UArizona’s Indige-FEWSS Partners with Navajo Communities for Clean Drinking Water Solutions

By Dr. Robert Arnold, Dr. Karletta Chief

A team of engineers from the UArizona and Diné College is developing solar-powered water nanofiltration devices to provide potable water and clean energy to off-grid homes on the Navajo Nation.

Introduction

FEWS insecurities have been amplified on the Navajo Nation during the COVID-19 pandemic. The Navajo Nation is a rural food desert with only 13 grocery stores across the 25,000 square miles of remote terrain for a population of nearly 200,000 tribal citizens. This is approximately 8 people/sq.mi. Furthermore, nearly 30% of remote Diné (Navajo) homes lack running water and 40% lack electricity. The Diné people haul water 5-50 miles away incurring an enormous expense of $13.30 per 100 gallons in comparison to 40 cents in a nearby city. Community resilience is critical for Diné communities to respond to and recover from perturbations such as pandemics and disasters. Developing technical solutions to these challenges requires an understanding of Indigenous societies, governance, and culture and the ability to work effectively in these contexts. Thus, our vision is to develop a diverse workforce with intercultural awareness and expertise in sustainable food, energy, and water systems (FEWS), specifically through the design of fit-for-purpose water and controlled environment agricultural (CEA) technologies to address the lack of safe water, energy, and food security in Indigenous communities. To develop this workforce, in partnership with Diné College, our project, Indigenous Food, Energy, and Water Security and Sovereignty or Indige-FEWSS is educating and engaging graduate students and tribal college students, with an emphasis on recruitment of first-generation and minority students seeking opportunities, to make a difference in developing communities.

We propose that the most effective and sustainable way to bridge the gap between feasibility and accomplishment in providing FEWS services to the highly distributed residents of the Navajo Nation, one of the largest tribes in the United States, is to (i) produce Diné College, NTU, and Diné community core technicians and professionals, (ii) assist in the provision of education and training materials necessary to magnify these capabilities, (iii) support the STEM pipeline from Diné College and NTU to the UArizona for tribal college students to pursue STEM and FEWS related degrees and (iv) motivate technical demonstrations that can be duplicated at other similarly underdeveloped communities. Thus, the goals are to train and enhance graduate education at UArizona by:

1) Integrating fundamental materials, hydrology, controlled environment agriculture, and energy research with unit and system concepts in the context of sustainable applications;
2) Providing teaching and science communication opportunities at tribal colleges and/or tribal professional development workshops;
3) Providing hands-on opportunities for Indigi-FEWSS students and faculty to work collaboratively with indigenous communities.

Challenges to Address

The large-scale problem. Water supply objectives in the Navajo Nation can be separated by scale. The large-scale need is for water distribution systems that support municipal and commercial development.
Impeding the construction of water distribution systems are the uncertainty of Navajo water rights and the acquisition of capital.

The Navajo Nation (Figure 1) lies in three states—Utah, New Mexico and Arizona. Two-thirds of the Reservation is in Arizona. The land is semi-arid with relatively few surface water features.

Figure 1. The Navajo Nation. The total land area, which exceeds 27,000 sq. mi., lies in Utah, New Mexico and Arizona. Located in the semiarid southwestern United States, there are relatively few surface water features.

The primary source of surface water in Navajo Nation is the Colorado River and its tributaries. The status of Navajo rights to Colorado River water is summarized (Table 1). Full resolution of those rights will likely take decades, particularly in Arizona.

<table>
<thead>
<tr>
<th>States with Navajo land area</th>
<th>Reservation area (sq. mi.), by state</th>
<th>Water depletion rights (volume, AFY)</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>New Mexico</td>
<td>7,600</td>
<td>326,000</td>
<td>Settled water depletion right.</td>
</tr>
<tr>
<td>Utah</td>
<td>1,800</td>
<td>81,500</td>
<td>Depletion right, approved in US Senate; awaiting HR approval.</td>
</tr>
<tr>
<td>Arizona</td>
<td>18,000</td>
<td>365,000</td>
<td>Estimated (unsettled) depletion based on land area.</td>
</tr>
</tbody>
</table>

Table 1. State-specific status of Navajo rights to Colorado River water.

