Autumn 2016

MIT CEEPR Newsletter

MIT Center for Energy and Environmental Policy Research

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MIT Center for Energy and Environmental Policy Research

As the United States prepares for a new federal administration to take office next January, the one constant in energy and environmental policy is continued uncertainty. While more specific details will only emerge over the coming months, it is safe to assume that the direction of future energy policy will mark a far-reaching departure from the guiding principles and objectives endorsed by the outgoing administration.

For the energy sector and other capital-intensive industries, such policy instability can create significant challenges for long-term investment planning. But the policy changes we can expect under the incoming administration are also likely to slow down or reverse transformational trends induced by policy and regulation, and it will be an important task for research and analysis to distinguish these from disruption driven by evolving market forces and falling technology costs. Decision making under conditions of uncertainty is a recurrent theme at MIT CEEPR, and has been a starting point of several past and ongoing research projects and working papers, as well as a dedicated conference on "Predicting the Unpredictable – Handling Uncertainty in Energy Economics and Management" organized with partners this past September in Berlin.

As the policy implications of the changing political landscape in the United States become more evident, CEEPR will, as always, provide a source of objective, fact-based analysis and a venue for balanced debate. With its international network of research affiliates and partners, moreover, it also offers a unique vantage point to engage audiences here and abroad, and bridge divergent understandings of U.S. and international policy developments. We invite you to participate in this important process, be it through our events, collaborative research projects, or direct dialogue with our staff and researchers.

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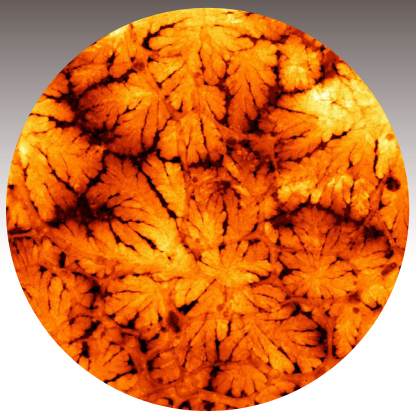

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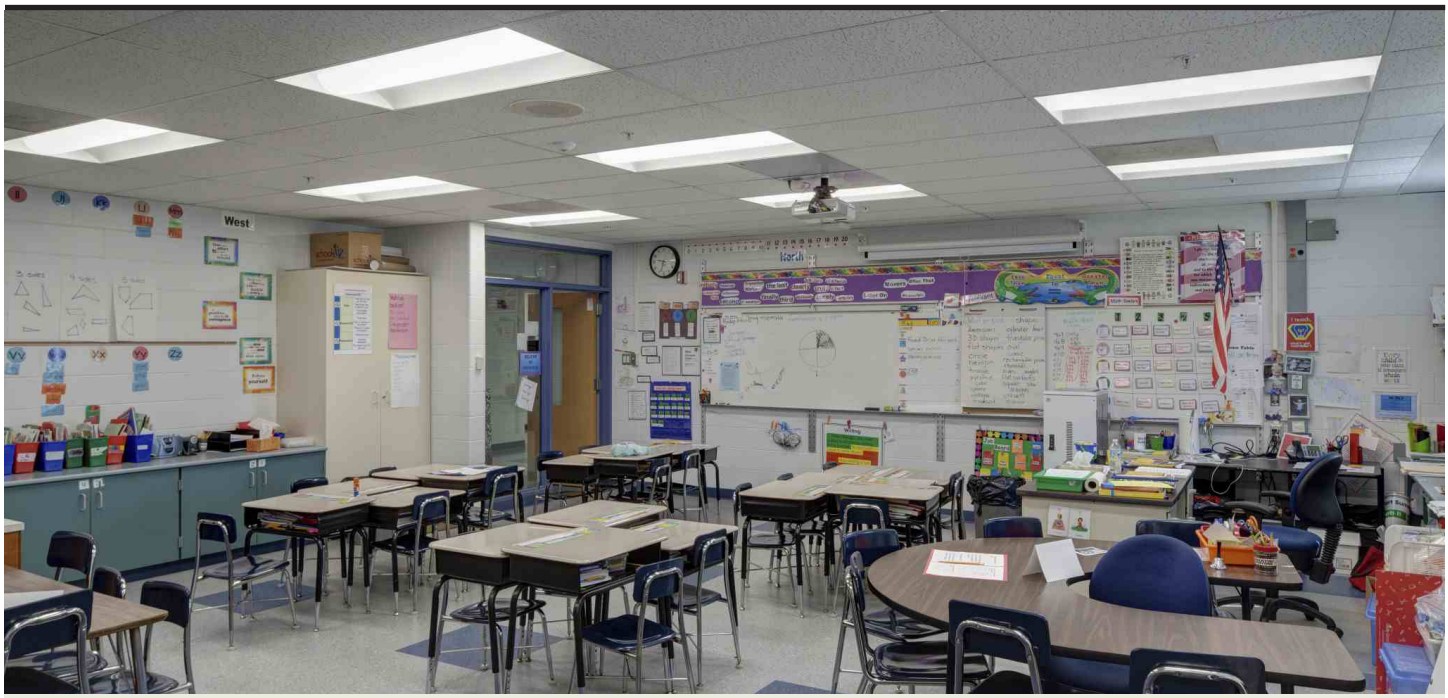
E2e Project Update: Evaluating Energy Efficiency Upgrades to K-12 Public Schools in California

