Sossina Haile, Professor of Materials Science and Chemical Engineering, researches ionic conduction in solids, with the twin objectives of understanding the mechanisms that govern ion transport and applying such an understanding to the development of advanced materials for energy technologies. In this article, she discusses her research in the area of solar fuels and her recent work in Africa.

Creating an Energy Roadmap to Maximize Societal Benefit

Energy—it is at the tip of the tongue of almost every politician today, the subject of many a heated dinnertime conversation, and the overriding technological challenge of our era. What should we do to solve the problem? How do we even define the problem? These are questions that scientists and engineers must address with full force if our society is to emerge from its current uncertainty into a sustainable energy future. We must help create the energy roadmap to maximize societal benefit.

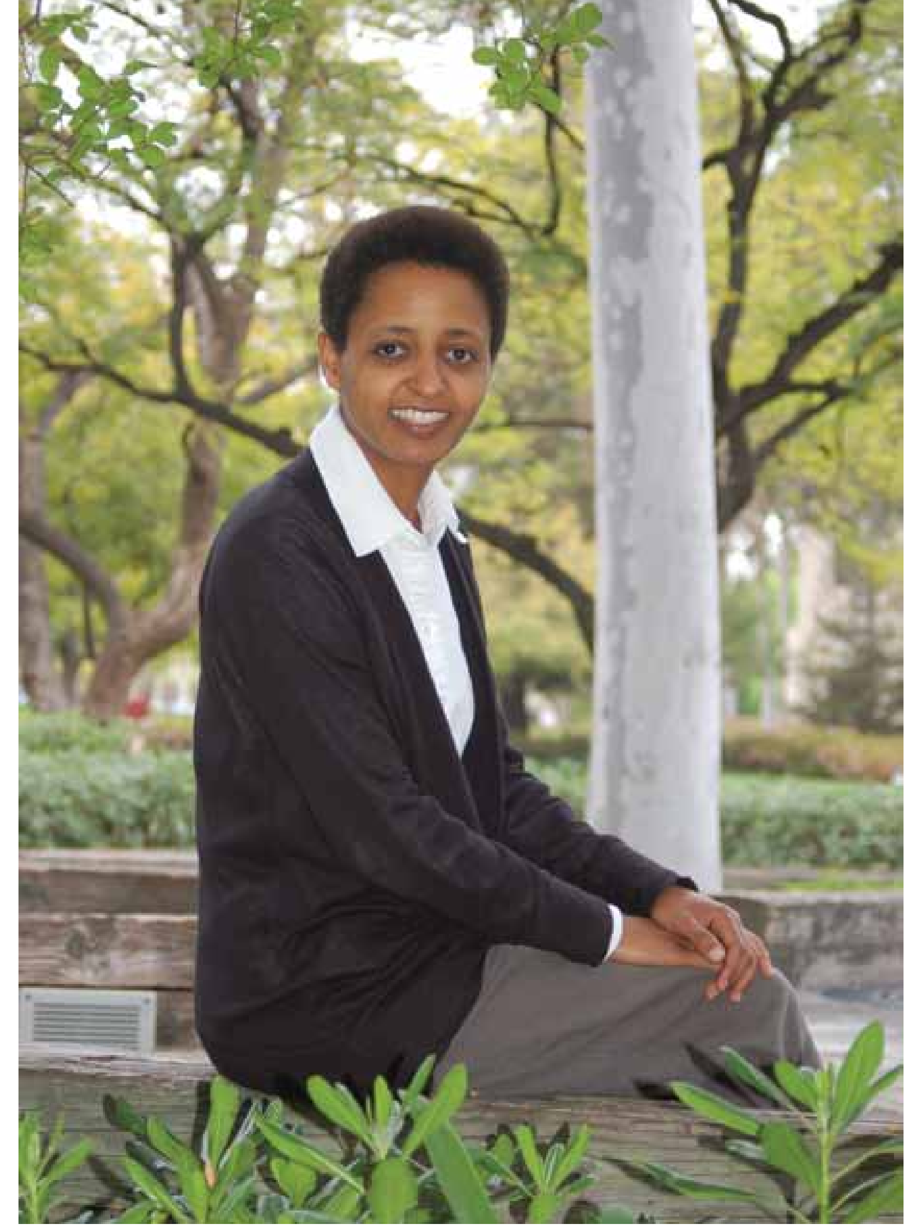
Let's accept that our energy problems encompass all aspects of finite supply, geopolitical instability, and environmental damage. The next questions concern the solution: Which energy resource and strategy makes the most sense? Is this a question even worth asking? Should all options remain on the table, or should we start to pare things down? In my view, we have to provide a balanced response. Of course, every energy solution involves trade-off, but we have to make the effort to sort out which are possible big players with potential impact on a large scale and in a time frame that matters. We have limited financial and human resources. We have to be strategic in how we deploy these resources. If we do make the effort, we can eliminate some ideas from the start, or at least put them on the back burner. Some approaches are unlikely to pan out for reasons such as very high cost or reliance on rare materials.

