**CAN WE POWER CIVILIZATION WITHOUT DESTROYING IT?**

AT PRINCETON’S ANDLINGER CENTER FOR ENERGY AND THE ENVIRONMENT, PROFESSOR EMILY CARTER LEADS A TEAM OF SCIENTISTS IN AN ARMS RACE AGAINST A DEADLY FOE: CLIMATE CHANGE.

**DICCON HYATT REPORTS, PAGE 29.**
When Princeton University received a $100 million donation to study energy and climate change in 2008, the search committee need not have looked far to find the perfect candidate to be the founding director of the new center.

In 2010 Princeton named professor Emily Carter, a prominent theorist in engineering and chemistry, to lead the newly founded Andlinger Center for Energy and the Environment. Carter had been with the university since 2004 working on engineering and applied computational mathematics. She had won grants to study surface materials, computational mathematics. She had written research papers on biofuel combustion and fusion reactor walls, solar energy conversion, and fuel cell materials.

In addition to doing this work of her own, Carter assembled an interdisciplinary team of faculty and administrators that today makes up the Andlinger Center. The center itself is based at the school’s engineering quadrangle while construction continues on a new building expected to be finished this summer.

Carter will speak about how this team of scientists and grad students plans to shape the future of sustainable energy at a presentation on Saturday, January 31, from 9:30 to 11 a.m. at the Princeton Plasma Physics Laboratory. The free talk is part of the lab’s Science on Saturday series lectures open to the public. For more information, visit www.pppl.gov.

The setting of the talk is fitting given Carter’s work in the field of nuclear fusion. The PPPL is one of the leading sites in the United States devoted to researching how to generate fusion energy.

“The 2007 Climate Change Report made it abundantly clear that our burning of fossil fuels is causing tremendous danger to the future survivability of the planet.”

Carter’s decision led her to pursue research in a wide variety of fields, but all towards the goal of improving sustainable energy. She wrote research papers on biofuel combustion and fusion reactor walls, solar energy conversion, and fuel cell materials.

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“I am a very big believer that if we properly invested in fusion, which we haven’t for decades, that it would be the ultimate solution to all of our electricity problems,” she says.

Fusion is the same nuclear process that powers the sun — the basic idea is to force molecules to fuse together, with heat being created in the process. In the sun, gravity and high temperatures force the molecules together. To achieve fusion here on earth, scientists have used magnetic fields to contain the hydrogen and deuterium (heavy hydrogen) atoms, and microwaves to heat them. The heat from plasma fusion could be used to create steam for a turbine, much like in existing nuclear power plants. Plasma physicists have been studying fusion power for more than 60 years, and while they have succeeded in creating fusion reactions, they have never been able to get more energy out of the reaction than they put in to create it.

Fusion power remains something of a holy grail for green energy in the eyes of many scientists, including Carter. Unlike existing nuclear power, fusion reactions don’t create any significant nuclear waste, and there is no danger of a fusion plant melting down like Chernobyl or Fukushima. The only downside is that they don’t yet exist. The world’s largest experimental reactor, the ITER, is currently being built in France by an international consortium of scientists. There is no counterpart to the ITER project in the United States. Carter would like to see the United States take more of a leading role in fusion power research because of its enormous potential benefits compared to other forms of sustainable energy. “With fusion, unlike solar and wind, you would have a continuous source of energy.”

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electricity,” she says. “There are still a lot of engineering problems to resolve in terms of how to make it happen, but the U.S. is being left behind. The investment in fusion technology research in the U.S. is just pathetic.” The U.S. spends about the same amount that South Korea does on fusion research. Selecting materials for the inside of a fusion reactor is one of many technical challenges for engineers because they have to meet a wide range of requirements. Fusion power is created by containing a field of plasma and heating it up with radio waves. The process has rapid heating and cooling and unleashes radiation, both of which rapidly corrode most materials. The ITER reactor will reach 2 million degrees Celsius.

But despite the many engineering problems that remain to be solved, Carter believes fusion is obviously a worthy investment to develop what could be a worldwide panacea for all energy problems, especially given the alternative uses that the government is currently putting tax dollars to. “The budget for fusion research right now is on the order of $400 million a year,” she says. “That’s less than 20 percent of a B-2 bomber. That’s one B-2 bomber that the U.S. military purchased decades ago. We are really falling behind. Other countries have seized the lead in developing new designs and working on materials problems associated with fusion power. That’s really sad. I would hope that the U.S. wants to be a leader in all future forms of energy technology. We would want to be an exporter of that, not an importer, but we are not on the right path, especially in terms of fusion energy.”

Carter says it makes sense to imagine a future where fusion power supplies the electricity, and ground-based vehicles are switched over to using electric power instead of internal combustion engines.

“You wouldn’t need oil, ultimately,” she says. However, the old joke goes that “fusion is the power source of the future, and it always will be.” It certainly isn’t here yet, at any rate.

So to Carter, it makes sense to explore other means of producing electricity, such as more efficient solar and wind power.

Carter believes natural gas is a good way to bridge the gap between the current mix of power sources, and the potential fusion-powered future. The need for a steady power source will remain even if solar and wind power become more widely used, she says. “When the wind doesn’t blow, unless you have storage — and storage is too expensive right now — then you don’t generate electricity.”

Carter advocates setting a ‘floor’ price of gasoline at around $3 or $4 a gallon. Consumers would pay a tax when prices were cheap, but not get squeezed too much if they rose.

The very cool thing about natural gas generators is that they can be turned on and off within minutes, so you can have a situation where a natural gas power plant runs in combination with wind and solar. When the wind doesn’t blow, or with solar power, at night time, you can’t generate electricity. Those are times when you could use natural gas.”