To put the Table 1 in perspective, the annual allotment of Colorado River water to the Lower Colorado River Basin states (California, Nevada and Arizona) is 7.5 MAFY. Settled and projected Navajo rights to Colorado River water sum to roughly 10 percent of the Lower Basin allocation. Based on a 2020 transaction involving Arizona’s share of Colorado River water, the market price for water rights within the Arizona water community is about $500 per acre-foot. This is based on a tentative transaction involving a single payment of $10.9M for perpetual rights to 1078 AFY of Colorado River water ($r = 0.05) By extension, 0.75 MAFY has a value of $375M per year.
Figure 2. Installation of a major water distribution pipeline in Navajo Nation. The line will transport Colorado River water for municipal and agricultural uses. Capital for large-scale pipeline construction is among the obstacles to commercial-scale water resource development.

Caution has been urged in “commodifying” Navajo water. Nevertheless, water is a commodity, and perhaps the most valuable natural resource in the Navajo Nation. Its value in agriculture offers a pathway to jobs for an underemployed population—in both resource development for municipal and agricultural uses and as a continuous source of future revenue from agriculture and other water-dependent industries. *It is crucial, however, that revenues from water-related construction and water use remain on the reservation, in Navajo pockets.*

**The small-scale problem.** The smaller-scale, water-related problem in Navajo Nation arises from the size of the reservation itself and consequent population density. At 27,413 square miles, Navajo Nation is the largest Native American homeland in the United States. On average, the population density is 13 per square mile—and much less in many areas (Figure 3). For economic reasons, some 30,000 homes in remote areas of Navajo Nation remain unconnected to water and power from central infrastructure. Those residents commonly haul water to their homes from informal water sources of questionable quality (Figure 4). Universal access to water and electrical power in those locations may depend on the eventual deployment of off-grid, disperse water systems driven by wind or photovoltaic power sources (Figure 5).

Figure 3. Well location near the city of Leupp in southwestern Navajo Nation. The average population density in Navajo Nation is 13/mi², sometimes much less.
Figure 4. About 60,000 Navajos are unconnected to a central water source. Many haul water to their homes, often from informal, unsanctioned sources.

Solar Nanofiltration Units

The University of Arizona is investigating the practicality of small-scale, solar-driven nanofiltration (NF) units for water purification and partial nighttime electrification in off-grid Navajo homes. At household-scale, these systems can reliably purify about 100 gallons per day. NF-system design, cost and performance characteristics are summarized in a journal article appended to this note. It is emphasized that solar-NF does not depend on new developments in science or engineering. These systems consist of off-the-self parts that are reasonably easy to assemble and maintain (Figure 6).

Figure 5. Home-scale, solar driven NF unit. The solar array is 1.2 m² and sits atop the 100-gallon finished-water storage tank (not shown). At right is the unit designer, Yaser Mehdipour.
Solar Nano-Filtration System

Figure 6. Schematic representation of solar-NF system parts, including photovoltaic array, pump, battery, membranes and water storage tanks (2). Later designs include UV treatment of finished water prior to use. System control elements are not shown.

Solar-NF does not solve the problem of transporting water to households for treatment and use. Those living in remote areas would still have to haul water or contract with a water-hauling service to deliver water to homes. Neither does solar-NF solve the problem of investment in such systems.

Instead of household-level water treatment for potable use, larger-scale solar-NF treatment can be provided at centralized locations, followed by delivery to household points of use. The treatment units (Figure 7) would necessarily be larger, say 1500 gallons per day, and water hauling of finished water would be required. This more centralized system configuration offers advantages in terms of economy of scale, system maintenance and security. A primary disadvantage lies in loss of opportunities for partial home electrification. Whereas household solar-NF can be sized to yield excess energy for nighttime use in the households served, for obvious reasons, the same opportunities are missing when water treatment capacity is concentrated at watering points.