by: Leila Safavi



Energy efficient lightning can lead to a 5-7% reduction in electricity use in K-12 schools during daytime hours. *Photo courtesy of Acuity Brands.*

A new working paper by Fiona Burlig, Christopher Knittel, David Rapson, Mar Reguant and Catherine Wolfram[1] studies the cost-effectiveness of energy efficiency investments in over 2,000 K-12 California public schools served by the Pacific Gas and Electric Company (PG&E). The study uses high frequency electricity metering data collected by PG&E to estimate the electricity consumption savings for schools, including using a novel machine learning approach to predict counterfactual electricity consumption in treated schools.

Focusing on lighting and HVAC upgrades, the authors find that schools with energy efficiency interventions reduced electricity consumption by 2-4% on average compared to control schools. Specifically, investments in energy efficient lighting lead to 5 to 7% reductions in electricity use in daytime hours and efficient HVAC systems produced a 2-4% daytime reduction in electricity when temperatures were highest. This decrease in consumption can result in substantial savings for public schools, although findings show that savings may be smaller than projected. While actual savings from HVAC and lighting upgrades are predicted to be 70-90% of ex-ante engineering estimates, the authors estimate that actual savings are only 15% of projected savings when a wide range of upgrades are considered. Many papers cite the discrepancy between actual and projected savings as cause for doubt on the extent to which energy efficiency can lead to reductions in emissions. However, results from the experiment show that, at least for lighting, interventions translated into real energy savings for schools and delivered a substantial part of the expected energy consumption reductions.

Looking forward to future projects, in June E2e solicited Letters of Intent for innovative economic research on critical or novel energy efficiency issues. This solicitation allocates up to $250,000 in funding per proposal and targets projects using rigorous empirical techniques, such as randomized controlled trials and high quality quasi-experimental methods, to evaluate the real-world impact of existing energy efficiency policies and programs. Five proposals have been selected to move to the next round of consideration and a full list can be found on the E2e website. Proposals span a variety of energy efficiency issues ranging from the impact of smart meter engagement on household energy savings to the effect of management practices on industrial energy use. During the next phase of review, the selected researchers will be asked to submit a complete proposal which will potentially be recommended to the Alfred P. Sloan Foundation for funding by the end of 2016.

[1] This paper will be published as a working paper in early 2017. Please visit e2e.mit.edu to learn more about this project.

The Economics of Unconventional Oil Development

by: Robert Kleinberg and Sergey Paltsev

A hydraulic fracturing rig drilling into the Bakken formation at the Williston Basin of North Dakota.

High oil prices in the first part of this decade provided a boost to U.S. oil production, which increased from about 5.5 million barrels per day (Mb/d) in 2010 to about 9.4 Mb/d in 2015. Most of the increase was due to the growth in production of unconventional (tight) oil. As a result of this rapid increase in oil production, numerous experts declared the United States to be a rival to Saudi Arabia as the world's most influential oil producer. At a time when oil prices were in the range of $100 per barrel, many analysts suggested that the cost of unconventional oil development in the US would be in the range of $60 to $90 per barrel. It was widely believed that once the oil price fell below $60 per barrel, many investments in unconventional oil projects would cease to move forward. For instance, in its editorial for the December 6, 2014 issue, *The Economist* stated that "since shale-oil wells are short-lived (output can fall by 60-70% in the first year), any slowdown in investment will quickly translate into falling production."

The $60-90 range for U.S. unconventional oil was thought to act as a shock absorber, with tight oil projects quickly coming onto production as prices increased, and dropping out of production as prices decreased through this range. With U.S. unconventional oil accounting for roughly 4% of global production, and seemingly able to respond to price signals considerably faster than conventional projects, analysts predicted that this new resource could bring welcome stability and price support to oil markets.

There is no documented evidence that OPEC acted on these assessments, but we can speculate that these considerations might have influenced their decision late in 2014 to pursue a strategy to preserve their share of the international oil market by increasing oil production. If conventional wisdom were to hold true, moderate increases in Middle East oil production, accompanied by a moderate oil price decline, would result in prompt declines of U.S. unconventional oil production, thereby preserving OPEC market share.

