Sizing Up a New Energy Era

Oil price freefall soothes consumers, worries environmentalists

By Alvin Powell

Oil’s dramatic price decline has rocked oil-producing nations, prompted consumer glee at the pump, and captivated the attention of economists and environmentalists alike, who view what may be the beginning of a new era of cheap energy with both fascination and foreboding.

Fascination comes at the brute force oil exerts in global economic and geopolitical arenas. Foreboding comes because cheap oil, perhaps not surprisingly, is bad news for climate change and for the environment broadly, putting a thumb on the economic scales that drive consumer purchase decisions and tipping them away from cleaner, though still more expensive, alternatives.

The foreboding comes also from a sense of déjà vu. Thirty-five years ago, the oil shocks of the 1970s boosted development of cleaner alternatives, which were subsequently killed when oil prices fell over the next decade. Cheap oil means more miles driven and more gas-guzzlers on the road. It means fewer electric cars and hybrids and makes next-generation biofuels tougher to bring to market. Even in
areas not touched by oil, cheap gasoline and home heating oil have a psychological impact, creating a broad sense that energy problems—and the perhaps painful action needed to solve them—are over.

At a time of tight budgets, that psychological shift could reduce the urgency around research and development into clean alternatives, work still needed to bring prices down and make alternatives commercially viable. It is in this arena, perhaps, that the echoes of the 1980s reverberate loudest, fueling fears that promising avenues will remain unexplored and climate change-easing solutions undeveloped, resulting in increasing amounts of world-warming carbon dioxide pouring into the atmosphere.

But the world is a different place than it was in the 1980s. Though falling oil prices will undoubtedly have an impact, experts point out that prices of their future influence and impact, whether heading into finance, energy, or high tech. I think this awe is something we all feel to some extent, as we say goodbye to some of our students and consider how our engagement with them at Harvard will influence decisions they make in the future. It reminds me of the seriousness of our mission, and how our engagement with students both in and outside of the classroom can have a catalytic effect on some of the world’s most pressing challenges. It also gives me hope for environmental stewardship for the future.

In this context, it is exciting to look back and see how HUCE has touched so many people in our community over the past year. Our academic programs continue to grow, with the start of our new Secondary Field in Energy and Environment, and the continued success of the Environmental Science and Public Policy Concentration, both overseen by Paul Moorcroft from OEB. Our Graduate Consortium is also thriving, with a huge new crop of applicants, and some new participation by faculty members including David Keith and Henry Lee. This year’s newsletter describes just a few of the many issues and activities of our faculty and fellows, including some exciting new efforts to engage with the arts and humanities—especially through a new collaboration with the American Repertory Theater, and its fabulous Artistic Director, Diane Paulus, and her colleagues, Diane Borger and Ryan McKittrick. I find working with these new partners to develop innovative ways of communicating incredibly inspiring. I hope you will share in the fruits of their efforts, or take part in some of the other ways that HUCE stimulates our thinking about the environment, when our activities begin again, with a fresh new crop of students, in the fall.

I wish you a healthy and productive summer.

Dan Schrag
Director, HUCE
have also fallen dramatically for alternatives like solar photovoltaics, which are seen as part of the future energy mix even by oil-producing nations. In addition, U.S. progress toward the adoption of renewable alternatives to fossil fuels is not solely at the mercy of consumer pocketbooks—some is baked in by relatively recent government subsidies, regulations and mandates, like California’s zero-emission vehicle program and Massachusetts’ renewable energy portfolio standard, strictures that aren’t going to be undone by cheap gas at the pump.

And, though some predict low oil prices will last a year or more, others say low energy prices might endure and that tomorrow’s oil market may be stabilized by new unconventional sources responding rapidly to market swings. In short, we just might be stepping into a new energy future.

**Consumer is (still) king**
From July 2014 until early this year, the U.S. price of a gallon of gas fell from about $3.70 to around $2. The environmental impact was likely felt almost immediately, as consumers responded not just with childlike joy at the gas station, but in their driving habits.

“The transportation question tends to be about which of the two cars in my driveway I use. I’ve got a truck, and I’ve got a sedan that gets twice the mileage of the truck,” said Professor of Government Stephen Ansolabehere. “When the price of oil is high, I think about which car I drive, and when the price of oil is low, I don’t think about it, I take whichever one I want.”

With low gasoline prices, drivers will also increase consumption in other ways—by going out instead of staying home or taking the car instead of the train—that together can make a big difference.

“If prices stay low, gasoline consumption will increase by about 8 percent in 2015. That would mean another 100 million tons of CO₂ in the atmosphere.

"It’s plausible to think that you’ll be seeing a pretty large effect … With lower prices, people consume more. That’s the way it works with everything,” said James Stock, Hitchings Burbank professor of political economy. “That’s a basic feature of economics, and it will be the case here.”

If prices stay low, Stock estimated gasoline consumption will increase by about 8 percent in 2015. That would mean another 100 million tons of CO₂ in the atmosphere this year, Stock
said, enough to wipe out somewhere between a third and a fourth of the expected reductions from the Obama administration’s proposed regulations to clean up power plant emissions.

“That’s a big deal. That’s a really big deal,” Stock said.

Vehicle sales statistics, meanwhile, show that consumers aren’t just driving differently, they’re also buying less fuel-efficient vehicles. The average fuel efficiency of U.S. vehicles bought in December fell 0.7 miles per gallon from November, a significant—and surprisingly rapid—response, according to Henry Lee, the Jaidah Family director of the Harvard Kennedy School (HKS) Environment and Natural Resources Program.

While buying a gas-guzzler may seem risky given that prices were high just a few months ago, according to Stock, consumers are sophisticated enough to discern temporary volatility from longer term trends that favor low prices.

“My sense is that consumers are reasonably good at differentiating between more persistent versus temporary price spikes,” Stock said. “Here we’re talking about a completely new revolution in extraction technology, and that’s not going away. Whatever the geopolitics are, fracking is a reality.”

“We have thirty-five years to deal with [the climate problem], and we’ve used up twenty of them. The severity of that problem is just enormous, and I do not think these prices are going to help.”

(Worried) Eyes on the future
Aside from the immediate increase in carbon dioxide emissions from American drivers burning more gasoline, cheap oil today has the potential to exacerbate harm to the environment tomorrow.

“My first concern is the subjective view of oil prices. People use it as a bellwether for the energy situation,” Lee said. “So when prices are down, there’s no energy problems. That’s really simplistic, but I think that’s how people look at it. So why invest in alternative fuels, alternate types of cars? Why invest in renewable energy, which has nothing to do with oil?

“I’m particularly worried about government being willing to support [research and development]. They’re going to say we don’t need R&D, we don’t have an energy problem. I think that’s a really, really big mistake for the climate. We have thirty-five years to deal with [the climate problem], and we’ve used up twenty of them. The severity of that problem is just enormous, and I do not think these prices are going to help.”

Daniel Schrag, director of the Harvard University Center for the Environment, Hooper professor of geology, and professor of environmental science and engineering, agreed, saying neither electric cars nor biofuels are ready to replace gasoline as a transport fuel, making continued investment—by government or private industry—in research and...
development critical.

“Most troubling is the question of people’s willingness to invest in alternative technology,” Schrag said. “This price drop has the potential to send a message to investors—that’s one of the most troubling aspects of this.”

Stock offered an example from the budding biofuels industry. After years of development, four commercial-scale plants are opening in 2014 and 2015 in Nebraska and Iowa. The plants make ethanol from agricultural waste, like stalks and leaves, a more difficult process than producing fuel from corn kernels but one that promises an 85 percent improvement in greenhouse gas emissions over petroleum.

“They say they’re economically competitive in the $70 range,” Stock said. “Seventy dollars a few months ago looked great. Seventy today is a real problem.”

With low gas prices shifting economic incentives away from biofuels, it’s more important than ever that the government step in and foster the transition to cleaner fuels, Stock said.

“We are going to be facing more economic challenges to … your favorite technology alternative in the transport sector: cellulosic ethanol, electric vehicles, fuel cells,” Stock said.

“Because of the oil price decline, their cost disadvantage has only heightened.”

**It’s electric**

Consumers voting with their pocketbooks are also bad news for the nation’s budding electric and gas-electric hybrid fleet, Lee said. Cheap oil makes them more expensive to drive compared with gasoline vehicles burning newly inexpensive fuel. Sales of the hybrid Chevy Volt, for example, plunged 48 percent from January to March 2015 from a year earlier. General Motors announced in April that it would suspend production for four weeks in early summer to use up existing inventory and prepare for 2016 model production.

But all is not lost, Stock said. Even though sales may dip, the vehicles’ environmental appeal should insulate them somewhat from pure market forces. Hybrid owners paid a premium for the cars even when gasoline prices were high, and he expects a significant number to continue to do so.

Robert Stavins, the Pratt professor of business and government at HKS and director of the Environmental Economics Program, agreed, saying the same dynamic applies to electric vehicles, particularly in California, which has an ambitious zero-emission vehicle program that will continue to foster electric car sales.

“Is demand greater when gas prices are high? Yes, but the major change is SUVs in and out,” Stavins said. “The core constituents of hybrids will buy and drive them anyway.”

That dynamic applies to Tesla, America’s flashiest electric vehicle, according to Eric Van den Steen, associate professor of business administration and author of a Tesla case study. Van den Steen said gasoline savings wouldn’t matter much for buyers of the $70,000 Model S, though it may make some investors in the company pause. This could crimp financing for still-needed growth, particularly in the company’s planned battery-building “Gigafactory” in Nevada.

