is doing too little? The whole family is responsible for the outcome of the referendum, not just me."

Helena sighed. "In an ideal world, you'd be right. The public would look at all thirty-odd members of the royal family, weigh up their individual contributions, and cast their vote accordingly. But you know very well that's not how it works. People are driven by headlines, and you're creating the headlines."

"Then we need to make new headlines," said Rose. "Or at least make the old ones fade away. And we can do that, if we all pitch in. Why is it headline news that I visited an art gallery with an alien? Because it's unusual. But if we all start reaching out—if more of us make an effort to meet the Felorians and include them in society—then it won't be unusual any more. It won't be news. Problem solved!"

"It's a major news item because it happened straight after your break-up with Gerrard," Helena said tartly. "You'll still have to face those insinuations . . . unless you get another boyfriend. Do you want me to set you up with someone?"

Rose laughed. "That's very kind of you. But you know what the media are like. Even if I had a boyfriend, they'd still claim I was flirting with Dorvin. They love the freakshow angle. The only way to deal with that is to make the Felorians look less like freaks, and more like regular folk. Then the media will get bored of sensationalizing them. And the more people see of the Felorians, the more they'll realize that the scare stories are ludicrous."

"That sounds optimistic," said Helena. "I wish I had your faith in human nature."

"Maybe it won't work. But we have to try."

"We?" Helena raised her eyebrows.

"Yes. I've got an idea. Let's take the focus away from individuals, and have a group event. How about a charity football match? Humans against aliens! We'll auction off places in the team, and sell tickets to the match, and sell the TV rights: plenty of money for good causes. Afterward, we'll have the usual dinner and drinks and whatnot. There'll be at least eleven Felorians, so lots more potential for interaction—different stories, new headlines. They'll start to look normal. And they can talk about their own sports, maybe show us some footage, and challenge us to try one of their games. . . . What do you think?"

Science Fact

Energy for the Future: Solar-Derived Fuels, Artificial Leaves, and Electricity-Eating Microbes that Poop Out Gasoline

Richard A. Lovett

People old enough to remember the Arab Oil Embargo of 1973 will recall it as America's first nationwide energy crisis. Not that it had anything to do with environmental issues or depleted oil reserves; the triggering events were political, stemming from America's relationship with Israel during the 1973 Yom Kippur War, but it was an event that sent shockwaves through America's commuter culture. In a single year, gasoline prices jumped by more than 40% and even then, there were enormous gas

Thermo-what? Novel Technologies that Might Replace Solar Panels

Solar panels and CSP generators aren't the only ways to harness sunlight for electricity. Here are three others:

• *Thermoelectrics*. Nearly 200 years ago, German physicist Thomas Johann Seebeck discovered that when different metals are joined in the right manner, with one metal hot while the other is cold, an electrical current will flow between them. It's a principle that has long been used to make temperature sensors called thermocouples, but it was never seriously considered as a source of power because it's relatively inefficient. Still, thermoelectric generators could power tomorrow's mobile phones, watches, laptop computers, and medical sensors (in some cases possibly even working from the owner's body heat). They might even increase automobile efficiency by converting waste heat into electricity. And who knows what could happen if thermoelectrics is merged with solar power. "It's a well-known effect but hasn't really been used in the solar world, yet," says Stein.

• *Thermionics*. Discovered by Thomas Edison in 1883, this is the "boiling away" of electrons from a hot cathode. It's the process that allows current to flow through vacuum tubes, making possible everything from pre-transistor radios to old-style tube televisions. Traditionally, thermionics uses electricity to heat the cathode—meaning that it's a net user of electricity, not a generator of it. But in principle, there's no reason the cathode couldn't be heated by focused solar power, converting it into a thermionic generator.

• *Artificial photosynthesis*. Sometimes referred to as the artificial leaf, this solar-panel-substitute uses sunlight to break water into hydrogen and oxygen. The oxygen is released to the environment, while the hydrogen is stored as fuel or used to power a fuel cell. The chemistry is complex, but more or less mimics natural photosynthesis, which also uses sunlight to split water into hydrogen and oxygen. "Whether you realize it or not, leaves are buzzing with electricity," says its leading proponent, Daniel Nocera, a chemist at Massachusetts Institute of Technology.

The process works well in tests. "We can put [an artificial leaf] in a bottle of water, hold it up to the sun, and see hydrogen and oxygen bubbles coming off," Nocera said at a 2011 meeting of the American Chemical Society. It also might be a way of making less expensive solar panels, because part of their cost is the wiring needed to collect the electricity. "This gets rid of all that," Nocera says.

ence between a CSP power plant and a coal-fired one is the source of heat. The holdup comes from the combination of construction costs and thermodynamics.

CSP's fuel, sunlight, is free. But the high-performance mirrors needed to concentrate it are expensive—pricey enough that to compete with fossil fuels, CSP plants have to be significantly more efficient.