Reality, however, proved to be different. As the West Texas Intermediate benchmark oil price fell from $108 per barrel in mid-2014 to $32 per barrel in early 2016, U.S. oil production was sustained even as prices fell below minimum breakeven points calculated by energy economists. According to the latest energy outlook from the U.S. Energy Information Administration, tight oil production was 4.28 Mb/d for 2014 and 4.89 Mb/d for 2015. It is projected to fall to 4.27 Mb/d for 2016.

A recent CEEPR working paper by Robert Kleinberg, Sergey Paltsev, Charles Ebinger, David Hobbs, and Tim Boersma[1] offers an investigation into this phenomenon. They have found that the cost of oil production is often misstated or even misused. In many instances, the lifting cost related to the incremental cost of producing from an existing well is quoted as the cost of oil production. This calculation does not include many components of the full cost, such as exploration and development expenditures, as well as the full cost of financing. The study provides a detailed assessment of these components and proposes a standardized definition of costs with a tiered structure that includes the full cycle, the half cycle, and the lifting cost.

The study also investigates a reduction in well drilling and completion costs. These costs fell by a reported 25-30% from 2012 to 2015 in different unconventional oil basins in the U.S., contributing to the resilience in U.S. oil production. Another factor in the inelastic response of oil production is explained by an illustration from a simple field-level production model developed by the authors. The model shows that while individual well behavior in conventional and unconventional oil basins differs substantially (see the figure below), where unconventional oil wells typically decline by about 60% in the first year and 25% in the second year of production, the field-level production profiles show a similar decline once drilling is stopped.

The dynamics at the field-level is driven by a larger number of older wells that are declining more slowly. Thus, the unconventional oil fields with large legacy inventories of wells will produce substantial quantities of oil for many years even after drilling has ceased. A decision by the traditional oil producers to increase production and reduce global prices might have been driven by misunderstanding the economics of unconventional oil development, where aggregate production from unconventional sources declines more slowly than suggested by an individual well analysis, where the companies continue to produce to cover their lifting costs rather than the full-cycle costs, and where the substantial improvements in well drilling and completion help to maintain the production activities.

As the majority of U.S. unconventional oil companies continue to provide negative cash and their levels of debt service as a share of operating cash flow are increasing, it remains to be seen if the financial sector will continue to keep lending money to unconventional oil companies. In a rapidly evolving industry such as unconventional oil production, many crucial drivers remain uncertain. While our study provides a close examination of certain aspects related to the dynamics of the response, many other components related to infrastructure, capital and labor markets might affect the prospects of this industry and influence global oil prices.

[1] Robert L. Kleinberg, Sergey Paltsev, Charles K. Ebinger, David Hobbs, and Tim Boersma (2016), "Tight Oil Development Economics: Benchmarks, Breakeven Points, and Inelasticities." *CEEPR WP-2016-012*, MIT, August 2016.