“My sense is that the impact on a company like Tesla would be relatively limited,” Van den Steen said. “First, the people who buy in the price range of a Tesla are unlikely to be swayed by some savings on gas, especially since the range issues imply that this would not be your first choice of car if you need to drive long distances.

“On the downside, non-professional investors who bought Tesla stock with gas prices in mind may be less attracted to the company. So the (likely bubble) price of the stock may come down a bit. That would make it harder to find rich financing. But that would not hamper Tesla itself, but may raise more issues for the Gigafactory.”

To Stavins, cheap oil’s most important price effect may very well be on commercial fleets. Major commercial fleets—like FedEx and airlines—log many more miles than the average commuter, he said. High oil prices encourage fleet owners to buy more fuel-efficient vehicles sooner while low prices encourage them to keep older, lower-mileage vehicles on the road.

**International negotiations**

Though auto-driving consumers around the world may be influenced by low oil prices, Stavins said he didn’t
expect cheap oil to affect their nations’ bargaining positions in international climate talks. Stavins, who leads the Harvard Project on Climate Agreements, said the agreement expected to be finalized in Paris in December won’t include limits that are likely to be upset by low oil prices, but rather “intended nationally determined contributions” that will be decided by—and give flexibility to—each nation.

In the U.S., that means, among other things, tougher mileage standards for vehicles and tougher clean air standards for power plants—whose proposed rules are set to be finalized this year.

But even if additional carbon dioxide emitted by U.S. drivers isn’t a hurdle in the Paris climate talks, Michael McElroy, Butler professor of environmental studies, said it may cause a problem with China.

Last November, President Obama announced a landmark agreement with China in which the world’s two largest carbon dioxide emitters pledged to cut greenhouse gas emissions. Low oil prices make it tougher to comply, McElroy said.

Obama said the U.S. would cut carbon emissions between 26 percent and 28 percent from 2005 levels by 2025. China, meanwhile, agreed to peak its carbon emissions and make non-fossil sources 20 percent of primary energy production by 2030.

The U.S. transport sector made up 34 percent of overall emissions in 2013, meaning a significant increase in miles driven can also significantly impact national carbon emissions. McElroy said the change in driving behavior will have to be compensated for somehow, perhaps by further cuts to power sector emissions—and zeroing out coal.

“If we’re going to meet the Beijing commitment, I don’t see it happening in the transportation section the way the White House hopes,” McElroy said. “If the best I can get is constant emissions from the transport sector, we have to double savings from the power sector. You can do it, but it’s a politically tough thing to do.”

Cheaper oil affects China as well, McElroy said. It means lower gasoline prices to the growing number of Chinese drivers but, since the government controls who buys cars and when, unlike in the U.S., it may not have an equivalent to the U.S. SUV dynamic.

**Politics and possibility**

With economic incentives for cleaner, greener vehicles and fuels falling, several said now is the time for the government to step in and support their use. A carbon tax, they argue, would provide an economic incentive to lower carbon emissions and be far less painful levied in a time of low fuel prices.

William Hogan, Plank professor of global energy policy, said a carbon tax would finally “internalize externalities” inherent in fossil fuels. In other words, a carbon tax would make fossil fuels’ price reflect their actual cost—including harm to the environment from carbon emissions.

“The price of oil going down makes it now important and easier to adopt the kinds of externality-internalizing taxes like carbon taxes. It doesn’t make it easy, but it makes it easier,” Hogan said.

“That makes it more important because it’s not happening by itself. More consumption of oil makes it harder for substitutes to come in.”

In a Jan. 4 op-ed in the *Washington Post*, Eliot University Professor
Lawrence Summers echoed Hogan’s call, saying the case for a carbon tax “has become overwhelming” with the oil price decline.

Summers said a $25 per ton carbon tax would increase gasoline prices by just 25 cents a gallon, an amount that could be borne even by low income Americans, who were paying more than just months ago. It would raise more than $1 trillion over the next decade, providing funding for infrastructure repairs, pro-work tax credits, or a reduction in the payroll tax. Similarly, David Keith, McKay professor of applied physics and professor of public policy, said low oil prices would make it easier to adopt a strict national low carbon standard, which would encourage low-carbon fuels in the transportation sector.

“The only potential upside, which hasn’t happened, is that it makes it more politically palatable to impose a stronger low-carbon fuel standard when prices are low because the consumer won’t see it,” Keith said.

The problem with either idea, Keith and Hogan agree, is politics.

In talking with colleagues, Hogan said the closer they are to Washington D.C., the worse chance they think a carbon tax has.

Stavins sees the same dynamic at work. “The political forces against … are so massive that lower gas prices are not going to make that much of a difference,” Stavins said.

If the politics can be overcome, low oil prices create an opportunity not just for carbon pricing but also to remove costly fuel subsidies, largely in the developing world, which keep fossil fuel prices artificially low, Stavins said.

Though political resistance to a carbon tax may be disappointing to environmentalists, it reflects public opinion, which politicians are following, according to Ansolabehere. The bad news is that, according to polls, the time may never be right for a new tax.

Though the public consistently supports environmental regulations, they also clearly favor regulatory approaches like EPA action or increased auto mileage standards over taxes, Ansolabehere said.

“When asked, people will favor more regulations on coal companies, more regulations on tailpipe emissions, on fuel efficiency and things like that,” Ansolabehere said. “What they’re very reluctant to embrace is gasoline taxes or electricity surcharges.”

And, though the public consistently favors cleaning up pollution, their concerns are focused locally. Global climate change doesn’t generate much fervor. “They’re much more concerned… about smog, mercury, or particulates, than they are about global warming,” Ansolabehere said. “So, when you look at policy options that … have immediate effect on carbon emissions—such as cap and trade, energy tax, or letting the EPA just cap carbon emissions—you don’t get a clear majority in favor of cap and trade, [you get] a large opposition to a gas tax, but you get pretty much majority support for EPA regulations, straight up.”

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Reliving the 1980s

Though 1980s flashbacks may not be useful in predicting clean energy’s track in the months to come, memories of that time are nonetheless relevant. In fact, they may be a major factor behind Saudi Arabia’s decision not to cut production to prop up oil prices, said Meghan O’Sullivan, who heads the Harvard Kennedy School’s Geopolitics of Energy Project.

In the 1970s, the oil crises roiled the U.S. and demonstrated the economic muscle of OPEC, the Organization of Petroleum Exporting Countries. But by the 1980s, the global oil marketplace was changing. New supplies came online from Mexico and the North Sea, driving the price down and presenting OPEC with the choice of accepting less money for their oil or voluntarily cutting production to keep prices high.

Most OPEC nations balked at cutting production, so Saudi Arabia decided to go it alone. Despite a production cut that eventually reached seven million barrels a day, however, prices remained stubbornly low. In the end, the Saudis lost market share and some of the shine on their reputation as the oil industry’s most important player.

Thirty years later, the situation repeated itself. Over the last five years, the hydraulic fracturing revolution brought vast new supplies of U.S. shale oil to market. From the Saudi point of view, conditions were disturbingly similar to those of the 1980s, O’Sullivan said.

New U.S. oil was hitting the market as economic growth cooled in the U.S., Europe, and Asia. As prices fell, OPEC nations struggling with unrest at home or budget woes refused to cut production, leaving Saudi Arabia again faced with the choice of whether to go it alone. This time, though, it decided to keep pumping and let prices fall.

“My sense is that the Saudis looked at the market and had uncomfortable flashbacks to the 1980s, a period when Saudi Arabia underwent enormous economic pain,” O’Sullivan said.

“If the price was up, it [might] spur new investment in North Dakota, spur more American production, so why would Saudi Arabia cut production to prop up prices when it would spur more American production?”

Though Saudi Arabia can pump oil profitably at prices as low as $10 a barrel in some fields, that course is not without pain. Its national budget is balanced on the assumption that oil averages $90 a barrel, O’Sullivan said, so prices below that—the U.S. Energy Information Administration is predicting Brent crude to average $59 a barrel in 2015—mean continuing budget deficits and tapping monetary reserves to cover them.

While economic reasons are likely central to the Saudi inaction, O’Sullivan said, rarely in the Middle East are consequential things done for just one reason. The fact that low oil prices cause pain to nations like Russia—whose support of Syria’s Assad regime Saudi Arabia opposes—and regional rival Iran, could certainly be viewed as an added geopolitical benefit.

In addition, the death in January of King Abdullah bin Abdulaziz Al Saud put new Saudi leaders in power, who run the risk of appearing ineffective and weak during a crucial transition if they try to prop up oil prices and fail, O’Sullivan said.
“It would send the message that the Saudi government is not in control of the oil market. That’s probably never a good message from a Saudi perspective, particularly with a new king in power,” O’Sullivan said.

Shale in the crosshairs
But the Saudi’s action isn’t just rear-looking. It also likely has a practical, economic purpose today, according to Leonardo Maugeri, an energy expert at the Harvard Kennedy School’s Belfer Center for Science and International Affairs. The Saudis, he said, want to make life difficult for their newest rival and the cause of all the trouble: U.S. shale oil producers.

“There’s no doubt [the Saudis’] first target is to get rid of U.S. oil production,” Maugeri said.

Unconventional oil, like that from shale deposits and tar sands, costs more to extract than in conventional wells. It was thought that unconventional sources needed prices at least $75 a barrel to remain profitable, well above the level that conventional wells can profitably pump. It is that price differential, Maugeri said, that the Saudis have banked on. By keeping prices low, they believed they could disrupt U.S. shale oil production.

