Caltech science exchange

Sustainability SOLUTIONS

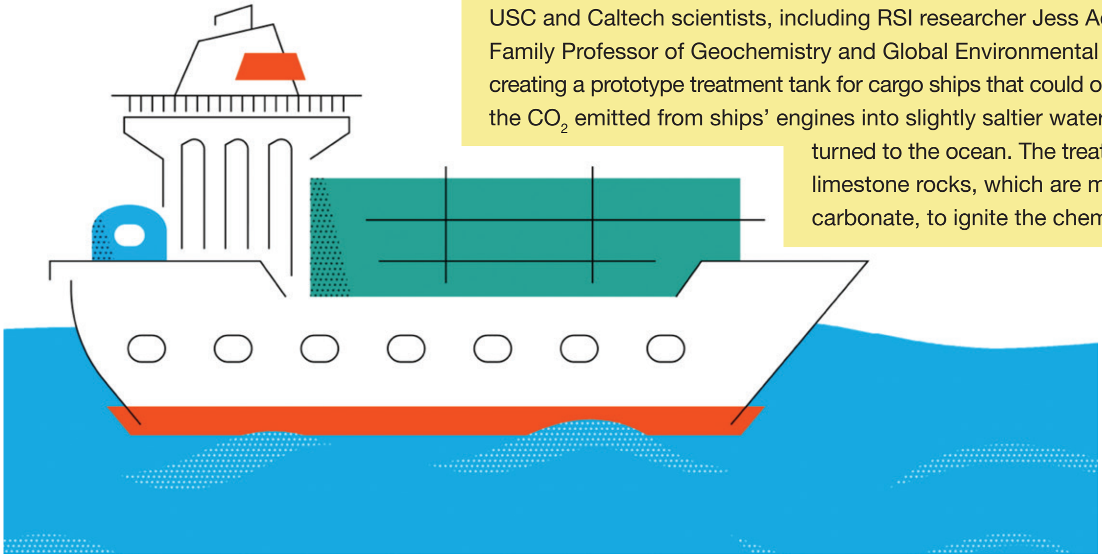
Caltech researchers and engineers on campus and at JPL are pursuing many novel approaches to mitigate the effects of a warming planet. They are using advanced computation to improve the precision of climate models; harnessing solar, wind, and other renewable energy sources; engineering new methods to reduce greenhouse gas emissions; and drawing on data from Earth-monitoring devices to inform more efficient use of resources.

Much of this vital research takes place under the auspices of the Resnick Sustainability Institute, which, in the fall of 2019, received a historic pledge of $750 million from philanthropists and entrepreneurs Stewart and Lynda Resnick. With the new resources and tools afforded by this pledge, Caltech's sustainability researchers have the freedom to explore bold solutions to society's vexing challenges in energy, climate, water, and the broader environment.

Here, as featured in the Caltech Science Exchange **(scienceexchange.caltech.edu)**, a web resource dedicated to explaining scientific issues, RSI-affiliated Caltech researchers share their perspectives on some questions that are central to addressing one of the most significant issues of our times.

How can we remove CO_2?

USC and Caltech scientists, including RSI researcher Jess Adkins, Smits Family Professor of Geochemistry and Global Environmental Science, are creating a prototype treatment tank for cargo ships that could one day transform the CO_2 emitted from ships' engines into slightly saltier water that can be returned to the ocean. The treatment tank uses limestone rocks, which are made of calcium carbonate, to ignite the chemical reaction.