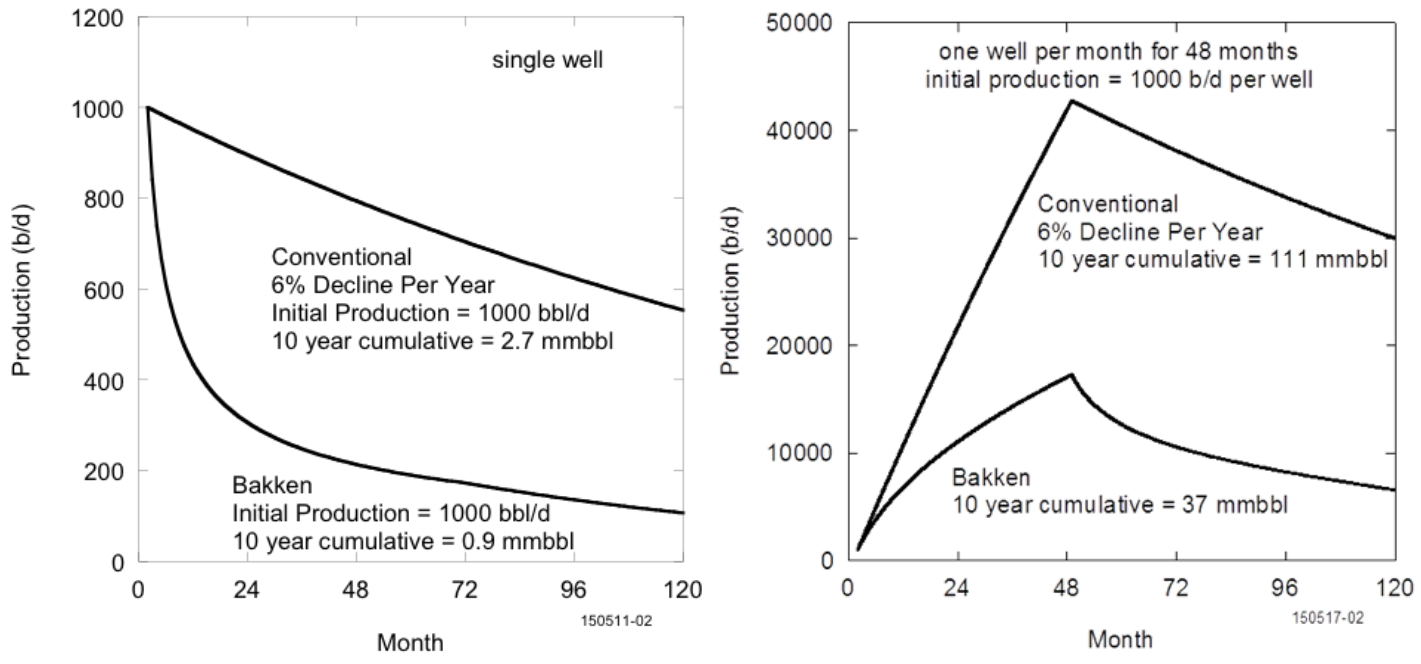


Figure: Decline curves for oil production from conventional wells and tight oil wells (left panel); field-level decline curves (right panel). For more information, see MIT CEEPR Working Paper 2016-012.

Lower Oil Prices and the U.S. Economy: Is This Time Different?

by: Christiane Baumeister and Lutz Kilian

The Qatif Central Producing Plants in Saudi Arabia. *Photo courtesy of Saudi Aramco.*

Between June 2014 and March 2016, the inflation-adjusted price of oil dropped by 66%, yet average U.S. economic growth accelerated only slightly from 1.8% at annual rates before the oil price decline to 2.2% thereafter. The fact that this decline in the price of oil failed to translate into faster U.S. economic growth has puzzled many observers who expected lower oil prices to create a boom in the U.S. economy. In a recent CEEPR Working Paper titled "Lower Oil Prices and the U.S. Economy: Is This Time Different?",[1] Christiane Baumeister of the University of Notre Dame and Lutz Kilian of the University of Michigan explain why this result is not a puzzle, but is in fact consistent with the predictions of conventional models of the transmission of oil price shocks.

As Baumeister and Kilian show, the traditional view in undergraduate textbooks that lower oil prices stimulate the economy by lowering the cost of producing domestic goods and services is at odds with the data. Not only are there few industries that heavily depend on oil as a factor of production (such as the transportation sector or rubber and plastics producers), but the stock returns for those industries increased only slightly more than the overall stock market after June 2014, if at all.

In contrast, the stock returns of industries whose demand depends on the price of oil (such as tourism and retail sales) have been far above average stock returns. This evidence is supportive of the view that that the primary channel through which unexpected oil price declines are transmitted has been higher demand for domestic goods and services. For example, consumers faced with a windfall gain in income caused by unexpectedly low gasoline prices will spend most of this extra income, stimulating economic growth via a Keynesian multiplier effect.

Recently, there has been much debate about whether lower gasoline prices may have failed to stimulate domestic spending this time. One concern has been that the decline in the price of oil may not have been passed on to retail motor fuel prices, but it can be shown that these cost savings were fully passed on by refiners and gasoline distributors. Another conjecture has been that consumers chose to pay back credit card debt or to increase their savings rather than spending their extra income, but this hypothesis is not supported by the data either. Nor is there support for the notion that increased uncertainty about gasoline prices has depressed automobile demand, slowing overall consumption growth.

As Baumeister and Kilian show, this debate ignores that there actually has been a remarkable increase in private consumption since June 2014. Average real consumption growth accelerated from an average annual rate of 1.9% to 2.9% between the third quester of 2014 and the first quarter of 2016. The authors demonstrate that U.S. consumer spending increased about as much as predicted by conventional models of the effect of lower gasoline prices on U.S. consumption.