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The strategy has already had an effect. Hundreds of wells have shut down and some weaker operators have closed their doors or been bought up by stronger companies, Lee said.

But a shakeout in the number of shale oil wells isn’t the same as crippling the industry. Unfortunately for the Saudis, U.S. shale oil production is marked by rapid technological innovation and efficiency improvements that have aggressively pushed down the prices at which the oil can be extracted.

“‘Their mistake, in a way, is that they believed that U.S. production was uneconomical at $75 a barrel. This is not true,’” Maugeri said. “Eighty-eight percent of U.S. shale production breaks even at $42 a barrel. Most of the U.S. shale production is still feasible.”

Maugeri doesn’t expect the Saudis to alter course, however. The kingdom has plenty of money to weather a price war and can wait for 18 months or longer, until supplies tighten and prices rise.

“Once the war has started, they want to win the war,” Maugeri said.

This particular war, however, may not be entirely winnable and John Shaw, the Dudley professor of structural and economic geology and chair of Harvard’s Department of Earth and Planetary Sciences, thinks the Saudis are savvy enough to understand that.

“Those resources aren’t going anywhere. We know where they are. People will go for them sooner or later. It may be stretching the timeline, but it’s not really changing the long-term dynamic of the market,” Shaw said. “They [the Saudis] are not going to want to hold oil to half its market value for very long because they would lose out in that equation.”

In addition, Shaw and Maugeri agree, the cost of extracting shale oil is only

Figure 2. Annual change in U.S. field production of crude oil (1960-2014)

Graph courtesy U.S. Energy Information Administration
headed in one direction: down.

New techniques to drill multiple wells from a single pad or to space wells more closely together are being developed. Producers are re-fracking existing wells and using contractors who’ve squeezed labor costs down to stay competitive. Together these factors will continue to lower prices at which shale oil can be extracted by roughly 10 percent a year, Maugeri said.

“It changes every six months with improved knowledge, shared information, improved technology,” Maugeri said. “The breakeven is a dynamic figure, not a given forever.”

Whatever their initial motivation, O’Sullivan said the Saudis are watching developments with great interest.

“No one knows how low the price has to go before you get a reaction. We’ve seen the number of rigs go down a lot, but haven’t seen it affect production yet. But it will. [And] nobody knows how quickly they can come back on when the price goes up,” O’Sullivan said. “It’s a completely new dynamic in the market and really central to OPEC calculations. I think the Saudis were interested in finding out at what point U.S. shale production will stop. I don’t think their objective is to kill all shale production.

“I don’t think they view shale as an unmitigated negative. It’s prevented a massive spike in the price of oil and would have saved them from investing in more capacity when they wanted to spend money on keeping their population content and not demonstrating for rights.”

A pipeline priced out?
Cheap oil, of course, impacts not just the economics of unconventional oil, it might also impact how it’s moved.

The proposed Keystone XL pipeline, which would transport Canadian tar sands oil to U.S. refineries, is at the center of a political debate between Congressional Republicans and the White House. Supporters say it will be a jobs producer, while opponents are concerned that the risk of rupture and spoiling the lands it runs through is too high. In February, President Obama vetoed legislation authorizing the pipeline, arguing it preempted ongoing government evaluation of the project.

Cheap oil may have drawn some of the steam from the debate by making tar sands oil, more expensive to extract even than shale oil, less attractive economically.

“I think it definitely makes it easier to say no to Keystone, that’s clear,” Keith said.

Whichever side you’re on, Stavins said, one thing does seem clear: the pipeline is not about jobs.

“Although it’s become a strong political-ideological issue, the proponents of it talk about massive economic benefits, that’s not really valid,” Stavins said. “There will not be many jobs created except in the construction phase. Obviously it’s a very large issue, ideologically, in the U.S, but my overall view on Keystone XL … it’s much ado about nothing.”

Impacting tomorrow’s oil today
While the world is watching for cheap oil’s impact on the U.S. unconventional oil business, future supplies of conventional oil may also take a hit. That’s because exploration for tomorrow’s conventional oil sources are also impacted by low oil prices.

Exploratory wells in many of the most prospective areas cost upwards of $300 million to drill and several may be needed to find a resource. While conventional oil producers will continue to pump from existing wells at lower prices, it is the exploration and development that is curtailed when prices drop, and Shaw said oil companies are “moving exploration down to cruise control.”

That can affect oil supplies five years down the road, Shaw said. More immediately, it means hundreds of millions of dollars of exploration and development have already been curtailed, sparking layoffs at oil service companies like Halliburton and Schlumberger.

“Clearly, all these activities are being curtailed.”

To Cox Professor of Law Jody Freeman, it is this dropoff in exploration—including that in environmentally sensitive areas—that keeps falling oil prices from being a clear loss for the environment.

“There are always arguments on both sides regarding what lower prices mean
for the environment,” said Freeman, who heads Harvard Law School’s Environmental Law Program and serves on the board of directors of ConocoPhillips. “On the one hand are arguments that low cost oil and gas will lead to more consumption and reduce incentives to invest in cleaner alternatives. On the other hand are arguments that the low prices will make it uneconomical for industry to drill in high cost and often environmentally fragile areas like ultra-deep water, the Arctic, and oil sands.”

A new energy era?
Energy economists agree we’re in the midst of a sustained period of low oil prices and that it may take one or two years until demand catches up with supply, or until production falls enough to match continued slow demand.

During that time, Maugeri predicts that oil prices will vary between $35 and $60 per barrel, with the volatility due to geopolitical events layered over the fundamental forces of supply and demand. Events such as unrest in the Middle East due to ISIS, Saudi intervention in Yemen, tension with Russia over Ukraine, or natural disasters that affect production facilities, can cause prices to spike regardless of fundamentals.

O’Sullivan, however, said the low prices may last even longer. “We’re probably in a new energy dynamic, with new fundamentals on the energy landscape that overall mean downward pressure on prices. It doesn’t mean prices won’t go up and down—it’s very easy to portray a geopolitical scenario with high prices in 2016. But the general trend is one where more supply abundance and slower, positive rates of demand grow together,” O’Sullivan said. “The new energy abundance, it’s a pretty big contrast from ten years ago, when it was all about scarcity, all about peak oil.”

Though some volatility seems assured, some say that another feature of our energy future may in fact be greater price stability. Since shale oil producers can curtail and re-start operations far more quickly than conventional operators, their activity might dampen the traditional oil price swings, according to Shaw and Stock.

“On the upside and downside, it should stabilize prices,” Stock said. “We’ll see. We’re running the experiment.”

Cheap oil or not, Stock expressed confidence that the transition to cleaner fuels is coming. Transformational change can be slow, he said, but it does happen.

Back in the early 1990s, Stock said, you would have been laughed at if you had said gay marriage would one day be legal. But change spread relatively quickly as a new generation with new sensibilities came into their own. He sees a similar transition in the offing, though perhaps still years away, for clean energy.

“That [example] makes one optimistic, but it forces you to be patient,” Stock said. “A generational patience.”

Right: Jody Freeman, Cox professor of law at the Harvard Law School. Below: Northwestern North Dakota is one of the least-densely populated parts of the U.S., but satellite imagery shows the Bakken shale formation where gas and oil production are booming.
Finding Poetry in Nature’s Crises and Wonders

By Jonathan Mingle

Does it ‘sift through leaden sieves?’”

Halfway through Boston’s epic, snow-smothered winter, Elisa New, the Cabot professor of American literature, posed this question to HUCE fellows Yige Zhang (geochemistry), Zoe Nyssa (sociology of science), and Timothy Cronin (earth and planetary sciences) in a dinner discussion at HUCE. The reference wasn’t to the flakes falling just outside, but to another scene almost a century-and-a-half prior, captured with those words by the poet Emily Dickinson.

Cronin broke the news diplomatically. “We all think of the sky as being kind of leaden in winter. But in a very literal sense, what clouds do with snow is the opposite of what a sieve does. Sieves sift the finest fibers or particles out of something and let them rain down, whereas a cloud takes the largest, heaviest snowflakes, and those fall, and the small ice crystals or water droplets remain.”

So Dickinson, who read and was interested in science, was no scientist. But the fellows agreed that some of Dickinson’s other images—descriptions of the snow piling up and

**Faculty Profile**

Mark Wu

Since his earliest days as a Harvard undergraduate, Mark Wu has been tackling complex issues on a global scale. In 1991, in his first year on campus, he co-founded the student-run Harvard Project for Asia and International Relations (HPAIR) to convene students from Harvard and top Asia-Pacific universities. “The conferences were eye-opening for me,” recalls Wu, now an assistant professor at Harvard Law School. “The students from Asia—who were trying to define their roles as future leaders of interconnected national economies—were wrestling with the implications of their countries’ emerging economic power and the challenge of balancing environmental sustainability and economic development.”

Though well-known for his work in international trade law—he co-authored *The Law of the World Trade Organization* and has served as Director for Intellectual Property in the Office of the U.S. Trade Representative (USTR)—Wu’s first career steps were motivated by interest in sustainable development, particularly in East Asia. “My earliest professional projects were with the World Bank’s rural water sanitation and urban environmental pollution teams,” he recalls. “My friends joked that I had done all this schooling to become a glorified toilet inspector.” Wu later broadened his focus to international trade after the Asian financial crisis, when he began studying opportunities for, and barriers to, sustainable economic growth.