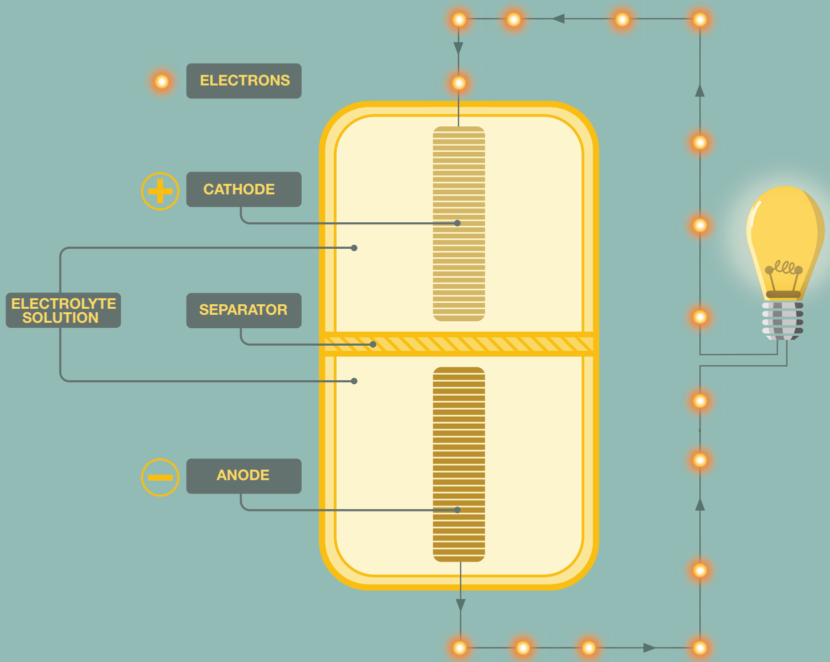
How batteries work

Batteries store chemical energy and convert it to electrical energy, which can be thought of as the flow of electrons from one place to another. Components called electrodes help to create this flow. Electrons move from one electrode, called the anode, to another electrode, called the cathode. The electrodes are separated by an electrolyte, which can be a solution or a solid. How efficiently a battery works depends on which materials are used as electrodes and electrolytes. Lithium-ion batteries, commonly found in portable electronics and electric vehicles, typically use a metal oxide as the cathode and graphite as the anode.

How can we develop sustainable alternatives to lithium-ion batteries?

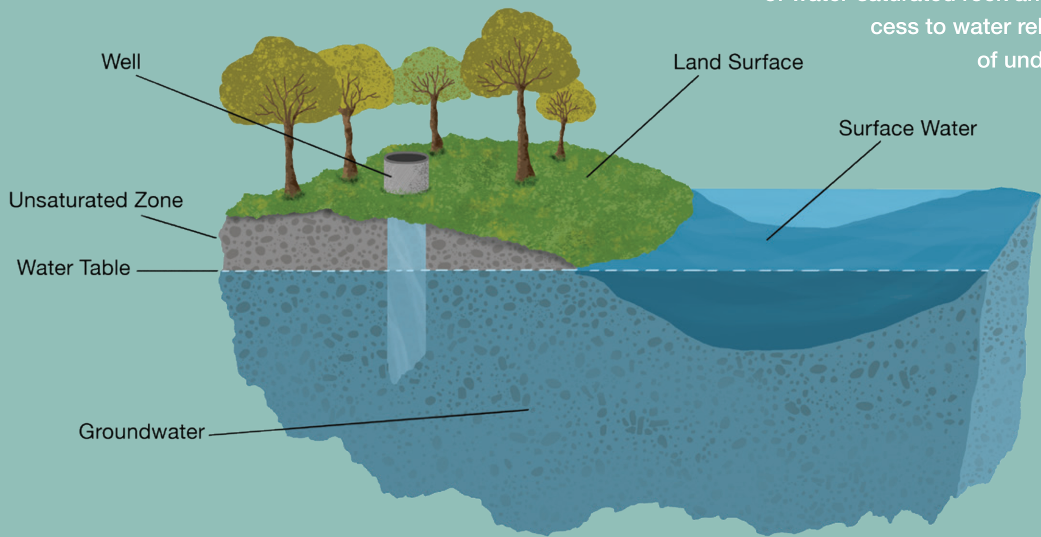
"To move toward renewable energy, we need battery storage. The lithium-ion batteries we use today are expensive and extracting the raw materials is harmful to the environment. In my research, we make new materials and we try to understand their ability to store electrons. These new materials are usually sourced from resources that are abundant in the earth's crust, like magnesium, iron, and sulfur. … One of the Holy Grails of chemistry in my lab is to target magnesium-sulfur batteries. It's a magnesium anode and a sulfur cathode. Both of those materials are very inexpensive. Magnesium is found all over the world. Sulfur is a by-product of petroleum refining."

