Estuaries, where rivers pour freshwater into the ocean, could become giant power plants with the help of a newly made membrane. LWM/NASA/LANDSAT/ALAMY STOCK PHOTO

Rivers could generate thousands of nuclear power plants worth of energy, thanks to a new ‘blue’ membrane

By **Robert F. Service**Dec. 4, 2019 , 3:05 PM

BOSTON—Green energy advocates may soon be turning blue. A new membrane could unlock the potential of “blue energy,” which uses chemical differences between fresh- and saltwater to generate electricity. If researchers can scale up the postage stamp–size membrane in an affordable fashion, it could provide carbon-free power to millions of people in coastal nations where freshwater rivers meet the sea.

“It’s impressive,” says Hyung Gyu Park, a mechanical engineer at Pohang University of Science and Technology in South Korea who wasn’t involved with the work. “Our field has waited for this success for many years.”

Blue energy’s promise stems from its scale: Rivers dump some 37,000 cubic kilometers of freshwater into the oceans every year. This intersection between fresh- and saltwater creates the potential to generate lots of electricity—2.6 terawatts, according to one recent estimate, roughly the amount that can be generated by 2000 nuclear power plants.

There are several ways to generate power from that mixing. And a couple of blue energy power plants have been built. But their high cost has prevented widespread adoption. All blue energy approaches rely on the fact that salts are composed of ions, or chemicals that harbor a positive or negative charge. In solids, the positive and negative charges attract one another, binding the ions together. (Table salt, for example, is a compound made from positively charged sodium ions bound to negatively charged chloride ions.) In water, these ions detach and can move independently.

By pumping the positive ions—like sodium or potassium—to the other side of a semipermeable membrane, researchers can create two pools of water: one with a positive charge, and one with a negative charge. If they then dunk electrodes in the pools and connect them with a wire, electrons will flow from the negatively charged to the positively charged side, generating electricity.

In 2013, French researchers made just such a membrane. They used a ceramic film of silicon nitride—commonly used in industry for electronics, cutting tools, and other uses—pierced by a single pore lined with a boron nitride nanotube (BNNT), a material being investigated for use in high-strength composites, among other things. Because BNNTs are highly negatively charged, the French team suspected they would prevent negatively charged ions in water from passing through the membrane (because similar electric charges repel one another). Their hunch was right. They found that when a membrane with a single BNNT was placed between fresh- and saltwater, the positive ions zipped from the salty side to the fresh side, but the negatively charged ions were mostly blocked.

The charge imbalance between the two sides was so strong that the researchers estimated a single square meter of the membrane—packed with millions of pores per square centimeter—could generate about 30 megawatt hours per year. That’s enough to power three homes.

But creating even postage stamp–size films has proved impossible, because no one has figured out how to make all of the long, thin BNNTs line up perpendicular to the membrane. Until now.

At the semiannual **meeting** of the Materials Research Society here yesterday, Semih Cetindag, a Ph.D. student in the lab of mechanical engineer Jerry Wei-Jen Shan at Rutgers University in Piscataway, New Jersey, reported that their team has now cracked the code. The nanotubes were easy. Cetindag says the lab just buys them from a chemical supply company. The scientists then add these to a polymer precursor that’s spread into a 6.5-micrometer-thick film. To orient the randomly aligned tubes, the researchers wanted to use a magnetic field. The problem: BNNTs aren’t magnetic.

So Cetindag painted the negatively charged tubes with a positively charged coating; the molecules that made it up were too large to fit inside the BNNTs and thus left their channels open. Cetindag then added negatively charged magnetic iron oxide particles to the mix, which affixed to the positively charged coatings.

That gave the Rutgers team the lever it was looking for. When the researchers applied a magnetic field, they could maneuver the tubes so that most aligned across the polymer film. They then applied ultraviolet light to cure the polymer, locking everything in place. Finally, the team used a plasma beam to etch away some of the material on the top and bottom surfaces of the membrane, ensuring the tubes were open to either side. The final membrane contained some 10 million BNNTs per cubic centimeter.

When the researchers placed their membrane in a small vessel separating salt- and freshwater, it produced four times more power per area than the previous French team's BNNT experiment. That power boost, Shan says, is likely because the BNNTs they used are narrower, and thus do a better job of excluding negatively charged chloride ions.

And they suspect they can do even better. "We're not exploiting the full potential of the membranes," Cetindag says. That's because only 2% of the BNNTS were actually open on both sides of the membrane after the plasma treatment. Now, the researchers are trying to increase number of open pores in their films—which could one day give a long-sought boost to advocates of blue energy.

***Correction, 6 December, 11:30 a.m.:** This article has been corrected to accurately reflect how many homes a blue membrane could power and how much energy per area it produces.*