As a Harvard Law School faculty member and HUCE faculty associate, Wu has brought his skills and expertise to take on a rising challenge playing out in national administrative agencies, in World Trade Organization (WTO) proceedings and negotiations, and other forums: a trade versus environment conflict that could have a long-term impact on global efforts to limit climate change and spur environmentally friendly industries. This conflict has emerged because, as Wu notes, “Nations are increasingly employing green industrial policies intended to aid development of environmentally friendly industries—with the goal of making their economies both more robust and more environmentally sustainable. But these policies sometimes provide a subsidy or other unique benefit to the domestic industries. Therefore, while they produce significant economic and environmental benefits, they have negative trade effects and often violate WTO rules.”

How to resolve the conflict and balance the competing goals? “Finding resolution will require fundamentally rethinking about how these cases are adjudicated and what types of penalties are imposed,” Wu explains. “We need to craft rules that allow countries to nurture their own green economies without unfairly tipping the scales against their trading partners … and engaging in beggar-thy-neighbor protectionism.”

Wu’s influential 2014 article in the *Northwestern University Law Review* (co-authored with James Salzman, a professor of law and of environmental policy at Duke Law School and a HLS visiting professor) helped prompt just such a rethinking and re-crafting process. High-level discussions have taken place at the United Nations Conference on Trade and Development, for example, and the WTO launched negotiations in 2014 for an Environmental Goods Agreement, with forty-four nations participating. Wu recently completed another article examining why more developing countries are not involved and how to draw them into the mix. Looking forward hopefully, he says, “If nations decide to work cooperatively rather than try to win markets at others’ expense, international trade rules can help facilitate resolution of global environmental challenges.”

—Merrill Meadow
erasing features from the land (“It makes an even Face / Of Mountain, and of Plain —”) and, in another poem, of a line of summer squalls passing through (“There came a Wind like a Bugle”)—were remarkably canny renderings of physical phenomena and how they strike human senses. The poems address our vulnerability as inhabitants of an ever-changing, sometimes violently energetic, natural world, and our awe of its forces.

“Scientists and artists have something in common, which is their powers of observation,” Nyssa offered. “What’s wonderful is you can return to these poems over and over again, knowing the answer in some sense, and yet finding something new from them every time. Science, when it poses really excellent questions, is the same way.”

This lively exchange was filmed for New’s “Poetry in America” project, which builds on her online HarvardX course of the same name, and combines video conversations, field visits to historic sights, interactive seminars and interviews with prominent Americans about famous and overlooked poems.

“For me it’s an extraordinary chance to reach so many more people. But it’s also an opportunity for Harvard, since I’m using Harvard’s resources: we throw open the doors to the Museum of Natural History, Houghton Library, we use footage from HUCE, and in many of the videos students join me on camera. It’s amazing to watch my students become teachers, with lecterns that face the world.”

In the course of working on the project New has had experiences that are powerful reminders of poetry’s ability to speak across disciplinary and cultural boundaries. “Anybody is interested in poetry if you give them a poem that is in their world,” she says.

Even if that world is underwater.

“In Papua New Guinea I actually went down under the sea in a submarine reading a poem by Marianne Moore called “The Fish.” I was there with people involved in Conservation International teaching local people how to patrol their waters, so that people don’t come in and bomb coral reefs to catch fish.”

Moore has a reputation as a “difficult” poet, but New was struck by how easily her companions took to the poem.

wonderful is how a poem gives us a common language, a starting point—and then we begin to find a common language together, to share vocabularies.”

A natural alliance

Sometimes that search for common ground must overcome some skepticism. When James Engell, Gurney professor of English literature and professor of comparative literature, is asked by scientists and policy researchers at environmental studies conferences what he does, they tell him he teaches literature.

“They then ask me why I’m interested in environmental studies,” he says with a chuckle, “as if being interested in literature is a kind of oddball thing… if you’re interested in environmental studies.” But Engell gently points out that the entire field of environmental inquiry has its roots in the literature of the late eighteenth and early nineteenth centuries. “You know, I’ve sometimes said to people that modern environmental consciousness in many ways begins with the poets.”

Poetry is fundamentally interdisciplinary, Engell maintains, and what’s more, “poets and scientists are pretty natural allies.”

“When Wordsworth writes the preface to the Lyrical Ballads, he talks about the ‘man of science’ and the poet. He says they both take pleasure in their work. The pleasure of the scientist is in finding out about nature; the pleasure of the poet is something different. But they both are in the business of doing something that they deeply enjoy and that in some way leads to a discovery,
or is revelatory.” The Romantic poets sought to remind their readers that nature was always in flux, never static. “Alfred North Whitehead, a philosopher here at Harvard, said that Romanticism was a protest on behalf of an organic vision of the universe. “So poetry, and literature more generally, it seems to me, have provided a construction of a certain consciousness about nature, without which research and knowledge cannot be knitted together into a larger kind of vision. We know for example that Rachel Carson was a very good scientist—she was a very good marine biologist. She was also a very fine writer. She was a poet in a real sense of the word, using the word poet more generally. She’s great with imagery, with language, with literary allusion.” He points out that the title of a famous chapter in Silent Spring about the damage done by the pesticide DDT to birds comes from the end of John Keats’ ballad “La Belle Dame Sans Merci” (“Though the sedge is withered from the lake, / And no birds sing.”)

In addition to this essential work of “knitting,” poetic inspiration has led to some history-altering, concrete outcomes. Engell points to Henry David Thoreau, the Harvard class of 1837 graduate who, in addition to his famous essays and journals, penned many poems celebrating the natural phenomena he closely observed. “We wouldn’t have national parks if it weren’t for Thoreau. John Muir read Thoreau, read Wordsworth. There’s a whole lineage here.”

Both Warren and Engell point to the work of A.R. Ammons, one of the most important poets of the latter twentieth century, as an example. Ammons was trained as a chemist; humans’ relationship with the natural world was one of his primary obsessions. Their colleague Stephen Burt, professor of English, explained in a 2008 essay how one of Ammons’ poems (“An Improvisation for Jerald Bullis”) syncs up the human with larger natural time scales: “Each day, each year, from a nonhuman perspective, includes a multitude of deaths, and each unit of time implies its own renewals: there are, in each year, ‘so many falls all summer and / even earlier in earliest spring and / later falls than fall.’ On each scale—a season, a

“It Sifts from Leaden Sieves
– Emily Dickinson

It sifts from Leaden Sieves -
It powders all the Wood.
It fills with Alabaster Wool
The Wrinkles of the Road -

It makes an even Face
Of Mountain, and of Plain -
Unbroken Forehead from the East
Unto the East again -

It reaches to the Fence -
It wraps it Rail by Rail
Till it is lost in Fleeces -
It deals Celestial Vail

To Stump, and Stack - and Stem -
A Summer’s empty Room -
Acres of Joints, where Harvests were,
Recordless, but for them -

It Ruffles Wrists of Posts
As Ankles of a Queen -
Then stills it’s Artisans -
lke Ghosts -
Denying they have been -

poets are accordingly exploring new ways to express the human experience of crises like rapid biodiversity loss, or climate change. The latter especially unfolds on time scales that are difficult to imagine, well beyond a single human lifespan. But climate change can also manifest suddenly, through tipping points and punctuated equilibria, terrible storms and heat waves. Poets are uniquely equipped to help us recognize and process these changes. “The problems of climate seem to affect us at a different speed from other problems,” notes Andrew Warren, the Loeb associate professor of the humanities, “and poetry is all about sensitizing us to changes and events that happen more slowly or more quickly than our default settings typically register. It makes sense that they might speak to each other.”

“A keen eye for observation
The modern descendants of that lineage live and write in a world where natural systems seem to be changing more rapidly than ever. Contemporary

James Engell, Gurney professor of English literature and professor of comparative literature.

“They ask me why I’m interested in environmental studies, as if being interested [in that subject and] literature is a kind of odd-ball thing…but I’ve said that modern environmental consciousness in many ways begins with poets.”
moment, a life span—Ammons has found symbols for persistence: ways to imagine conclusions, and then to go on.”

“One of the things that poets do is that they observe keenly,” Engell says. “They see. And they don’t see in the way a scientist always sees. But they see in a way that breaks habits of perception. And when you break a habit of perception you can see new connections.”

As another example of this perceptive power, Engell cites the work of Seamus Heaney, the celebrated late Irish poet and Nobel laureate who started teaching as a visiting professor at Harvard in 1979; served as the Boylston professor of oratory and rhetoric from 1984 to 1995; and the Ralph Waldo Emerson poet-in-residence until 2006. Heaney’s short poem “Höfn” begins:

“The three-tongued glacier has begun to melt. / What will we do, they ask, / when boulder-melt / Comes wallowing across the delta flats / And the miles-deep shag ice makes its move?”

“It’s about a glacier that seems to be advancing on a little harbor town, apparently calving, melting,” Engell explains. The poem simultaneously communicates a deep sense of unease at the evidence of our own power—we’re melting the glacier—and an abiding awe at the unfeeling, implacable, freezing power of the ice itself. “Seamus is a person who understood perfectly what was going on in the world. He didn’t just write that poem because he decided it would be picturesque or quaint. He was a person deeply informed by history, a person very interested in science.”

Engell and Warren both hold up the poetry of the current Boylston professor of oratory and rhetoric, their colleague Jorie Graham, as work that engages deeply with the existentially fraught subject of global environmental disruption.

