# 對外合作組織與機構動態報導

2018/5/31

## SHAKE RATTLE AND CODE

## 搖動與編碼

By Jared Sagoff • March 9, 2018

Southern California defines cool. The perfect climes of San Diego, the glitz of Hollywood, the magic of Disneyland. The geology is pretty spectacular, as well.

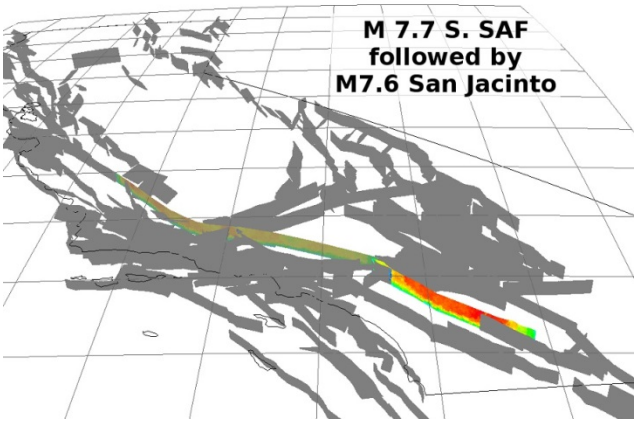
"Southern California is a prime natural laboratory to study active earthquake processes," said Tom Jordan, a professor in the Department of Earth Sciences at the University of Southern California (USC). "The desert allows you to observe the fault system very nicely."

The fault system to which he is referring is the

### 報告摘要(KEY INFORMATION)

1. 聖安地列斯斷層系統的中心帶是研究地震的絕佳地點。一南加大研究團隊運用美國能源部阿岡領導運算設施(ALCF)的超級電腦，精細模擬該處複雜斷層系統的地震行為，建立地震風險模型並研究如何降低風險。
2. 土耳其原子能管制機構於今年四月通過該國第一張核電廠的建造許可，並立即破土動工；而在美國，核能相關產業的發展環境依然艱困：俄亥俄州的第一能源發電及其零售子公司宣布將在 2021 年前關閉三個發電站的四座核能電廠，主因是在自由化電力市場中其躉售電力價格低，且未來需求缺乏成長潛力。
3. 國際海事組織(IMO)4 月在倫敦舉行會議，著手有關國際航運的溫室氣體排放減量的問題。資料指出國際航運過程的二氧化碳佔全球能源相關排放量的 2.3%，且至 2050 年可能增加 50-250%。IMO 自 2015 年起推動相關任務，目標是將 2050 年的排放量降為 2008 年的 50%，並這世紀末前達到零排放。
4. 史丹佛大學研究團隊以生物工程方式製造一類蛋白質合成物，經大鼠實驗，可保持受傷肺葉的呼吸功能，此研究有望為急性肺損傷帶來更好、更經濟的治療方式。
5. 目前，我們在進行污廢水處理時，仍需耗費大量成本以扇葉將空氣打入混有一般細菌的處理槽，史丹佛大學研究團隊提出以厭氧菌進行處理，將能提高污廢水處理量。

San Andreas, among the more famous fault systems in the world. With roots deep in Mexico, it scars California from the Salton Sea in the south to Cape Mendocino in the north, where it then takes a westerly dive into the Pacific.




Situated as it is at the heart of the San Andreas Fault System, Southern California does make an ideal location to study earthquakes. That it is home to nearly 24 million people makes for a more urgent reason to study them.

Jordan and a team from the Southern California Earthquake Center (SCEC) are using the supercomputing resources of the Argonne Leadership Computing Facility (ALCF), a U.S. Department of Energy (DOE) Office of Science User Facility, to advance modeling for the study of earthquake risk and how to reduce it.

Headquartered at USC, the center is one of the largest collaborations in geoscience, engaging over 70 research institutions and 1,000 investigators from around the world.

The team relies on a century's worth of data from instrumental records as well as regional and seismic national hazard models to develop new tools for understanding earthquake hazards. Working with the ALCF, it has used this information to improve its earthquake rupture simulator, RSQSim.

RSQ is a reference to rate- and state-dependent friction in earthquakes — a friction law that can be used to study the nucleation, or initiation, of earthquakes. RSQSim models both nucleation and rupture processes to understand how earthquakes transfer stress to other faults.