—**Kimberly See,** *Assistant Professor of Chemistry*



Where does our water supply come from?

Communities get the water they need from two major sources: surface water and groundwater. Surface water collects on the ground or in streams, rivers, lakes, reservoirs, or oceans. Groundwater collects in aquifers, underground layers of water-saturated rock and sediment. Solutions for protecting access to water rely on precise measurement and monitoring of underground aquifers.



RSI researcher and JPL chief scientist Mark Simons, John W. and Herberta M. Miles Professor of Geophysics, is applying satellite radar technology to track changes in the terrain of Southern California as a result of water flow in and out of aquifers, helping to inform water management districts about the impact of the region's water use on those aquifers.

How can we make chemical manufacturing more sustainable?

"To make a difference in global sustainability via chemical manufacturing, we want to prioritize. Which chemicals offer the best opportunities? That depends on the scale at which they are produced and how much associated CO_2 and other pollutants that production puts in the air. The production of ammonia and ethylene has a significant impact on global CO_2 emissions.

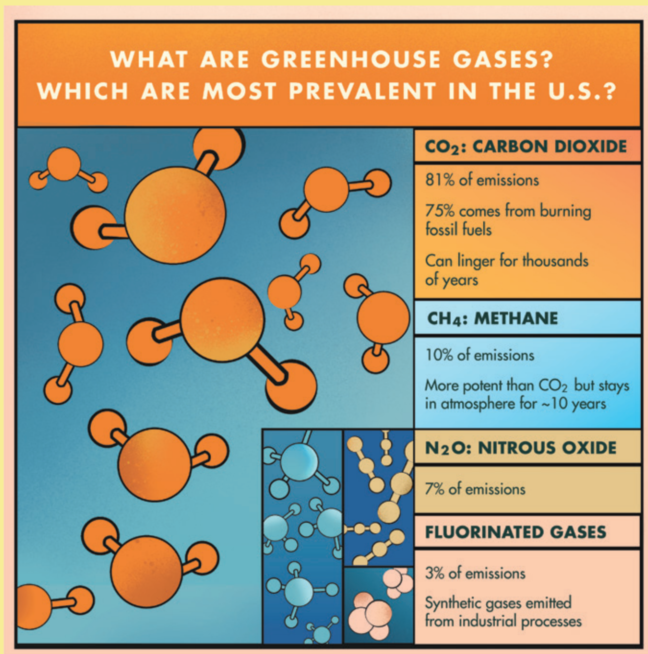
"… In my lab, we think about new ways to make ammonia and ethylene, and other challenges in chemical synthesis that can advance how we make more complicated molecules, such as drug molecules used in medicines. Along with our collaborators, we aim to develop catalysts that can, ultimately, enable carbon-neutral production of ammonia and ethylene using renewably sourced electricity, water, nitrogen gas from the air, or industrial CO_2 waste streams.

"… My lab is working on a new, different way of producing ammonia, through electrochemical conversion of nitrogen, the main component of air. After years of fundamental research, we now have exciting science that demonstrates how to achieve electrochemical ammonia generation with molecular catalysts. We, along with others in the field, are also excited by the promise of potentially more durable heterogeneous catalysts."

—Jonas Peters

Bren Professor of Chemistry and director of the Resnick Sustainability Institute

What are greenhouse gases and where do they come from?



What is the future of wind energy technology?