To confront an all-encompassing phenomenon like climate change head-on is too disorienting, too vast in scope and consequence. “Poetry lives by specifics,” Engell says. “It lives by images, it lives by the eye and the ear and the sense of our senses. Without that it tends pretty quickly to lose its appeal. There’s that old Greek myth: when Antaeus is wrestling and he’s lifted off the earth he loses his strength because he’s no longer rooted in the earth. But then when he’s let down the

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**Embodies**

– Jorie Graham, 1950

Deep autumn & the mistake occurs, the plum tree blossoms, twelve blossoms on three different branches, which for us, personally, means none this coming spring or perhaps none on just those branches on which just now lands, suddenly, a grey-gold migratory bird—still here?—crisping, multiplying the wrong air, shifting branches with small hops, then stilling—very still—breathing into this oxygen which also pockets my looking hard, just that, takes it in, also my thinking which I try to seal off, my humanity, I was not a mistake is what my humanity thinks, I cannot go somewhere else than this body, the afterwards of each of these instants is just another instant, breathe, breathe, my cells reach out; I multiply on the face of the earth, on the mud—I can see my prints on the sweet bluish mud—where I was just standing and reaching to see if those really were blossoms, I thought perhaps paper from wind, & the sadness in me is that of forced parting, as when I loved a personal love, which now seems unthinkable, & I look at the gate, how open it is, in it the very fact of God as invention seems to sit, fast, as in its saddle, so comfortable—& where does the road out of it go—& are those torn wires hanging from the limbs—& the voice I heard once after I passed what I thought was a sleeping man, the curse muttered out, & the cage after they have let the creatures out, they are elsewhere, in one of the other rings, the ring with the empty cage is gleaming, the cage is to be looked at; grieving, for nothing, your pilgrimage ends here, we are islands, we should beget nothing & what am I to do with my imagination—& the person in me trembles—& there is still innocence, it is starting up somewhere even now, and the strange swelling of the so-called Milky Way, and the sound of the wings of the bird as it lifts off suddenly, & how it is going somewhere precise, & that precision, & how I no longer can say for sure that it knows nothing, flaming, razory, the feathered serpent I saw as a child, of stone, & how it stares back at me from the height of its pyramid, & the blood flowing from the sacrifice, & the oracles dragging hooks through the hearts in order to say what is coming, what is true, & all the blood, millennia, drained to stave off the future, stave off, & the armies on the far plains, the gleam off their armor now in this bird’s eye, as it flies towards me then over, & the sound of the thousands of men assembled at all cost now the sound of the bird lifting, thick, rustling where it flies over—only see, it is a hawk after all, I had not seen clearly, it has gone to hunt in the next field, & the chlorophyll is coursing, & the sun is sucked in, & the chief priest walks away now where what remains of the body is left as is customary for the local birds.
strength flows into him from the earth. And poetry needs that.”

Graham touches the earth in this way in her poem “Embodies,” from her 2008 collection *Sea Change*, zooming in on a particular tree to broach a larger, foreboding question:

“Deep autumn & the mistake occurs, the plum tree blossoms, twelve / blossoms on three different / branches, which for us, personally, means none this coming spring or perhaps none on / just those branches on which / just now / lands, suddenly, a grey-gold migratory bird – still here? – crisping / multiplying the wrong / air…”

When *Sea Change* was published, Graham told a interviewer on Poets.org that the book was her attempt to describe for future generations inhabiting a warmer world what our present-day experience—with ample water, say, and the regular march of seasons—was like. “Sometimes I feel I am living an extended farewell,” she said, “where my eventual disappearance, my mortal nature, normally a deep human concern, has been washed away by my fear for the deeper mortality—the extinction of other species, and of the natural world itself. I cannot look at the world hard enough. My love for it has never been so directed. I can take nothing for granted.”

**Poetry’s past and future**

Gillian Osborne, an incoming HUCE fellow whose scholarship focuses on the intersection of nineteenth-century literature and botanical inquiry, notes that these mounting changes inevitably cast our collective glance backward. “Climate change is changing our understanding of the future, but also about how deep our past is,” she says. “When does the modern era start? When do we start releasing greenhouse gases, when does the weather start changing?” One of Osborne’s own scholarly investigations has to do with Thoreau’s interest in “recovering a deep American history”—one that includes the continent’s plant life and the experience of its native peoples.

Poetry is more foundation to that deep American past than we might realize. Elisa New recalls filming a visit to Pamet Harbor on Cape Cod, the spot where the members of the Mayflower Party got off the ship on their second day in the New World, looking for a good place to live. They decided it was too shallow for a port.

“So what did they do? They began to write poetry about the environment! Some of that poetry is in prose, expressing their astonishment at the fecundity of this new world. It’s the natural world that registers, from first contact.”

Poetry about the environment has a deep future, too. New’s next project is a partnership with the Harvard School of Education to craft a special course for K–12 teachers and students, called “The Poetry of Earth, Sea and Sky,” which she thinks of as a “sustained dialogue between poetry and the environmental sciences.”

Meanwhile, Osborne is co-editing an upcoming anthology on “ecopoetics”; she notes that there are many poets and scholars today doing vital work to actively confront unsettling questions about our impact on other species and on the climate, and about seismically shifting modes of thinking about humans’ place in the natural world. She cites the work of both Ed Roberson (particularly his 2010 collection *To See the Earth Before the End of the World*), and of Juliana Spahr, a poet “who is really thinking about how to deal with loss on this scale.”

Dickinson and her heirs may not be
scientists, but the work of Harvard’s humanists prove they are indeed scientists’ “natural allies.” Poets help us all process and give meaning to the changes measured by science. And they help us decide where to train our attention among a compounding profusion of data, and motivate us to act to protect the natural world.

“I am like all those people who feel like the ‘firehose’ is trained on me—it’s hard to imagine the largeness of the crisis, hard for me to assimilate,” Elisa New admits. “But when I read about the earth, and our environmental predicament through these poets, I not only love it more, and value the precious endowment of the natural world more, but I feel as though I have my own purchase on it.”

**FACULTY PROFILE**

**Ali Malkawi**

Ali Malkawi, Professor of Architectural Technology at Harvard’s Graduate School of Design and Founding Director of the new Center for Green Buildings and Cities (CGBC), is passionate about dispelling the many myths surrounding sustainable design. If the greener solution is not the cheaper one, he emphasizes, you are doing something wrong. This idea is at the core of Malkawi’s research agenda. Having lived and worked internationally and in several different regions of the United States, he is keenly aware that buildings must suit their environments—that a “one-size-fits-all” approach to the built environment bypasses the potential for design-based innovation. Raised in Jordan (with several siblings who also went on to become architects and engineers), he earned a B.S. in architectural engineering and environmental design from Jordan University of Science and Technology, followed by a Master’s in architecture from the University of Colorado, and then a Ph.D. from the Georgia Institute of Technology in architectural technology, artificial intelligence, and mechanical engineering. As a graduate student, he specialized in building simulation—using computational and software tools that can predict, analyze, and improve a building’s performance. He taught at Georgia Tech, the University of Michigan, and the University of Pennsylvania, where he chaired the Ph.D. Program in Architecture and founded and directed a center focusing on building simulation and energy studies, before joining the GSD faculty in 2013.

His work takes him on the road frequently, often as a consultant on diverse projects including an airport terminal in Mexico, a Ferrari factory in Italy, the World Trade Center in New York City, and developing a performance-based building rating system for the state of Qatar. From his international perspective on the built environment, Malkawi observes that while some issues do affect buildings worldwide, other challenges are very local and require sensitivity to the immediate climate, terrain, and cultural context. Globalization can make it more difficult to retain and cultivate this important sensitivity. Whereas the United States faces the challenge of retrofitting its existing transportation and building infrastructure, newly industrialized countries (e.g. China, Brazil, India) have both the challenge and the opportunity to build better infrastructure from the ground up, benefiting from the increased global emphasis on sustainability that Ali dates to the early 2000s.

What would it mean to rethink—as Malkawi and the CGBC want to do—the function of buildings and cities? As a start, Malkawi says, we might view them not solely as consumers of energy and resources, but as resources in themselves. Take the example of the CGBC’s new home, a 1940s house on Sumner Road, just behind the GSD. Retrofitting such an old house for energy-efficiency is already a challenge, and achieving zero cooling and heating status is an even greater one. But on Sumner Road, the goal is to make the house a net producer of energy. As Malkawi told *Architectural Record*, “We’re not going easy on ourselves. We are looking at carbon emissions associated with our materials from fabrication to demolition. If you think about materials that way, you’ll want to use less of everything.” Buildings, he emphasizes, are not like cars—they are not self-contained capsules that can be engineered, built, and then deployed. Rather, buildings have symbiotic relationships with both their environments and their occupants, with thousands of different variables influencing performance, environmental impact, and comfort on a daily, seasonal, and long-term basis. With that guiding principle, Malkawi is committed to rethinking how buildings are designed, constructed and operated through long-term research and commitment to architectural education, and sees the CGBC as occupying a unique position from which to influence future generations of architects and planners.

— Mariel Wolfson
Daniel Schrag: Diane, *O.P.C.*, Eve Ensler’s play at the A.R.T. this past fall, wasn’t by any means the first A.R.T. production that had an environmental theme, but in some way, you said when you introduced it that it was the first “ecotheater.” What did you mean by that?

Diane Paulus: Because Eve’s play dealt with issues of consumerism and waste, we decided that as an institution, we had to “walk the walk” and embrace a culture of reuse and sustainability throughout the entire creation of the production. We decided not to print programs for the show, and we also stopped selling bottled water in our lobby. Rather than ordering wood, our scenic artists took inspiration, and their raw materials, from local waste—and as a result our set was composed of 80% recycled materials. Eve was a galvanizing force at the theater—she helped us think critically about our own impact on the environment.