ALCF staff were instrumental in adapting the code to Mira, the ALCF's 10-petaflop supercomputer, which allows for the larger simulations required to model earthquake behaviors in very complex fault systems, like San Andreas, and which led to the team's biggest discovery.

The SCEC, in partnership with the U.S. Geological Survey, had already developed an empirically based model that integrates theory, geologic information and geodetic data, like GPS displacements, to determine spatial relationships between faults and slippage rates of the tectonic plates that created those faults.

Though more traditional, a newer version is considered the best representation of California earthquake ruptures, but the picture it portrays is still not as accurate as researchers would hope.

"We know a lot about how big earthquakes can be, how frequently they occur and where they occur, but we cannot predict them precisely in time," notes Jordan.

The team turned to Mira to run RSQSim to determine whether it could achieve more accurate results more quickly. A physics-based code, RSQSim produces long-term synthetic

earthquake catalogs that comprise dates, times, locations and magnitudes for predicted events.

Using simulation, researchers impose stresses upon some representation of a fault system, changing the stress throughout much of the system and thus changing the way future earthquakes occur. Trying to model these powerful stress-mediated interactions is particularly difficult with complex systems and faults like San Andreas.

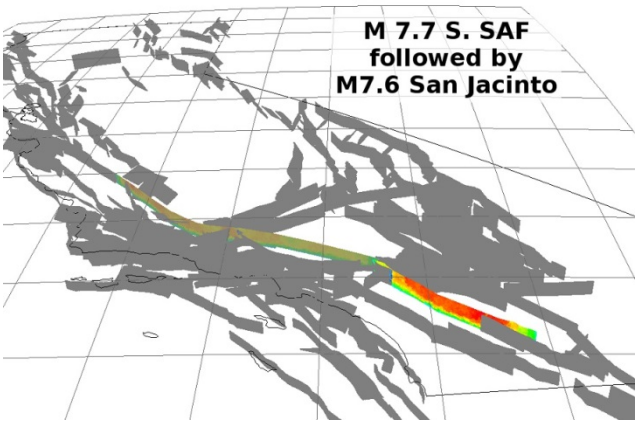
“We just let the system evolve and create earthquake catalogs for a hundred thousand or a million years. It’s like throwing a grain of sand in a set of cogs to see what happens,” explained Christine Goulet, a team member and executive science director for special projects with SCEC.

The end result is a more detailed picture of the possible hazard, which forecasts a sequence of earthquakes of various magnitudes expected to occur on the San Andreas Fault over a given time range.

The group tried to calibrate RSQSim’s numerous parameters to replicate the model designed by the SCEC and the U.S. Geological Survey. But the group eventually decided to run the code with its default parameters. While the initial intent was to evaluate the magnitude of differences between the models, they discovered, instead, that both models agreed closely on their forecasts of future seismologic activity.

“So it was an aha moment. Eureka,” recalled Goulet. “The results were a surprise because the group had thought carefully about optimizing the parameters. The decision not to change them from their default values made for very nice results.”

The researchers noted that the mutual validation of the two approaches could prove extremely productive in further assessing seismic hazard estimates and their uncertainties.




Information derived from the simulations will help the team compute the strong ground motions generated by faulting that occurs at the surface — the characteristic shaking that is synonymous with earthquakes. To do this, the team couples the earthquake rupture forecasts, the SCEC-U.S. Geological Survey code and RSQSim, with different models that represent the way waves propagate through the system. These models involve standard equations, called ground motion prediction equations, used by engineers to calculate the shaking levels from earthquakes of different sizes and locations.

“These experiments show that the physics-based model RSQSim can replicate the seismic hazard estimates derived from the empirical model, but with far fewer statistical assumptions,” noted Jordan. “The agreement gives us more confidence that the seismic hazard models for California are consistent with what we know about earthquake physics. We can now begin to use these physics to improve the hazard models."

This project was awarded computing time and resources at the ALCF through DOE's INCITE program. The team's research is also supported by the National Science Foundation, the U.S. Geological Survey and the W.M. Keck Foundation.

## DEVELOPMENTS IN NUCLEAR POWER

## 核能發電的近期發展

By Tomoko Murakami

On April 2, the Turkish Atomic Energy Authority issued a construction license for the country's first nuclear power station, Akkuyu Unit 1 (Rosatom VVER, 1200 MW), and construction fully started the following day, April 3. Turkish Prime Minister Recep Tayyip Erdogan and Russian President Vladimir Putin both participated in the groundbreaking ceremony via video conference, emphasizing that the groundbreaking is a historic moment for the development of the Turkish economy and bilateral energy cooperation. The plant is scheduled to start operation in 2023, and the process should help inform Turkey's other new-build project, the Sinop project, in which Japanese corporations are participating.