Why then did U.S. real GDP growth remain so sluggish? Given that the U.S. produces about half of the crude oil that it consumes, Baumeister and Kilian stress that in assessing the overall stimulus to spending we also must take into account the response of domestic oil producers to lower oil prices. They demonstrate that there has been a dramatic drop in U.S. oil-related nonresidential investment in response to the decline in the price of oil, which largely offset the

Table : The Net Stimulus from Unexpectedly Lower Real Oil Prices

Effect on Real GDP of	Percent of Cumulative Real GDP Growth	
	2014Q3-2016Q1	1986Q1-1987Q3
Discretionary Income Effect on Private Consumption	+0.61	+0.28
Operating Cost Effect on Private Consumption	+0.09	+0.08
Oil-Related Private Nonresidential Investment	-0.57	-0.43
Non-Oil Related Private Nonresidential Investment	+0.22	+0.11
Petroleum Trade Balance	+0.04	-0.41
Net Stimulus	**+0.39**	**-0.37**

NOTES: The estimates of the stimulus have been adjusted based on a marginal an import propensity of 0.15 and take into account the share of each expenditure component in real GDP. A net stimulus of 0.39 percentage points translates to an increase in the average growth rate of real GDP of 0.2% at annual rates.

consumption stimulus, resulting in a net stimulus for the U.S. economy close to zero.

This type of response is by no means unprecedented. The authors make a point of comparing the most recent oil price drop with events in late 1985, when a shift in Saudi policies caused a large and sustained decline in the global price of oil in 1986, resulting in an increase in private consumption and a decline in oil-related nonresidential investment – much like today. The main difference between now and then is that the decline in oil-related investment after June 2014 was about twice as large. The magnitude of this decline is not surprising upon reflection, Baumeister and Kilian argue, because the cumulative decline in the price of oil after June 2014 was also twice as large as that after December 1985, while the share of oil and gas extraction in GDP was about the same in 2014 as in 1985 (see above table).

Much has been made of the increased importance of shale oil for the effects of the recent oil price decline on the U.S. economy. For example, it has been suggested that bad oil loans may have caused fears of contagion in the banking sector undermining financial intermediation not unlike bad mortgages during the housing crisis. Baumeister and Kilian show that there is no empirical support for this view. It has also been argued that declines in investments by the oil sector may have spilled over to other investment expenditures. There is no empirical support for this view either. More generally, the case has been made that lower growth in the oil-producing states (Alaska, Montana, New Mexico, North Dakota, Oklahoma, Texas and Wyoming) has dragged down overall U.S. economic growth. These effects can be shown to be too small to matter, however. Yet another argument has been that frictions in reallocating workers from the oil sector to other sectors may have caused higher U.S. unemployment. This view is not only hard to reconcile with the continued rapid decline in the overall U.S. unemployment rate, but there is evidence that even in most oil-producing states the unemployment rate has been declining, and that these declines cannot be explained simply by migration away from oil-producing states.

This does not mean that the U.S. shale oil boom did not matter for the response of the U.S. economy. Clearly, without this boom, the share of oil and gas extraction in GDP, which in 2014 was almost the same as in 1985, would have been much lower and the sharp decline in oil-related investment would have mattered less for U.S. real GDP growth. There is also evidence that the recent oil price decline was not met by increased oil imports, as occurred in 1986, given the ready availability of shale oil, which allowed real GDP to remain higher.

This is not the only difference, however. The authors point out that the oil price drop in 1986 was caused by developments in the global oil market alone, whereas in 2014-15, it was in part associated with a global economic slowdown which is reflected in a lower average growth in U.S. real exports (see, e.g., Baumeister and Kilian 2016[2]). Had U.S. real exports continued to grow at the same average annual rate of 3.2 percent as between the first quarter of 2012 and the second quarter of 2014, Baumeister and Kilian note, average U.S. real GDP growth after mid-2014 would have – all else equal – increased by 0.3 percentage points to 2.5 percent (up from 1.8 percent on average between 2012 and mid-2014).

[1] Christiane Baumeister and Lutz Kilian (2016), "Lower Oil Prices and the U.S. Economy: Is This Time Different?" *CEEPR WP-2016-014*, MIT, October 2016.

[2] Baumeister, C., and L. Kilian (2016), "Understanding the Decline in the Price of Oil since June 2014," Journal of the Association of Environmental and Resource Economists, 3(1), 131-158.

The Rise of NGO Activism

by: Julien Daubanes and Jean-Charles Rochet

Non-governmental organizations (NGOs) frequently oppose corporate practices, even where such practices have been approved by public regulators. These NGOs are consumer associations, environmental groups, and stakeholders' advocacy groups, and are particularly active in the energy, food, retailing and banking sectors. They often convince firms to "self-regulate" when public regulation seems too lax.

In recent years, many companies have significantly strengthened their social, environmental, and risk criteria following NGO intervention. Endocrine disrupting chemicals (EDCs) are a case in point: although the inaction of public regulators—and the influence of industry—on EDCs are often denounced, NGO pressure has prompted an increasing number of companies to commit to the objective of zero EDCs discharge. NGOs' rising influence is considered one of the most significant changes in business over the past decades.