During my time here at A.R.T., I have been interested in programming that tackles the important issues of our day. I look at theater as an opportunity to provoke dialogue and catalyze discussions around important subjects. That is one the guiding principles behind the artistic choices I’ve made, and where my heart is in terms of artists I invite to make theater here.

“I look at theater as an opportunity to provoke dialogue and catalyze discussions around important subjects. That is one the guiding principles behind the artistic choices I’ve made, and where my heart is in terms of artists I invite to make theater here.”

This is about getting everybody thinking about the environment—including artists who hadn’t thought about the environment previously. How can we make issues of climate change and the planet part of our reflexes as artists? How can they enter our creative process and our creative thinking, and become one of the constants when we think about the work we make? Eve Ensler is already committed to the cause—she’s already activated as an artist. And I look at our partnership as an opportunity not only to bring artists who are already thinking about these issues, but also to raise awareness and activate artists.

Schrag: So, we were sitting at dinner last year, and you cautiously asked me whether the Center for the Environment would be interested in sponsoring playwrights and artists to create works here at Harvard. How long have you been thinking about that idea?

Paulus: We don’t have a regular commissioning program at the A.R.T., and it’s something that I realized we were lacking. I’m very interested in how we can change the assembly line of creating a production. We tend to think about bringing the expert in at the end of the process to comment on the production or lead a post-performance discussion. And I thought, “What if we...
change that assembly line and bring in a leader in a field, or a leader in research—or, like you said—an economist, a thinker, a writer, a public policymaker at the beginning of the process? How could those experts actually be part of the generation of a creative project?"

So I’d been thinking about new ways of commissioning work, and your stepping forward was catalytic. We’re putting into motion the idea of not only commissioning new work, but also doing it in partnership with experts at the Center for the Environment and the rest of Harvard.

**Schrag:** I think that to me what’s so exciting is that it’s another mode of interaction between the A.R.T. and our university. Frankly, the A.R.T. is fabulous for those of us who go to the performances. We are the consumers of what you produce and love it, but I think there’s a broad thirst—not just among the English faculty and the art history faculty, but among all of the faculty—to experience or take part in the artistic process. Not directly, and again as I’ve told you, I don’t think it’s a good idea for scientists to tell artists how to talk about climate change. I have a lot of faith that the interaction will lead to something interesting, though I hope it’ll surprise us. I mean, it shouldn’t be linear. It should be surprising and unusual.

**Paulus:** Yes, exactly.

**Schrag:** Ryan, do you want to weigh in on this mode of interaction between A.R.T. and the University? You’ve been part of this university community for a long time.

**Ryan McKittrick:** To echo what Diane said, what’s so exciting here is that we’re not just bringing faculty members in at the end—it’s at the beginning and middle and end of the process. We did something like this with our Civil War Project, a multi-year initiative that is just coming to an end. As part of that project, we led a series of roundtable discussions with artists and professors from all around the University, who got together to talk about a wide range of topics related to the Civil War. A number of projects in our current season at the A.R.T. developed out of that process. We’ve already started talking with artists we know about our collaboration with the Center for the Environment—and they’ve all immediately responded to the idea. They’re excited not only about the idea of creating work that’s related to the environment, but also about being in dialogue with faculty members from around the University as they’re creating a piece. We found that with the Civil War Project, the professors were inspired by the artists, and the artists were inspired by the professors.

**Paulus:** Very much of a two-way street—it was really thrilling to see that interaction.

**McKittrick:** And it also means that when you involve people over a long period of time, rather than just after the production has opened, faculty have a stake in the work, and there’s a possibility to design courses around [it]...this allows us to integrate the projects into the life of the University in a completely different way.

**Schrag:** I think that’s exactly right.

**Diane Borger:** The one thing I want to add, is that when we look at the work that we’ve done here that we consider to be the most successful on artistic grounds, it’s work that we’ve put the time into developing. And that’s another thing that’s fantastic about partnering with you, because it gives us the opportunity to be thinking two or three years in advance, and theater doesn’t always do that. I know universities do, but we often are in the mode of, “what just came through the letter box … let’s get it on stage.” And so I think that it will lead to better work: thematic work that we feel is so important, but also the quality of work has a chance of being higher.

**Schrag:** I hope that it creates an atmosphere where arts are part of the conversation—over in my part of campus, too.

"When you involve people over a long period of time, rather than just after the production has opened, faculty have a stake in the work, and there’s a possibility to design courses around [it]...this allows us to integrate the projects into the life of the University in a completely different way."
That it’s not something you dabble with every now and then, or you go to the theater once every couple months, but it’s actually something that’s part of our regular conversation.

Borger: I think that’s really important, and often we find that our natural partners are scientists—though it may seem counterintuitive at first glance. We’re all trying to solve a problem, or explore something that we don’t know.

And just to add to that, this idea of making art a part of the conversation—that’s been our fight here at the A.R.T., and it’s the fight of arts in America right now. The arts are not the add-on sort of luxury entertainment for diversion that can be cut out of a school curriculum because you don’t need it.

Paulus: We really—on the artist end of it—need to change the perception of arts in America. Otherwise, we’re in trouble. This kind of partnership is critical because it suggests that an arts component is needed for the most important political, social, and scientific inquiries. It speaks volumes about the role the arts play in our lives as citizens engaged with our planet.

That’s a huge symbolic gesture that I hope will reverberate from our partnership not only throughout the arts here at Harvard, but arts in the public education system across the country, which is in need of this kind of example.

Schrag: I think it’s really exciting. Of course, it also means the pressure’s on—you have to produce something beautiful and inspiring and impactful.

Borger: Yes!

Schrag: Last night, I attended the opening of The Last Two People on Earth: An Apocalyptic Vaudeville. To put it simply, I was stunned. Who would have thought that a musical with almost no spoken words could have made such a powerful statement about the future? It seems like a perfect example of how artists see the world in a slightly different way, and a perfect example of what we are trying to achieve. How did this production come about?

Borger: The producer Staci Levine talked to us in 2011 about an idea that Mandy Patinkin and Taylor Mac were exploring—they’d met and loved each other’s voices and asked director Susan Stroman to join in with them to make a piece from scratch based on the music they both loved. We were of course intrigued as they are such phenomenal artists so we agreed to support it. The first workshop was in 2012, and they continued to work on developing the show whenever their busy schedules permitted over the next couple of years, with a couple of workshop runs along the way. It is thrilling to see what it’s become, and we were delighted to premiere it at the Loeb.

McKittrick: It’s a piece about companionship and survival after a flood—a source of hope and inspiration, perhaps, as we think about the challenges we face now and in the future.

Schrag: So let’s just briefly touch base on what’s in the pipeline. There’s some exciting work developing around the theme of indigenous people and nature. Do you want to say a few words about that?

Borger: Do you remember the genesis of the NOMAD project?

Schrag: Yes, I was a videoconference participant in one of the early meetings in New York.

Borger: It started with the photographer Russell James, who grew up in Western Australia and felt he had to reconcile his upbringing with what indigenous people in Australia had gone through. And inevitably, when you talk with aborigines, the conversation turns to land, and how to preserve it. And now Russell’s work has expanded into this amazing collaboration to promote art and artists from indigenous and marginalized communities around the world. We are working with Russell and his organization, NOMAD, to develop a piece that explores the shared spaces between indigenous and non-indigenous cultures. Karole Armitage, a dancer and Tony-nominated choreographer, is coming to campus in September as a Radcliffe Fellow, and will help us move along our thinking on our
FACULTY PROFILE

Elizabeth Wolkovich

Elizabeth (Lizzie) Wolkovich grew up in rural New Hampshire, but her early excitement about science didn’t come from her backyard. It came from her television. “I used to love NOVA,” says Wolkovich, assistant professor of organismic and evolutionary biology, of the long-running PBS series. She particularly remembers an episode that profiled researchers at the Keck Observatory in Hawaii. “They were classic scientists—people running around with backpacks, poorly dressed, running up and down the stairs in the observatory and looking at the sky. I thought that looked awesome.” She always wanted, she says, a job where she could wear a backpack.

It’s now part of her uniform as a field ecologist, where her work focuses on the effect of climate change on various plant species. “What we’ve fundamentally done with climate change is altered how organisms experience time,” she says. Plants have longer growing seasons, animals have shifted their reproduction and hibernation schedules—all these critical facets of survival have been distorted. What does this mean for the future of these communities? “I don’t think we, as scientists, have the full set of theories and knowledge we need to predict that yet.”

Addressing that deficit requires data. As part of her postdoctoral work, Wolkovich pulled together historical observations on phenology—when plants bud and flower—to better understand the effect of climate change on both native and invasive species. Wolkovich and her research partners compiled datasets that tracked all of the species in a variety of sites—including author Henry David Thoreau’s recordings from Concord, Massachusetts in the 1860s—to create their own phenological database. They used it to confront a question fundamental to the ecology of climate change: as the seasons change, will invasive species compete more successfully than native plants?

Wolkovich’s hypothesis argued that, yes, invasive species might do better because their inherent flexibility makes them able to react more quickly to earlier seasons than native species. One of the most extreme examples of this ability came from Concord—in the last 150 years, they found, the average day that a native species begins to bloom hasn’t changed. Exotic species, though, according to their data, have made it easier to be an exotic species and invade a community,” says Wolkovich. “It would suggest that the exotics are getting a leg up in performance through climate change, and perhaps humans have made it easier to be an exotic species and invade a community,” says Wolkovich. “If we continue at this rate of warming, it may be hard to have the time and resources to manage how much exotic species will increase.”