The environment remains severe for the nuclear business in the US. On March 28, FirstEnergy Solutions (FES), the generation and retail subsidiary of FirstEnergy which is based in the Midwest including Ohio, announced plans to close its four nuclear power plants at three power stations, namely Davis Besse, Perry, and Beaver Balley Units 1 and 2, all by 2021. The company gave the reason for closing as "the inability to obtain sufficient results in capacity auctions in the liberalized market run by independent grid operator PJM, low wholesale electricity prices, and lack of growth in electricity demand in the future." FES also said that it would seek legal remedies for the four plants until their planned closure date, and indeed, petitioned US Energy Secretary Rick Perry on March 29, the following day, to take appropriate measures under the Federal Power Act to enable PJM to keep these power plants operating in the long term considering their contribution to the security of the energy market. After taking these measures, FES filed for Chapter 11 bankruptcy on March 31. The four plants might remain open if FES were to recover in the future, but this would require a major improvement in market conditions, which FES cited as the reason for closure.

Meanwhile, on April 12, New Jersey passed a bill which includes "Zero Emission Credit (ZEC)," a financial assistance program for nuclear power plants in the state. To be eligible for ZEC, each of the state's four operating power plants including Salem Units 1 and 2 needs to pay a registration fee of up to $250,000 and disclose their financial information to prove that they are not receiving assistance under any federal system or any other state. Operators must note that financial support comes with "conditions" such as these, and even if they do receive assistance, they cannot survive in a competitive environment if they are not cost competitive.

In Japan, a steam leak from a deaerator air extraction pipe occurred in Kyushu Electric's Genkai Unit 3 which resumed power generation on March

25. After replacing the pipe and conducting safety checks, the plant started load-following operation on April 18. Similarly, operators aiming to resume power generation after a long outage should learn from this event and respond calmly to any sort of trouble.

## UPDATE ON POLICIES RELATED TO CLIMATE CHANGE

## 氣候變遷議題近期發展

By Takahiko Tagami

The Marine Environment Protection Committee (MEPC) of the International Maritime Organization (IMO) convened in London from April 9 to 13 to adopt the Initial IMO Strategy on Reduction of GHG Emissions from Ships. In 2015, international shipping accounted for 2.3% of global energy-related CO2 emissions, and, according to an IMO estimate, emissions will increase by 50-250% by 2050. The six flag states of Panama, China, Liberia, the Marshall Islands, Singapore and Malta account for more than half of the CO2 emissions from international shipping. Meanwhile, regarding international aviation, the International Civil Aviation Organization (ICAO) had agreed in October 2016 to a global market-based measure scheme.

The Initial Strategy sets out a vision for aiming phase out GHG emissions from international shipping as soon as possible in this century. Levels of ambition directing the Initial Strategy are as follows: (1) to reduce the carbon intensity of ship through the implementation of further phases of the energy efficiency design index (EEDI) (fuel consumption standard) for new ships, (2) to reduce carbon intensity of international shipping by at least 40% by 2030, pursuing efforts towards 70% by 2050, compared to 2008, (3) to peak GHG emissions from international shipping as soon as possible and to reduce the total annual GHG emissions by at least 50% by 2050 compared to 2008 whilst pursuing efforts towards phasing them out as called for in the Vision as a point on a pathway of CO2 emissions reduction consistent with the Paris Agreement temperature goals. Further, regardless of the IMO's principle of non-discrimination of flag state, the Initial Strategy included the principle of common but differentiated responsibilities in consideration of the impacts of means on developing States. MEPC will continue to develop a programme of follow-up actions to the Initial Strategy.

Pacific island states including the Marshall Islands demanded a complete decarbonization of international shipping by 2035. The EU similarly supported reducing emissions by 70-100% by 2050 from 2008 levels (though Malta, etc. opposed), while the European Parliament approved the proposal to include international shipping in the EU ETS (European Union Emission Trading System) if IMO does not approve an ambitious emissions reduction target. Meanwhile, Brazil, India, Saudi Arabia and others opposed any absolute emissions cap, projecting an increase in maritime trade. Japan as chair proposed a compromise resolution of a

50% reduction by 2050 from 2008 levels, which was approved.