Because natural gas is better for the environment than oil, Carter is a qualified supporter of fracking.

“Hydrofracking plus horizontal drilling (the two must be done together), done sustainably (without environmental harm), is an essential bridge technology to cleaner energy. Hydrofracking plus horizontal drilling has allowed our carbon emissions to decline for the first time ever, because the cheap natural gas it has engendered now is displacing the more CO2-intensive coal in electricity production. I’m in favor of well-monitored/regulated hydrofracking and horizontal drilling, to ensure no environmental harm,” she says.

But what about nuclear power, a proven electricity source that produces no carbon emissions? “The problem really is dealing with nuclear waste, and that’s been a political football. We don’t have a decent way to deal with nuclear waste,” Carter says. “It’s also easy to understand why people are nervous about it after Fukushima, even though it seems the damage to Fukushima is fairly localized. It’s still awful that that happened, so people would naturally be very concerned about it.” Carter also says the enormous capital expense of nuclear plants makes the cost of it “prohibitive.”

Carter believes in pursuing all avenues available to combat climate change because of the dire threat it represents to the future of humanity. Carter wants the public to understand that to the scientific community, global warming is not “just a theory,” but a fact, despite disagreement among researchers

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about exactly how much temperatures and sea levels will rise, and how fast. “The public thinks that if you talk about the fact that there is some uncertainty in, for example, the amount the earth will warm, that means somehow the science itself is not trustworthy,” she says. “That’s not at all true. It’s just that we scientists, in general, are our own worst critics. If we say it’s going to warm two to four degrees, we are being very honest about that. We have extrapolated by pure ex- actly how much it will warm, but it would be dishonest to say we are absolutely sure it is going to warm one or two degrees over the next 30 to 40 years.”

Politicians have used un- certainty, and differing climate models, to create a false sense that there is disagreement in the scient- ific community over whether mankind’s activities are causing climate change. But the underlying science behind the different models is sound, Carter says, and there is a call to action no matter which mod- el turns out to be correct. “The models are based on global mea- surements over decades,” she says. “There will always be some uncertainty, but the physical sys- tem is not going to do a U-turn and stop warm- ing.”

The effort to move to sustain- able fuel sources has been dealt a blow recently by falling gas prices. As New Jersey drivers know, the plummeting price of oil on the in- ternational markets, due to Ameri- can oil exploration, has had its ef- fect at the pump. That makes oil—one of the more environmentally unfriendly power sources—more competitive against solar, wind, and natural gas.

Carter is against expanding oil drilling, but her position on the controversial Keystone XL oil pipeline is complicated. “In princi- ple, pipelines are safer than rail, but this all depends on who is in charge of them. We should only agree to pipelines administered by compa- nies with impeccable safety re- cords,” she says. “But my worry is that with pric- es so cheap, we’re just going to sit back and not be leaders in this, and not do the right thing in terms of using this opportunity to generate revenue and change people’s behavior.”

Carter advocates setting a “floor” price of gasoline of around $3 or $4 a gallon, so that consumers would pay a tax when gas prices were cheap, but not get squeezed too much if they rose. “Below that $3 or $4, the rest of it goes into a kitty that gets used in all the ways we need to rebuild infrastructure and plan for the future.”

And until electric cars catch up to the gas-powered cars, she wants to explore other ways of making fuel for internal combustion en- gines. “How do we produce gasoline or some equivalent liquid fuel some other way than just pulling it out of the ground?” she says. “A lot of chemists are working on ways to do not what we’ve been doing for the last 100 years, which is generat- ing gas from petroleum, but figur- ing out how we can generate a good, energy-dense liquid fuel by chemical means. “There are a lot of people work- ing on biofuels, and that could be a solution, but there is a lot of con- cern that biofuels are taking away land and nutrients and water from food crops. That’s a huge problem.

Command Post: Emily Carter, founding director of the Andlinger Center, is overseeing construc- tion of a new center on Prospect Avenue at Olden (opposite page). It is due to be finished this year.

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Carter is leading the direction of the Andlinger Center while allowing its individual researchers to pursue their own research projects.

The work of the Andlinger Center is entirely voluntary," Carter wrote in an E-mail. “Our faculty, research scholars, and students want to help solve the problems of energy and the environment. Often, this goal intersects with the expertise and activities already underway by those involved in our Center, so it is a win-win for everyone. Additionally, sometimes our community of researchers has reoriented their research to get involved in our mission, using their expertise to work on new problems. We offer incentives to get involved in our work, through grants, fellowships, and internships.

Carter’s management style is one of consensus building. “Most important is to be a good listener to understand people’s aspirations and then to figure out ways to sensibly and efficiently address those needs within the confines of the larger mission,” she says. “While I often have in mind a particular path forward, I always work to build consensus, otherwise any initiative without buy-in will ultimately be unsuccessful. I also have high expectations for the performance of my teams; those expectations are only reasonable if I hold myself to at least that standard, which I do. I try to act as an exemplar. Lastly, I work hard to build a culture of respect, collegiality, and a sense of responsibility to keep learning from and teaching/helping others, so that we all appreciate that we can have more impact working together than separately or in competition.”

Throughout all this, Carter teaches engineering classes. She has noticed some changes over the years in the way her students approach class. “The diverse and ever-present new media students are exposed to now make it difficult to hold their attention to dig deeply into a subject,” she says. “I worry that too many students want to just use Google to find answers; that isn’t what true learning is all about. One needs to learn to think for oneself, to analyze and to critique, and to create.”

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