At her lab, Wolkovich is now trying to figure out the impact of that growth on plant communities. “What does the trend in climate—where we’re shifting spring forward—mean to coexistence?” says Wolkovich. “What does it mean to the types of communities that we’ll have in the future?”

— Dan Morrell
O.P.C.

A HUCE – A.R.T. Collaboration
O.P.C., a new comedy written by Eve Ensler (The Vagina Monologues), delves into the prickly intersection of consumption and politics, rebellion and conformity, and asks, “How are we to survive as a species if we insist on destroying the world we love?”

Produced by Harvard’s A.R.T. (American Repertory Theater), the play is the first act in a three-year collaboration with HUCE to foster cross-disciplinary dialogue on climate change and the arts and seeks to foster far-reaching engagement throughout the University community.

The satirical plot of O.P.C. follows Romi, a freegan, whose lifestyle of anti-consumerism—squatting in an abandoned building and eating only what she finds discarded in dumpsters—pits her in conflict with her mother, a Democratic candidate who’s toeing the party line. Romi struggles with what is later diagnosed as a curable disease: obsessive political correctness (O.P.C.). The mother-daughter dichotomy exemplifies the struggle (and sometimes delicate balance) between liberalism and radicalism.

All aspects of the play’s production drew on the play’s theme of waste reduction and environmental awareness. Recycled, upcycled, and found objects formed the entire set, from the wooden pallets that served as the backdrop and buildings, to cardboard boxes from local Cambridge grocery stores, plastic bottles strung as garland decoration, to one of Romi’s dresses, made entirely from old yoga mats.

Throughout the run of the play, the A.R.T. welcomed audiences to a series of free events, including skillshares, an ongoing freecycle, and an interactive lobby experience featuring artists from the local community. Several post-production discussions included HUCE Director Dan Schrag, Professor of Government Stephen Ansolabehere, Divinity School lecturer Daniel McKanan, and Naomi Klein, award winning author of This Changes Everything: Capitalism vs. The Climate. These conversations explored the environmental, economic, and socio-cultural themes threaded into O.P.C.’s narrative.

The collaboration between HUCE and the A.R.T. (see page 18 for more information) will extend into future seasons to include more roundtable discussions and the development of new works that grow out of these conversations.
CLIMATE WEEK AT HARVARD

Harvard University hosted the inaugural Climate Week from April 6-10, a weeklong series of events across all of Harvard’s Schools that explored the many dimensions of climate change. The week’s program, recapped below, drew more than 1,000 participants to more than a dozen events. View videos from the talks at our website, www.environment.harvard.edu.

• Each morning a Climate Science Breakfast featured a discussion with Harvard faculty members from the School of Engineering/Department of Earth and Planetary Sciences, including Steven Wofsy, Brian F. Farrell, Robin Wordsworth, James Anderson, and Zhiming Kuang.
• The Harvard Graduate School of Education presented “Educating for Climate Change in K-12: Discussion and Sharing of Resources” with Tina Grotzer, associate professor of education at Harvard University.
• The Harvard Law School welcomed Dan Dudek, vice president, Environmental Defense Fund–China office, for a talk on “The Long March to Reducing Carbon Emissions in China.” Commentary was provided by Harvard Law School’s Jody Freeman, Cox professor of law and Richard Lazarus, Aibel professor of law.
• Laurel Kearns, associate professor of sociology and religion and environmental studies, Drew Theological School, presented the Harvard Divinity School talk, “Changing the Religious Climate: The Role of Faith Groups in Climate Change Awareness and Action.”
• The Belfer Center at the Harvard Kennedy School welcomed Amory B. Lovins, chairman/chief scientist of the Rocky Mountain Institute, for a discussion on “Reinventing Fire: Profitable Low-Carbon Futures for the U.S. and China.” Moderated by Meghan O’Sullivan, Kirkpatrick professor of the practice of international affairs.
**2015 Undergraduate Summer Research Award Winners**

The Center’s annual Undergraduate Summer Research Fund provides scholarships for students to complete research across a variety of disciplines. This year, the Center offered twelve assistantships for research with Harvard faculty and twelve awards for independent research to undergraduate concentrators in Chemistry, Environmental Science & Public Policy, Engineering Sciences, Social Studies, Earth & Planetary Sciences, Computer Science, Government, Integrative Biology, Physics, Economics, Chemistry and Physics, and East Asian Studies. Summer research opportunities are made possible by the generous support of Bertram Cohn ’47, Barbara “B.” Wu ’81 (Ph.D.), and Eric Larson ’77.

- **Tyler Barringer** ’16, will study green buildings, cities, and the electric grid with Professor Na Li.
- **Savannah Butler** ’17, “Understanding the Behavior of Various Trace Gases within a Forest Canopy” with Professor Amory Lovins.
- **Louise Eisenach** ’16, “The Characterization and Analysis of Membranes for Applications in a Redox Flow Battery” with Professor Steven Wofsy.
- **Harold Eyster** ’16, “Plant Invasion Ecology Research in Europe” with Professor Andrew Richardson.
- **Sabrina Ghouse** ’15, “A Changing Sphere: Visual Representations in Environmental Discourse” with Professor Diane Davis.
- **Alexander Hem** ’16, will work with Professor Jerry Mitrovica on “Holocene Equatorial Sea-Level Highstands.”
- **Claudia Huang** ’18, “The Development of a 3D Molecular Visualization for the Clean Energy Project Database” with Professor Ann Forsyth.
- **Jung Jae (Jason) Kwon** ’16, will study the political and social responses in China to environmental problems with Professors Steven Ansolabehere and Dustin Tingley.
- **Matthew Luongo** ’17, will work with Professor Steven Wojsy on the project, “Analysis of Eddy-Flux and Aircraft Concentration Measurements of Carbon Dioxide and Methane on the North Slope of Alaska.”
- **Carolyn O’Connor** ’18, will work with Professor Elizabeth Wolkovich to study “Predicting Future Northeastern Landscapes: Building from traits to species and communities.”
- **Woojin Park** ’17, will work on the project “Housing as an Effect Modifier of Air Pollution and Health Risk” under the mentorship of Professor Gary Adamkiewicz.
- **Dhruv Pillai** ’17, will work with Professor Michael Aziz on the project, “Investigation of Redox-Active Organic Molecules in Pseudocapacitors.”
- **Ellen Robo** ’16, “Building a Model of Clouds Associated with the Hadley Circulation and Testing their Climate Feedbacks” with Professor Na Li.
- **Evan Sandhoefner** ’17, “Climate Change, Labor Productivity, and Global Poverty: Temperature stress and academic performance in NYC high schools” with Professor Alan Aspuru-Guzik.
- **Emma Schwartz** ’18, will work with Professor Chad Vecitis on “Oxidative Analysis of AFF Precursor Compounds in Cape Cod Groundwater by GC/MS/MS.”
- **Claire Stolz** ’16, will study growth limitation in New England forest trees with Professor Andrew Richardson.
- **Alvaro Valle** ’18, will work on the project “Separator Development for Organic Molecule-Based Flow Batteries” with Professor Michael Aziz.
- **Wendy Woodin** ’17, will work with Professor Alan Aspuru-Guzik on “Development of Tools to Facilitate Interaction with the Database of the Clean Energy Project.”
- **Sohyun (Kate) Yoon** ’18, will partner with Professor Diane Davis to study the role of political leadership in transforming urban transportation.
Introducing the 2015-17 Environmental Fellows

The Center for the Environment extends a warm welcome to its incoming cohort of Environmental Fellows, who will begin their research appointments at the Center this fall. Fellows work for two years with Harvard faculty members to advance research on a wide variety of environmental topics and strengthen connections across the University’s academic disciplines. Fellows also meet twice a month for Fellows dinners, which bring them together with a larger, diverse group of Harvard faculty for discussions on environmental issues. Visit our website, www.environment.harvard.edu, to learn more about the Environmental Fellows program or to apply to join the 2016-18 cohort.

Sebastian Eastham is an environmental scientist interested in the transport and impacts of pollutants and trace species over long distances through the atmosphere. Sebastian received an MEng. in aerospace and aerothermal engineering from Cambridge University in 2011, and a Ph.D. from the MIT Department of Aeronautics and Astronautics in 2015. Sebastian will work with Daniel Jacob in the School of Engineering and Applied Sciences to investigate the failure of Eulerian atmospheric models to reproduce observed synoptic-scale transport of pollution in narrow plumes and quasi-horizontal layers. The goal of this research is to identify new and efficient modeling techniques capable of accurately reproducing and maintaining the observed high chemical gradients over global distances without requiring prohibitively fine global grid resolutions.

Evan Herrnstadt is an economist interested in the design and performance of energy and natural resource markets. Evan earned a B.S. in economics and political science from the University of Iowa in 2006. After graduating, he was a research assistant at Resources for the Future in Washington, D.C., where he worked on energy and climate policy. He moved to the University of Michigan in 2009, where he earned a M.A. in economics in 2011, and a Ph.D. in economics in 2015. As an Environmental Fellow, Evan will work with Ariel Pakes of the Department of Economics on the implications of common contracting practices in the oil and natural gas drilling industry. He will also develop improved empirical tools for the analysis of data from natural resource auctions. These insights and tools will improve our understanding of important institutions governing energy production, and help to predict the response of the energy industry to climate and environmental policies.