IMO implemented the EEDI in 2013 for both new and existing ships to make new ships 30% more energy-efficient by 2025 than those built in 2014. Further, it has made it mandatory for ships to install a system for collecting data on fuel oil consumption (Mandatory data collection system), which will start collecting data from 2019.

Ahead of the implementation of the 0.5% limit on sulfur in fuel oil in 2020, this MEPC meeting approved draft amendments to the International Convention for the Prevention of Pollution from Ships (MARPOL) to prohibit the carriage of non-compliant fuel oil on board a ship and agreed to develop a ban on heavy fuel oil for use and carriage as fuel by ship in the Arctic waters.

## A SOAP-LIKE SYNTHETIC AIMS TO RESTORE BREATH TO INJURED LUNGS

### 介面活性劑合成物，為受傷的肺留一口氣

By Bruce Goldman · May 02, 2018

Stanford University researcher has bioengineered an effective protein mimic that restored breathing capacity to the injured lungs of rats, according to a new study.

This synthetic product could lead to better, cheaper treatments for acute lung injury in humans. When used in the rats, it equaled or outperformed a costly natural counterpart in several physiological measures, the study said.

A paper describing the research will be published online May 1 in *Scientific Reports*.

Imagine the force you'd need to blow up a balloon whose surface area nearly matched that of a tennis court. To make things challenging, imagine further that the balloon is made of exquisitely delicate material. That balloon is your lungs, and every breath you take is a miracle. What makes it possible is a thin coating of a soap-like film, or surfactant, that lowers the tension of the lung's inner surface, radically reducing the amount of force required to inhale. Without this surfactant, you couldn't breathe.

"Lung surfactant is endowed with amazing biological properties," said Annelise Barron, associate professor of bioengineering. "The key to this is the presence, in the surfactant, of two special proteins whose structures uniquely enable them to cut surface tension." But those same amazing structural properties, she said, also make these proteins difficult to synthesize

and purify, and relatively unstable in solution, limiting shelf-life and increasing price.

“One of them contains the most hydrophobic, or fat-resembling, stretch of chemical constituents of all known human proteins,” Barron said. “It’s really hard to work with because that fatty stretch makes it tend to clump up, ruining its activity.”

With the new study, Barron, who’s been working on stable, synthetic substitutes for these special proteins for two decades, appears to be nearing success. She shares senior authorship of the study with Ruud Veldhuizen, associate professor of medicine and of physiology and oncology at the University of Western Ontario, whose team performed the animal experiments. The study’s lead author is Ann Czyzewski, Barron’s former graduate student at Northwestern University, where Barron worked before coming to Stanford.

**The first big challenge**

Breathing is the first big challenge a newborn faces. Each year in the United States, some 20,000 to 30,000 infants born too early to produce their own natural surfactant are treated with an animal-derived variety, which is expensive. It’s only in richer countries that this life-saving therapy occurs: The cost of a single vial containing enough animal-derived natural surfactant to coat the tiny lungs of a newborn infant is prohibitive in developing countries.

An adult’s lungs are more than 20 times bigger than a baby’s — their surface area approaches that of a tennis court, Barron said — pricing natural surfactant out of reach for many life-threatening cases of acute lung injury, which affects 200,000 adults annually in the United States. Surfactant dysfunction can result from severe lung infections, including bacterial and viral pneumonia; lung-collapsing trauma from impacts, such as those that occur in a car accident; inhalation of water in near-drownings; or aspiration of foreign materials in a drug overdose.

Ironically, attempts to keep patients breathing via mechanical ventilators often cause a surfactant-depleting lung infection, Barron said. “People who wind up on ventilation in intensive-care units are intubated. A breathing tube is inserted into their nose and threaded down to their lungs,” she said. “If that intubation lasts for more than three days, their chance of acquiring a lung infection rises to 100 percent.” Even four hours spent on a ventilator spells a 1-in-6 chance of lung infection.

Until recently, the only way to obtain functional surfactant was to rinse it from the lungs of cattle, or chemically extract it from the lungs of pigs farmed for that purpose. “You get only a tiny amount per animal,” Barron said. “And whatever you’ve collected, you have to purify very carefully, as the material is so fragile you can’t treat it with high heat to kill microbial pathogens.”

In recent years, a somewhat cheaper substitute has become available. It contains a water-based dispersion of fatty lipids along with short protein snippets that, to an extent, mimic the surface-tension-reducing capabilities of their natural counterparts, the surfactant proteins.

