these topics into the curriculum, and by conducting research in NEWT labs during the school year or as part of our REU program, which targets students from local community colleges.

The goal of NEWT's **pre-college program** is to engage and educate students, teachers, and our community in STEM and to cultivate a workforce capable of developing sustainable nanotechnology-based solutions to facilitate access to clean water almost anywhere in the world. This objective echoes one of the primary missions of the National Science Foundation, namely to ensure a broadly inclusive workforce for STEM that reflects the diversity of the nation. It also directly relates to our mission: NEWT will educate the next-generation workforce to be creative, versatile leaders in the industry of sustainable technologies for water treatment.

To address the longer-term challenge of ensuring that we have an educated, talented pool of students, and to ensure that NEWT's K-12 pre-college educational activities make the broadest possible impact, we are developing or leveraging existing partnerships with multiple public school systems in Houston, New Haven, El Paso, and the Phoenix-Tempe areas. NEWT's pre-college program recruits teachers and students into its main three activities: (1) NEWT Research Experiences for Teachers (RET), (2) a Nano-Environmental Engineering for Teachers (NEET) course, and (3) the Young Scholars program.

Innovation Ecosystem

NEWT's goal is to develop and leverage an innovation ecosystem that yields high-impact research discoveries and knowledge that can be utilized to create tangible societal and commercial benefits in the field of water treatment. To achieve this goal, the center engages with its industry partners to identify translational NEWT projects that: (a) are of mutual interest, (b) are commercially relevant, (c) have substantial educational value for students, and (d) accelerate commercialization of research results. Center members, from small/medium enterprises to large firms, are integral to the innovation ecosystem, providing ongoing advice for, and assessment of, research projects, testbeds, and new technologies created by NEWT's investigators.

Engagement with industrial, practitioner, and innovation organizations within the innovation ecosystem is critical to increasing NEWT's capacity for driving transformation in the field of water treatment. As Center participants continue to bring their respective strengths and inputs to bear in the areas of research and innovation, NEWT will provide drinking and industrial wastewater treatment thought and practice leadership for the broadest public benefit.

Facilities

NEWT headquarters houses leadership and staff in a 1,000-ft^2 office suite at Rice University. An adjacent conference room is suitable for over 30 and has been equipped with videoconferencing capabilities, includ-

ing a 65-inch HD screen, Logitech conference camera, and speakerphone equipment. This room allows the NEWT team members to web conference and screen share with researchers throughout the Center and the world. Additional testbed space is also located at Rice University that allows for testing and treatment of 1,000 gallons of water per day.

Center Configuration, Leadership, Team Structure

NEWT is a partnership of four universities headquartered with the Center Director at Rice University. The leaders of the innovation and education teams are also based at Rice. In research across the Center, Rice brings to the team strengths in catalysis, nanophotonics, microbial control, and membrane technologies. Researchers at ASU (the home institution of the Deputy Director) have strengths in adsorption and photocatalysis which lead to their important presence in Thrust 1. There is also a focus on systems integration, a strength of the ASU team; this facilitates efforts to transfer NEWT technologies from across the Center into MobileNEWT (our drinking water testbed). Researchers at Yale University have a strong history of research in water treatment, photocatalysis, and membrane-based desalination. They play an important role in bench scale nano-science research for Thrusts 1, 2, and 3. Yale also plays a key role by assessment of the most promising NEWT treatment processes before they are selected for testing as modules in the testbeds. The University of Texas at El Paso's research in nanochemistry (including analytical aspects) and green synthesis is adding to efforts in each research thrust as well as in the Safety & Sustainability theme.

NEWT receives guidance from its Scientific Advisory Board, Industrial and Practitioners Advisory Board, Deans' Council, Institutional Oversight Board, Student Leadership Council, and Innovation Ecosystem Advisory Council.

NEWT is multi-disciplinary. The Center has faculty and staff involvement from Civil and Environmental Engineering, Bioengineering, Chemistry, Electrical and Computer Engineering, Chemical and Biomolecular Engineering, Sociology, Physics and Astronomy, Social Work, Materials Science and Nanoengineering, and Chemical and Environmental Engineering, as well as the Schools of Engineering; Forestry and Environmental Studies; Electrical, Computer, and Energy Engineering; Engineering and Applied Science; and Sustainable Engineering and Built Environment. NEWT is also unique because of participation by the Rice Alliance for Entrepreneurship.

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