On the other hand, we cannot focus all the way down to one single solution. We are simply not so prescient to be able to say with full certainty what will work and what won't. Even if we were, Earth is not a "one-size-fits-all" kind of place. Different parts of the world have different energy resource bases. It goes without saying that some places are sunny, others are windy, and others still are bombarded with tidal waves or have vast, powerful rivers. We have to recognize that Earth is varied, and so our energy solutions will also have to be varied to maximize benefit.

solar fuels

That said, let's go back to the idea of picking likely winners. Among the energy resources available to the planet, hands down, the solar resource base is largest. It is an oft-repeated statistic that the amount of sunlight that hits Earth in one hour is more than all the energy we consume in a year. Therefore, it makes a whole lot of sense to increase the amount of solar energy we use. It won't run out, it is domestically available, and, for the most part, it is environmentally sound. But everyone knows that the sun doesn't shine all the time. So how do we make this resource available whenever it is needed? How do we store the solar energy for immediate, on-demand use? The scientific community has created an answer—"solar fuels." This is an entirely new strategy for solar energy storage that was born in just the past decade.[1] What this appealing phrase means is to use solar energy to convert carbon dioxide and water, which don't inherently have any energy content, into chemical fuels such hydrogen, methane, synthesis gas (a mixture of hydrogen and carbon monoxide), or whatever compound you prefer, that do have energy content. Essentially, the solar energy is used to "undo" the effects of combustion. Fuel is a fantastic way to store solar energy because we already have an infrastructure that makes use of it, it has an infinite shelf-life (it doesn't self-discharge like batteries), and the amount of energy stored per unit volume or per unit mass is extremely high (several times higher than batteries). So converting solar energy into liquid fuels has become a major topic of research.

[1] In the period from 2000 to 2010, the number of annual scientific publications with the phrase "solar fuel" in the abstract skyrocketed from 430 to almost 8,000.



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There are many ways to go about making solar fuels. Our approach involves concentrating the sunlight to create high-temperature heat that can drive the chemical reactions. The big advantage here is that we are able to use the entire solar spectrum—that is, all the wavelengths of sunlight. Most other approaches use some but not all of the wavelengths, which means some of the light gets thrown away. Another major advantage is that our process works extremely well for making carbon-containing fuels, whereas many others are very much focused on producing hydrogen. Hydrogen will be terrific if and when we have a hydrogen delivery infrastructure. In the meantime, converting solar energy into liquid fuels makes a lot of sense. Of course, there is no silver bullet. Our process requires extremely high temperatures, up to a whopping 1600 degrees Celsius. It can be done, but the engineering required is quite impressive. To get to these temperatures, we work with colleagues who know how to design and construct parabolic mirrors that can concentrate sunlight one thousand times—meaning the sunlight is focused down to an area one thousand times smaller than the original area of solar exposure. At the same time, we are modifying our reaction scheme so that it can work at lower temperatures. Even without improvements, we probably hold the world's record for solar fuel production.

Recently, I've come across a wonderful opportunity to become more directly involved in the societal impacts of technological advances. I have started work with the National Science Foundation (NSF) to advance educational opportunities and technology transfer with Africa, beginning in East Africa. The NSF invited two colleagues and me to establish a materials institute that would initially be a virtual institute. There, we will bring together young American and African scientists—at the graduate student and postdoctoral scholar level—for an extended workshop to provide educational opportunities and to uncover potential areas for collaboration. Our plan is to offer the content in the area of materials for energy in a two-week, short-course format in a relatively intimate setting of 60 students. The NSF has agreed to support a one-year pilot, which is tentatively scheduled for mid-June and will be held in Ethiopia. The topical area is, I believe, timely. The sustainable energy resource base in Africa is enormous, including solar, hydro, and geothermal, yet less than 20 percent of the population has access to electricity. In many cases, making use of these resources requires advanced materials, and our short course will address precisely the development of such materials. My work in Africa is only beginning, but I am hopeful its impact will be far-reaching. ENG

Sossina Haile is Professor of Materials Science and Chemical Engineering.

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