To oppose corporate projects and practices they disapprove of, activist NGOs hardly lobby regulators[1]. Instead, they often use their influence to constrain firms directly by, for example, calling for a boycott, mounting a negative advertisement campaign, and so on.

A fundamental question emerging from this trend is why societies rely on NGO activism when externalities could be resolved at the outset by public regulation. In a recent MIT CEEPR working paper[2], we offer a possible answer. We start with the observation that, since the mid-twentieth century, public regulators have lost public trust. Recent catastrophes, such as the global financial crisis, the explosion of the Deepwater Horizon oil-drilling rig, and the Fukushima disaster, have reinforced this dynamic, raising questions about the independence of the agencies involved.

The paper develops a theory of NGO activism as a response to extensive lobbying by industries. Over the past few decades, the rapid growth of industrial projects' size and value has increased corporate lobbying and, therefore, the vulnerability of public regulation. In response, activist NGOs have increasingly decided to monitor industrial projects. At the same time, the Internet and associated communication technologies (ICT) have dramatically accelerated the rise of NGOs. There are two important aspects: first, the ICT revolution has led to more information dissemination, enabling NGOs to examine more opaque or complex issues; second, it has greatly improved the ways in which the public can be mobilized through social media, as well as NGOs' ability to coordinate their efforts through networks.

With increased transparency, NGOs have become more effective at reducing the impact of lobbying and, therefore, the influence of companies. For the period from 2002 to 2014, for example, we find NGO criticism levelled against U.S. industrial sectors has been negatively associated with companies' subsequent lobbying expenditures (see figure below).

This raises the issue of the legal status of NGO activism, which is ambiguous in most countries because NGO actions, such as calls for boycott, may violate refusal-to-deal, anti-discrimination, and anti-defamation laws. Besides, the legal protection of NGO activism is a more urgent issue for developing countries, in which NGOs are often banned, especially in autocratic governments.

[1] Over the period 2002-2014, for example, U.S.-based NGOs' lobbying expenditures amounted to $2.3 billion, while lobbying expenditures by U.S.-based companies exceeded $36 billion.

[2] Julien Daubanes, and Jean-Charles Rochet (2016), "A Theory of NGO Activism," *CEEPR WP-2016-010*, MIT, July 2016.

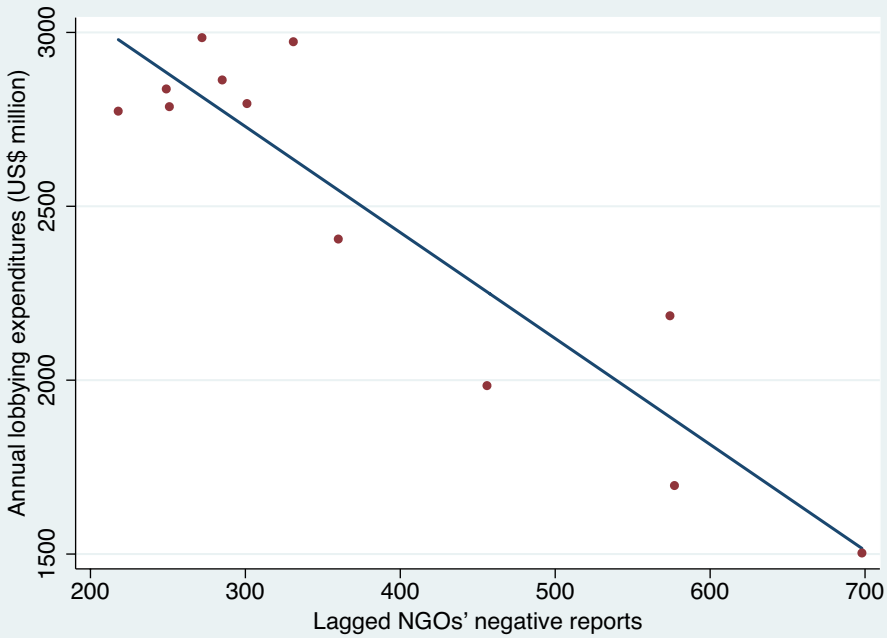


Figure: Lagged NGOs' negative reports and lobbying expenditures.

CEEPR-EPRG European Energy Policy Conference

On July 7th and 8th, 2016, CEEPR cooperated with EPRG and Electricité de France to convene the 2016 European Energy Policy Conference in Paris, France. Over 70 participants from research, industry, and the public sector converged at the historic George C. Marshall Center for a varied program covering key topics in the energy and environmental policy arena. A debate on the principles and objectives that should guide the search for good energy policy design as well as a timely discussion of fossil fuels and energy security kicked off the substantive portion of the conference.