That's where thermodynamics comes into play. A steam-driven turbine is a heat engine governed by a principle known as Carnot's theorem, which holds that the maximum possible efficiency of any heat engine is related to the difference between its operating temperature and the temperature of its ambient environment (its heat sink). In other words, hotter operating temperatures are better.

In theory, that's a simple fix: just focus the sunlight more intensely. But if you do this, things start burning up like Archimedes's invading warships—not literally, but chemically, as the heat takes a toll on turbine blades and pipes.

One solution is simply to wait for metallurgists to come up with alloys that can better withstand extreme conditions. A better solution is to find ways to design turbines that don't unnecessarily waste energy, allowing them to operate as close as possible to their theoretical maximums.

Traditional power plants employ steam turbines that use a two-cycle design to tap heat for electricity. In one cycle, they use heat to boil water, then use the pressure of the expanding steam to spin the turbine blades and generate electricity. In the second cycle, the steam is allowed to condense back into water, for reuse. And that's the problem, be-

unknown boson with a mass-energy of 125 GeV. After the study of decay modes, this particle was confirmed to be the long sought-after Higgs boson, the particle that Nobel Laureate Leon Lederman had dubbed "The God Particle." In one way, the Higgs discovery was a great triumph for high-energy particle physics, since the Higgs was the missing puzzle piece that gave mass to fundamental particles and had been predicted by the standard model of particle physics.

But in another way, it was more of a placeholder. Before the LHC, all major high-energy physics accelerators had regularly produced new physics, unexpected particles, and unanticipated surprises. But the LHC had thus far only delivered a discovery that had been long expected, the Higgs boson. Other searches for new physics at the LHC had, up to that point, failed: none of the many particles predicted by super-symmetry, no mini black holes, no evidence of extra dimensions, etc. The Higgs was *supposed* to be there, and sure enough, it was. But where were the surprises we had come to expect?

On February 14, 2013, the LHC shut down for two years of improvements. On June 3, 2015, running resumed again with the collision energy now boosted from 8 TeV to 13 TeV. After about six months of running at this new energy, on December 15, 2015, there was an announcement that both the CMS and ATLAS detectors had observed hints of a new particle with a mass-energy of 750 GeV (six times the Higgs mass). It decayed into two gamma rays, was not observed in several other decay channels, and might be a second Higgs boson.

By high-energy physics convention the true discovery of a new particle requires a statistical precision of at least 5 standard deviations (or 5 σ). The ATLAS observation was 3.6 σ and the CMS observation, based on fewer events because of detector startup problems, was 2.6 σ. Thus, their results are a suggestion, not a discovery. Nevertheless, there is only one chance in about 96 that the observation is a statistical fluke. The new particle is probably a second Higgs boson.

The significance of this observation is that the standard model does not predict that there should be a second Higgs, so this represents new physics beyond the standard model. There are already a flurry of new theoretical papers proposing extensions of the standard model that can accommodate the new 750 GeV Higgs boson. It has been theoretically connected to heavier unknown quarks and has been viewed as the harbinger of extra dimensions. It will take some time for the observation to be confirmed at the 5 σ level of statistics, for other decay modes to be fully explored, and for the theoretical dust to settle. We'll see in six months or so.

But there seems to be a good chance that the standard model has been broken and is in need of repair. One physicist, recalling Lederman's designation of the Higgs as the God Particle, speculated that particle physics may be entering the era of polytheism, with multiple Gods.

My AV column published in the May 2016 issue of *Analog* reported the discovery in data from NASA's Kepler exo-planet-finding satellite mission of unexpected intensity fluctuations in the starlight from KIC8462852, a yellow-white main sequence F3 V star of about 1.43 solar masses that is about 1,481 light years from the Earth. The star has been informally given the name "Tabby's Star" after astronomer Tabitha Boyajian of Yale University, the leader of the reporting group. Their investigation showed bizarre starlight intensity fluctuations including deep dips of 15% and 22% lasting about a day each at two separate times during the Kepler observation. The scenario that the Boyajian group favored for explaining the fluctuations was that the dips were a coincidence that happened to be produced by an infalling comet swarm. The hypothesis is that the comet swarm intercepted light flux from the star at just the time period when Kepler was making its observations. A distant-binary companion of Tabby's Star had been found, and it was suggested that orbit perturbations by this companion may have produced the swarm of comets. Such an occultation by comets, however, would probably be a rare and fairly brief event, and so the group urged additional observations.

Another group of astronomers led by Jason T. Wright of Pennsylvania State University suggested the alternative that the light flux variations might indicate the presence of a large Dyson-type swarm of orbital mega-structures around Tabby's Star, presumably placed there by a high-technological-level extraterrestrial civilization. Assuming that a swarm of eight or