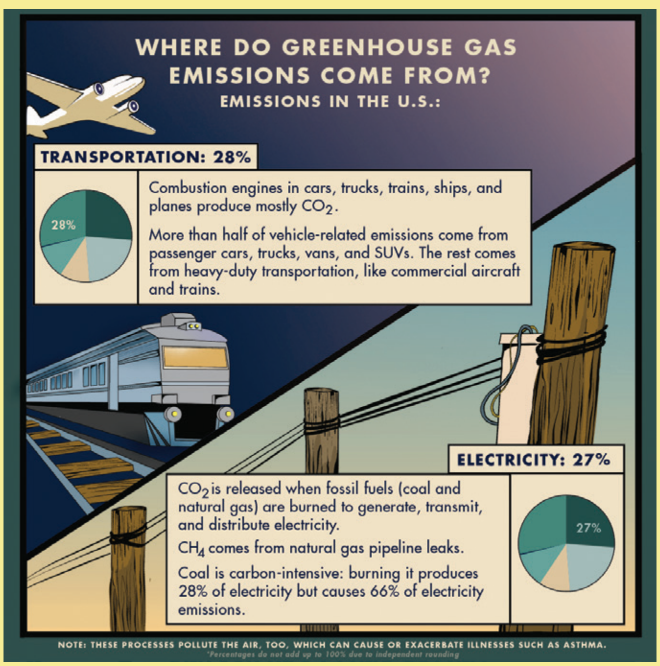
"One of the technologies we're interested in developing are these smaller, distributed wind energy systems that can be equally applied in Pasadena as they can be in rural China. The benefit of these smaller systems is that the local community can take a part in building them, in installing them, maintaining them, and ultimately in consuming the electricity that's generated by them. And they can do it without grid infrastructure.

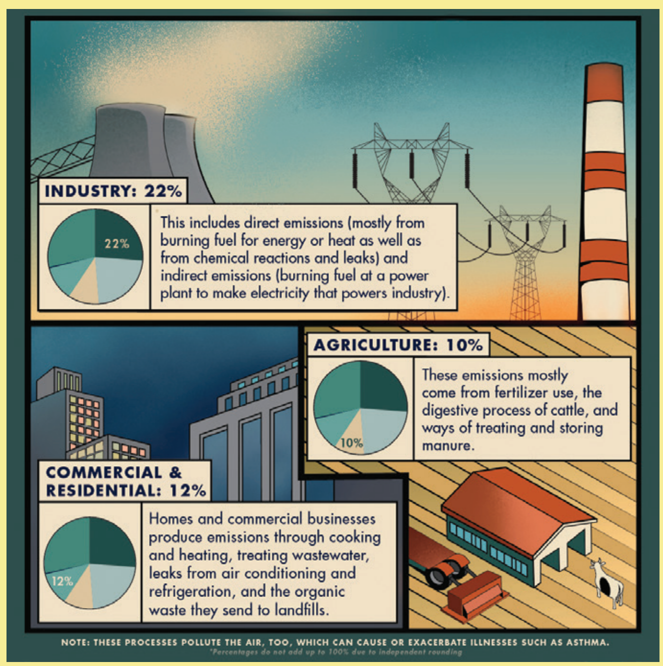
"In our lab, for example, we've developed systems that are called vertical-axis wind turbines. Instead of the blades rotating on a horizontal axis parallel to the ground, they rotate around an axis that points straight up out of the ground. … And those vertical-axis turbines, we've found, can make better use of the wind as a group than the individual horizontal-axis wind turbines that we're more commonly using today.

"An exciting place where we're able to demonstrate the vertical-axis wind turbines is a fishing village in Alaska. It's a community of only about 70 people, and they currently rely on diesel fuel being flown into the village because of its remote location. That is a high cost for them, so they pay much more for their energy than we do in the lower 48. And, of course, the fuel itself is quite polluting. At the same time, the village has a wonderful wind resource.

"The challenge of reliability is really important when you're so remote. These systems have to work. And if you're in a village like this, in the middle of winter, you don't want your power going out. So it's really important that these systems can perform well. And we're almost there."

— **John Dabiri** (MS '03, PhD '05)
Centennial Professor of Aeronautics and Mechanical Engineering





Learn more about sustainability at **scienceexchange.caltech.edu**