Speakers and moderators at the CEEPR-EPRG European Energy Policy Conference with Dr. Fatih Birol, Executive Director of the International Energy Agency (IEA).

Over lunch, Dr. Fatih Birol, Executive Director of the International Energy Agency, shared a preview of his agency's latest research on large-scale energy trends. Evolving business models in the electricity sector and the role of nuclear energy in decarbonizing the energy sector featured in the afternoon sessions of the first conference day.

On the second conference day, participants had an opportunity to learn about recent developments in energy storage and its technological and economic potential, followed by a roundtable discussion on the challenges faced as nations move to implement the national climate contributions entered under the Paris Agreement adopted only months earlier in the same city.

Presentations by distinguished policy architects and leading experts in their field, as well as a consistently high level of discussions, once again characterized this annual event, which – already in its 15th installment – thus marks a fruitful tradition of cooperation with industry partners and colleagues at the University of Cambridge.

Predicting the Unpredictable – Handling Uncertainty in Energy Economics and Management

"We have to make Black Swan events manageable."

— Frank Mastiaux, CEO, EnBW

Together with partners from German utility and CEEPR Associate Energie Baden-Württemberg AG (EnBW), the University of Duisburg-Essen and the Stiftung Energie & Klimaschutz, MIT CEEPR organized a conference on September 8th and 9th, 2016 to discuss analytical tools and decision making strategies for dealing with uncertainty in energy policy, economics and management. Hosted at the European School of Management and Technology in the historic center of Berlin, Germany, this event brought together leading decision makers from public policy and industry with researchers from a diverse range of disciplines to discuss the behavioral economics and psychology of decision making under uncertainty, the role of markets and risk in energy economics, new approaches in energy economic modeling, and practical management and forecasting strategies used in the private sector. Keynote presentations were delivered by Dr. Frank Mastiaux, Chief Executive Officer of EnBW, John B. Emerson, U.S. Ambassador to the Federal Republic of Germany, and Dr. Rainer Baake, State Secretary at the German Federal Ministry for Economic Affairs and Energy. CEEPR Director Christopher Knittel, Professor Robert Pindyck, Dr. Sergey Paltsev, Joshua Hodge, and Michael Mehling participated in the conference on behalf of MIT.

2016 Spring Research Workshop

by: Mary Claire Morris

A panel session about the COP21 Paris Agreement during the 2016 Spring CEEPR workshop.

In the development of energy and environmental policy, cooperation between research, industry and policy making is critical. This message was central to the work presented and discussed at the MIT Center for Energy and Environmental Policy Research (CEEPR) 2016 Spring Research Workshop. As always, the two-day event highlighted the complex dynamics and implications of energy and environmental policy at the forefront of today's policy debates.

Workshop participants gathered in Cambridge, Massachusetts on May 12th and 13th to discuss a wide range of topics across the energy sector. Following opening remarks from CEEPR Director Christopher Knittel, the first session provided an outlook for fossil fuels. Dan Domeracki, Vice President of Government and Industry Relations for Schlumberger, an oilfield services company, discussed the balance that sound policy needs to strike between the interests and objectives of different stakeholders in the energy sector. With increasing environmental concerns, Domeracki explained, the fossil fuel industry must identify and mitigate the environmental risk of operations in order to effectively reduce social risk. Public opinion plays a crucial role in the industry's ability to operate. But Domeracki also cautioned that policy occasionally misses the mark when attempting to address environmental concerns without compromising the affordability of energy supply. Policy informed by scientific research in consultation with industry is better able to adequately address both environmental and economic concerns.

Following on Domeracki's presentation, Knittel drew attention to the growing support of climate action, which in turn points to a need to curb fossil fuel use. Although fossil fuels are finite, known reserves have continuously grown over the past decades due to the development of new production and extraction technologies, a trend that can be expected to continue into the future. Likewise, global demand for fossil fuels has not decreased as the fixed costs of cleaner alternatives remain high. To reduce fossil fuel consumption, therefore, serious policy action and a globally concerted effort will be necessary, Knittel concluded.

MIT's John Reilly and Jessika Trancik followed on this theme with presentations on the achievement of decarbonization objectives through policy, reflecting on the Independent Nationally Determined Contributions (INDCs) and broad principles set at the Paris Climate Summit (COP21) in December 2015. Reilly, who serves as the Co-Director of the MIT Joint Program on the Science and Policy of Global Change, emphasized the need for engagement with and expansion of knowledge for the evaluation and financing of the Paris goals. He explained that the goals set at the summit have the potential to decrease atmospheric carbon dioxide levels, but that procedural, economic and diplomatic challenges remain. In order for emission reductions to occur, countries must be held accountable and global cooperation must continue beyond the conference.