While much better than nothing, this mixture is not quite as effective as animal-derived surfactant.

**Synthetic mimics of two proteins**

Barron's designer polymers, called peptoids, have specific sequences and helical structures that mimic key bioactive portions of the two important proteins, surfactant proteins B and C, found in the lungs. The mimics, which she calls pB and pC, resemble the proteins. But their component building blocks differ subtly from those of proteins in a way that makes them extremely resistant to breakdown by heat or naturally occurring bodily enzymes called proteases. In addition, they are much less inclined to aggregate into clumps and lose their bioactivity than their natural counterparts. They can be synthesized at one-quarter to one-third of the cost of obtaining the surfactant from animals or of the available synthetic version.

Most important, the rodent study indicated that a surfactant containing pC was superior to the animal-derived surfactant in oxygenating blood, which is the lungs' main purpose.

The trial pitted the two designer substances against the animal extract and against a control solution. The researchers administered different surfactant candidates to anesthetized rats whose lungs had been rinsed to rid them of their own natural surfactant, and then assessed several physiological outcomes at various time points. The solution containing pC was equal to or better than the animal surfactant in every outcome — a "shocking result," according to Barron.

Annelise Barron, associate professor of bioengineering.

"This opens up new frontiers," Barron said. "Our relatively simple synthetic mimic of a very complex material will have a much longer shelf life and can be made in large amounts at reasonable prices. Reasonable enough, we hope, that it may for the first time be possible to conduct a clinical trial in adults in intensive care units who've been intubated and who might benefit substantially from surfactant replacement. And it would, finally, also be available to premature babies in developing countries like Bolivia, where my father was born."

Further preclinical and clinical trials lie ahead before that day comes, she added.

Other Stanford co-authors are former postdoctoral scholar Michelle Dohm, former graduate student Maruti Didwania, research engineer Jennifer Lin and research technician Lauren Broering. Researchers at the University of Western Ontario and Northwestern University also contributed to the study.

The study was funded by the National Institutes of Health, the National Science Foundation, and the deans of both the School of Medicine and the School of Engineering, and was also supported by the Molecular Foundry at Lawrence Berkeley National Labs. Stanford's Department of Bioengineering, which is jointly operated by the schools of Medicine and of Engineering, also supported the work.

# OLD BACTERIA, NEW TRICKS: THE FUTURE OF WATER PURIFICATION

## 老菌新把戲：純化水的未來

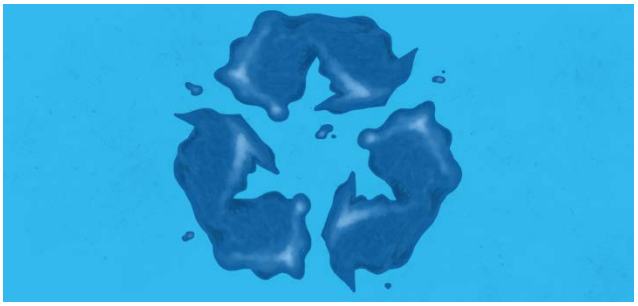
By Tom Abate and Andrew Myers · May 15, 2018

Billions of years ago, when Earth's atmosphere reeked of unbreathable gases, microbes evolved in the absence of oxygen.

As Earth matured and the nitrogen-oxygen atmosphere formed, these anaerobic, or oxygen-averse, bacteria retreated into the mud of the ocean floor and other environments where they would be safe from oxygen-rich air.

Now Stanford environmental engineers Craig Criddle and Bill Mitch are putting these ancient microorganisms to work in the largest demonstration of a more cost-effective wastewater treatment process, supported by a $2 million grant from the California Energy Commission (CEC). Smaller plants based on anaerobic bacteria are currently treating wastewater in South Korea and on the Stanford campus.

Working closely with environmental engineers from Silicon Valley Clean Water (SVCW), a water treatment utility, the Stanford team will help build and operate a small anaerobic treatment plant in Redwood Shores, California, alongside the enormous conventional plant that purifies wastewater for a quarter million people and businesses from Redwood City to Menlo Park.



The group has broken ground on the demonstration plant, which is slated to come on line in fall 2018. It will eventually process 20,000 gallons of wastewater per day to provide validation and operating experience for what could become a full-scale plant capable of processing millions of gallons of wastewater per day.