Figure 7. Large-scale (1500 gpd) solar-NF system—all parts.
Solution of water-related challenges in Navajo Nation. Satisfaction of water-related objectives in Navajo Nation should result from Navajo efforts, creating jobs for Navajos and allowing related expenditures to remain in Navajo hands.

This should be a guiding principle in any approach to water-related development in Navajo Nation in order to maximize the benefits of capital expenses, mitigate underemployment, and otherwise improve the quality of reservation life. In the context of water development, job creation is expected in civil engineering, environmental engineering science, and related construction fields.

Navajo educational institutions are fit for the task and have taken initial steps in those directions. The Navajo Technical University (NTU), for example, was awarded a National Science Foundation (NSF) grant to plan a baccalaureate program in Environmental Engineering. Diné College recently submitted a TEA-Center application to NSF for water-related educational development. If successful, the grant will improve gathering, storage and access for environmental data in Navajo Nation; provide analytical equipment to expand regional environmental monitoring efforts; and initiate off-grid water treatment systems throughout Navajo Nation—among other water-related benefits.

Navajo educational institutions understand that advancement of Navajo goals in environmental and economic areas are among their primary responsibilities. The University of Arizona Indige- FEWSS faculty (visit faculty pages: https://energy.arizona.edu/indigefewss/indigefewss-team) can assist in these efforts, helping in the development of program curricula and creating a permanent interface with Navajo educational professionals. Effort that brings Navajo graduate students to the University of Arizona or creates anecdotal technical demonstrations in food-energy-water technologies may be less beneficial than a permanent educational partnership with Navajo institutions in areas important to food, energy and water development in Navajo Nation.

Both Diné College and NTU enjoy strengths in environmental and agricultural science, as well as reasonable access to external support. Both are expanding faculties in areas critical to future Navajo Nation education and development. The UA Indige-FEWSS team will actively support efforts by NTU and Diné College to (i) grow F-E-W curricula for ABET accreditation, (ii) produce graduates who are prepared for post-graduate education, and (iii) improve Navajo life though advancements at the food-energy-water interface. This should be a decades-long partnership. It takes little imagination to see that successful efforts at NTU and Diné College can be templates for educational advancement elsewhere.
Next Steps with the Nanofiltration Units

By Dr. Vasiliki Karanikola

Many without connections to centrally treated water, haul water from distant, often unregulated sources, resulting in opportunity costs (time spent) and health impacts. In an effort to provide short and long-term solution to address the challenges related to safe potable water access, the University of Arizona team with the support of the Haury Foundation has started a project that involves designing and deploying off-grid water purification units within the Navajo Nation. The project’s main goals are to first deepen our partnerships with the Navajo Nation through agencies such as the Navajo Tribal Utility Authority (NTUA), the Indian Health Service (IHS) and Chapter Houses. As we are in constant communication and open conversation with the communities and Chapter Houses, we are listening to the priorities and needs related to water access. The second main goal of our project is to design based on what we are learning from the communities, solar nanofiltration systems to address water quality issues of the local water. Our systems utilize pressure-driven desalination methods, nanofiltration (NF) and reverse osmosis (RO) that are economically attractive for treatment of brackish waters such as
those on the Navajo Nation while producing high quality water. NF membranes coupled to a solar energy source provide fit-for-purpose water for potable use. Designs are site-specific—dependent on local water quality, solar characteristics and the size and needs of the population served—but easily adapted for deployment at other sites. We are collaborating with a non-profit Dig Deep, that operates and assists Navajo Nation communities in many technical aspects and are assisting the UA team with the deployment of the systems, and connections with the Chapter Houses. We are expecting to deploy at least three systems at Chapter Houses with water production capacities that range from 50 to 100 gpd. The overall goal of the project is to provide mid and long-term solutions to the food, energy and water challenges in the Navajo Nation.

Figure 9. Indige-FEWSS is collaborating with the non-profit organization Dig Deep that works to ensure every American has clean, running water forever.