Melissa Kemp is an evolutionary biologist who uses the fossil record and historical data to investigate species responses to global change phenomena. Melissa earned her B.A. in biology from Williams College in 2010 and her Ph.D. in biology from Stanford University in 2015. As an Environmental Fellow, Melissa will work with Jonathan Losos of the Department of Organismic and Evolutionary Biology to investigate how past global change forces have altered species distributions in Anolis lizards. This will reveal population trajectories before, during, and after environmental perturbations are encountered, and provide a framework for evaluating future range shifts.

Brian Lander employs textual, archaeological, and paleoecological sources to study the human impact on the environment in ancient China. Brian received a B.A. in history from the University of Victoria, an M.A. in East Asian studies from McGill University and a Ph.D. in Chinese history from Columbia University. As an Environmental Fellow, Brian will work with Rowan Flad of the Department of Anthropology to study the environmental history of central China’s wetlands. The Yangzi valley once had some of the largest wetlands in the world, but these were gradually transformed into rice paddies and fish farms and the region is now home to hundreds of millions of people. This research seeks to explore this process from the origins of agriculture to around 600 CE.

Daniel Madigan is a marine ecologist interested in the interaction between pelagic ecology, contaminant transfer in food webs, fisheries, and anthropogenic environmental change. Dan earned a B.A. in biology from Dartmouth College in 2005 and a Ph.D. in biology from Stanford University in 2013. As a HUCE Environmental Fellow, Madigan will work with Elsie Sunderland of the Harvard T.H. Chan School of Public Health and the School of Engineering and Applied Sciences and James McCarthy of the Department of Organismic and Evolutionary Biology. His

2013-15 Environmental Fellows

Environmental Fellows Charles Willis, Nathaniel Mueller, and Pedram Hassanzadeh capped off their time in the program with an April 29 dinner presentation of their research. They were joined by Harvard faculty and continuing Fellows, who together with the new cohort, will comprise a community of eleven energy and environmental scholars.

-Pictured, left to right: Marie-Abèle Bind, Charles Willis, Zoe Nyssa, Tim Cronin, Yige Zhang, and Nathaniel Mueller. Pedram Hassanzadeh not pictured.
work at HUCE will focus on understanding the impacts of changing contaminant levels in the environment on the overall health of global fisheries. Dan will be part of an interdisciplinary team that also includes researchers at MIT and UBC to combine contaminant emissions, atmospheric and ocean transport, ocean ecology, and fisheries dynamics into a single “unified global model” that assesses the present and future effects of contaminants on global fisheries and potential harmful consequences.

Laura Martin is a historian and ecologist who studies the cultural and political dimensions of ecological management. Laura earned an Sc.B. in biophysics from Brown University in 2006, an M.S. in natural resources from Cornell University in 2010, and a Ph.D. in natural resources from Cornell in 2015. As an Environmental Fellow, Laura will work with Peter Galison from the Department of the History of Science. She plans to develop her dissertation research into a book that explores how ecological restoration became such a widespread and important environmental practice. She will also begin a project on the use of counter-terrorism technologies for international biodiversity protection. By fostering conversations among scientists and humanists, Laura hopes to generate research that can guide twenty-first-century environmental management.

Gillian Osborne is a literary scholar interested in nineteenth-century American and Romantic literature, the history of popular botany, and contemporary ecopoetics. Gillian holds a B.A. in comparative literature from Columbia University, and a Masters in English and Ph.D. in English and American literature from the University of California, Berkeley. As an Environmental Fellow, under the mentorship of James Engell in the Department of English, Gillian will research how exposure to Romantic science, popular botany, and an inherited uncertainty about what American literature might be, led Henry David Thoreau, Emily Dickinson, and Herman Melville to develop literary practices that valued processes of attention and openness to natural forms and experience over the creation of enduring literary works.

Environment @ Harvard
A sampling of the academic year’s events

Ongoing Series
Science & Democracy
This series, co-sponsored with the Harvard Kennedy School Program on Science, Technology, & Society, explores the benefits and potential harmful consequences of scientific/technological breakthroughs. The fall installment of the series welcomed Martin Rees, Institute of Astronomy, Cambridge University; Astronomer Royal; President, Royal Society (2005–2010). Lord Rees examined the sources of possible “global crises” for humanity—ranging from climate change to artificial intelligence—through the lenses of various disciplines. The panel discussion, which featured Sven Beckert (History), George Daley (Harvard Medical School), Jennifer Hochschild (Government), and Daniel Schrag (HUCE), then examined ways to mitigate such challenges.

The spring installment featured a discussion by Peter Thiel, Palantir Technologies; Thiel Foundation; Founders Fund; and PayPal co-founder. Together with panelists Antoine Picon (Graduate School of Design), Margo Seltzer (School of Engineering and Applied Sciences) and Samuel Moyn (Harvard Law School), Thiel discussed the role of technology in society, particularly whether our level of technology will sustain our society for the foreseeable future.

Both installments were moderated by Sheila Jasanoﬀ, Pforzheimer professor of science and technology studies at the Harvard Kennedy School.

HUCE Film Screening
Merchants of Doubt
HUCE hosted a special advance screening of the Sony Pictures documentary, Merchants of Doubt, inspired by the book of the same name co-authored by Naomi Oreskes, professor of the history of science and HUCE faculty associate. The film exposes the disinformatiﬁcation and doubt peddled by pundits-for-hire who present themselves as scientiﬁc authorities, yet instead aim to spread confusion about tobacco and, currently, climate change. Daniel Schrag (HUCE) and Katie Anderson (Edmond J. Safra Center for Ethics at Harvard), led a discussion after the film screening.

HUCE Special Lectures
The President’s Effort to Combat Climate Change Without Congress: What is EPA Proposing to Do and Is It Legal?
HUCE Harvard Law School faculty associates Jody Freeman, Cox professor of law and director, Environmental Law Program and Richard Lazarus, Abelson professor of law, explored the legality of the EPA power-plant regulations outlined in its Clean Power Plan. Perhaps the most ambitious action on climate change to date, the regulations seek to cut CO2 emissions by 30 percent from 2005 levels by 2030, with each state given flexibility in exactly how they reach the target. The discussion, moderated by HUCE Director Daniel Schrag, explored the feasibility of the plan, which Freeman and Lazarus said has the potential to radically alter the national energy scene and breathe new life into international climate change negotiations.

American Public Opinion on Climate Change: Motivated Cognition?
Stanford University social psychologist Jon Krosnick visited campus to share his survey research on climate change attitudes. In his presentation, Krosnick argued that public acceptance of climate change science is rising, but this growing consensus is not reﬂected in our domestic political system. Dustin Tingley, the Paul Sack associate professor of political economy in the Department of Government moderated the discussion.

Harvard Food+ Research Symposium
Together with the Weatherhead Center for International Affairs, the Office for Sustainability and the Sustainability Science Program at the Harvard Kennedy School, HUCE sponsored an afternoon workshop on the food research underway at Harvard. Twenty-three faculty members—including HUCE faculty associates Joyce Chaplin (History), George Church (Harvard Medical School), Ann Forsyth (Graduate School of Design), Noel Michele Holbrook (Organismic and Evolutionary Biology), Peter
Huybers (Earth and Planetary Sciences), Sheila Jasanoff (Harvard Kennedy School), Michael Kremer (Economics), Samuel Myers (Harvard School of Public Health), Daniel Schrag (Earth and Planetary Sciences / School of Engineering and Applied Sciences), Elsie Sunderland (School of Engineering and Applied Sciences) and Elizabeth Wolkovich (Organismic and Evolutionary Biology)—gave seven-minute “TED-style” talks on a variety of subjects, ranging from genetic alternatives to pesticides, to food production and politics in Africa.

Driving the Future: Combating Climate Change with Cleaner, Smarter Cars

Margo Oge, vice chairman of the board of Deltawing Technologies, and former director of the Office of Transportation Air Quality at the U.S. Environmental Protection Agency, visited campus for a talk on her recent book, which explores the new transportation technologies the world will see over the foreseeable future. Her talk gave an insider’s account of the partnerships and innovations that led to President Obama’s historic 2012 policy to target passenger vehicles, doubling their fuel efficiency by 2025. She also discussed her vision of the future of cars, with cleaner, more intelligent vehicles that produce zero emissions and average 100+ mpg.

To pursue this goal, says Oge, continued development of power train technologies and cleaner transportation infrastructure are vital.

10th Annual Plant Biology Symposium: “From Leaves to Ecosystems: Plants in a Changing World”

Hosted by the Department of Organismic and Evolutionary Biology’s Plant Biology Initiative and co-sponsored by the Center for the Environment, the two-day symposium opened with an afternoon keynote lecture by Chris Field, Carnegie Institution for Science and a leading member of the Intergovernmental Panel on Climate Change, on “Understanding, Managing and Reducing the Risks of Climate Change.” With the Earth’s temperature having already risen by one degree Celsius over the past century, many climate change effects are now unavoidable, says Field. We are now entering a period of “climate responsibility,” according to Field, where we must work to contain the effects of climate change by dramatically reducing global carbon emissions. If emissions are not curbed, he says, the planet could warm by as much as five degrees Celsius by 2100, with effects that will be much greater and more difficult to counter.

The symposium continued with a day-long series of presentations by plant biologists and researchers, including a discussion featuring Harvard Plant Biology faculty William Friedman, Noel Michele Holbrook, Paul Moorcroft, Steven Wofsy, and Andrew Richardson.