"Anaerobic processing can reduce energy use and decrease costs, and make wastewater treatment more sustainable," said Criddle, a professor of civil and environmental engineering.

In addition to cost-effectiveness, the researchers believe anaerobic processing could prove better at filtering household and industrial chemicals out of the waste stream, so that the treated water can drip back underground to replenish aquifers or even, one day, yield water pure enough to irrigate the garden or even quench one's thirst.

"Anaerobic treatment is a fundamental shift in water recycling technology," said Mitch, also a professor of civil and environmental engineering.

**Aerobic vs. anaerobic**

For over a century, wastewater treatment has relied on aerobic bacteria that require oxygen to survive. Wastewater treatment plants provide that oxygen with huge and costly electrically powered blowers.

"The time has come for a technology change," said Eric Hansen, the Stanford-trained civil engineer spearheading Silicon Valley Clean Water's involvement in the project. "Taking those blowers out of the process helps to reduce the cost of water recovery and makes municipal treatment operations more sustainable."

Reducing cost is just one advantage of wastewater treatment based on anaerobic bacteria, according to Sebastien Tilmans, the civil engineer who runs the Codiga Resource Recovery Center on the Stanford campus. At Codiga, which has a smaller version of the technology, the oxygen-averse bacteria clean wastewater and belch out methane. Commonly known as natural gas, this output can be burned as fuel or used as a chemical feedstock to make biodegradable plastics. That, Tillman said, exemplifies a change in thinking.

“The concept of waste doesn’t exist in nature,” he said. “Every byproduct of some natural process is an input for another. All the things we flush down the toilet or into sewers — water, energy, fertilizer — can be recovered as valuable byproducts of the anaerobic process.”

**Welcome to the methane world**

Anaerobic water treatment technology was pioneered decades ago by Stanford environmental engineer Perry McCarty, now a professor emeritus. But back in the 1950s, when he first began working with these oxygen-averse, methane-making bacteria, energy seemed cheap and inexhaustible. There was no compelling reason to test an energy-saving alternative.

Over the ensuing decades, as costs for energy and biosolids disposal rose, anaerobic processing gradually became more appealing. In 2008, McCarty helped build a unique anaerobic treatment system in the South Korean city of Bucheon that proved highly effective for wastewater treatment. In 2016, Stanford researchers built a slightly larger system at the Codiga facility, which became the first such plant in the Western Hemisphere. The new demo plant at Redwood City will be the largest, and only the third anaerobic treatment plant of this type in the world.

**Downstream benefits**

Once in the plant, wastewater passes through a silo of anaerobic bacteria that slowly digest the waste. Water then squeezes through an ultrafiltration membrane to eliminate bacteria and is then clean enough for landscape irrigation and some industrial applications. With the help of advanced treatment systems donated by the Santa Clara Valley Water District and others, the group will also examine the water’s suitability for further treatment prior to reuse as drinking water.

In addition to its energy efficiency, an anaerobic treatment system needs less space than traditional wastewater treatment plants, which require huge tanks and more complex filtration systems. An industrial-scale anaerobic plant might be as much as 40 percent smaller than a conventional plant and produce at least 30 percent less solid waste, a byproduct that currently must be further treated and trucked away, generating additional costs and greenhouse gases.

The researchers estimate that a full scale anaerobic plant capable of operating at 15 million gallons per day might save as much as $3,000 per day in energy demand — $1 million per year — over a comparable aerobic plant. Factoring in other savings from the more efficient process, the researchers estimate a potential savings of over $2 million per year.

**Looking to the future**

In addition to saving space and money, the Stanford researchers said that their anaerobic process has yet another benefit: the ability to digest pharmaceutical drugs and powerful household and industrial herbicides that have proven difficult for standard aerobic bacteria to digest.

That’s why McCarty thinks the future belongs to hardy anaerobes.

**“They’ve adapted to the harshest environments on Earth,” he said. “They can eat most anything.”**

The demonstration project at Redwood Shores is currently slated to operate until March 2021. Whether the project continues and scales up will depend in part on how well those methane-belching microbes live up to McCarty’s expectations.

“We believe that this prototype system could benefit electricity rate-payers by offering a sustainable approach to wastewater treatment given a successful demonstration,” said David Weightman of the California Energy Commission, which funded this project.

Meanwhile, the researchers take the long view.

“We’re proposing changing a technology that hasn’t changed in over a hundred years,” Hansen said.