Meanwhile, Trancik, an Assistant Professor of Energy Studies at the MIT Institute for Data Systems and Society, spoke on the need for innovation in mitigation and adaptation efforts to achieve climate objectives. She argued that, to reach the goals set out in the Paris Agreement, countries would need access to affordable renewable energy resources, something that would only come with innovation. Trancik further explained that local economic conditions and policies play a significant role in the renewable energy market, shaping the global distribution of energy. The levelized cost of a given energy resource varies across the world based on a country's unique economy and resources. In order to drive down the cost of renewable energy resources, policy-supported market expansion and publicly funded research is vital.

Later in the day, MIT's Richard Schmalensee and Michael Mehling discussed lessons learned with, as well as future prospects of, emissions trading. Schmalensee, a Professor at the MIT Sloan School of Management, gave a

retrospective of emissions trading systems, focusing on a number of case studies to illustrate the different variables at play in the creation, implementation and impacts of these market-based policies. Schmalensee explained that although a cap-and-trade system is theoretically straight forward, nuances in a system's design greatly impact its effectiveness. He argued that clear, informed rules improve cap-and-trade systems. Enforced restrictions on emissions must be continually informed by scientific research, and adjustments to system design – for instance through price collars – may be needed to promote price stability.

Mehling, Executive Director of CEEPR, spoke on the possibility of carbon market linkages following COP21. By allowing for voluntary cooperation between parties, the Paris Agreement established a framework for bottom-up cooperation between emissions trading systems and other policies that could lead to greater policy integration. But in order to effectively link domestic carbon markets, systems have to be compatible, limiting the possibility of market integration to jurisdictions with relatively homogeneous market designs. Alternative approaches to market linkage based on comparability rather than compatibility, operating through discounts or exchange rates, may help overcome system heterogeneity, but the research there has only begun.

Erin Mansur, professor at the Tuck School of Business of Dartmouth, and Stephen Zoepf, Executive Director of the Center for Automotive Research at Stanford University, brought the conversation back to innovation in the energy sector, presenting on transportation trends. Mansur's presentation focused on the environmental impact of electric vehicles relative to vehicles with internal combustion engines. His model reveals that, on average, electric cars produce substantially more environmental externalities than conventional cars, with large geographic variation in regional results. This difference is largely due to the air pollution emitted from generating electricity to charge the vehicles in coal-fired power plants, Mansur explained. Pending a large-scale transition to cleaner electricity generation, driving electric vehicles may make local air cleaner, but deployment of electric vehicles will likely make society as a whole worse off.

Discussion resumed on Friday, May 13th, with presentations on energy and environmental policy in India delivered by Ujjayant Chakravorty, Professor of Economics at Tufts University, and Maureen Cropper, Professor of Economics at the University of Maryland. Chakravorty spoke on groundwater extraction for agricultural use in India, explaining that the region's small farms are dependent on groundwater in order to maintain irrigation agriculture. A high demand for groundwater has created groundwater markets and led to excess entry into this market. As the regional aquifers begin to deplete, Chakravorty proposed a tax on the fixed cost of groundwater and a subsidy for the production cost of groundwater.

Cropper presented on the health harms associated with the rapid expansion of coal-fired electricity generation in India, and the resulting need for stronger environmental regulations of power sector emissions. Cropper investigated the effectiveness of retrofitting these power plants with flue gas desulfurization units (FGDs), or scrubbers, to help mitigate the health impacts of electricity production. To weigh related costs and benefits, Cropper calculated the cost of FGD installations in relation to potential lives saved. According to Cropper, the results indicated that the benefits of FGD installation clearly outweigh the costs.

Electricity market design featured in the last session, with presentations by Fernando de Sisternes, a CEEPR Research Affiliate and Energy Systems Engineer with the Argonne National Laboratory, and Steven Puller, a Professor at Texas A&M University. De Sisternes shared his work on capacity remuneration mechanisms as a possible solution to the challenges posed for energy development and investment by demand and policy uncertainty in low carbon energy systems. He explained that, in an electricity market, a variety of factors, including weather variability, policy changes, and economic fluctuations, cause demand instability. In turn, this creates uncertainty in demand distribution and growth, which leads to a reduction in the expected operating profits generated by scarcity rents. Without an expectation of constant demand growth, investors lack incentives to increase generation capacity. According to de Sisternes, capacity mechanisms can address the risk of inadequate generation capacity by expanding revenue sources to include both energy output and capacity, protecting investors against risk.

Puller presented on pricing challenges in retail electricity, explaining that – given the goal of emissions reductions – electricity consumption may not be easily curbed by simply increasing market competition or the price of a good. Conventional economic policy solutions do not always produce the expected consumer response. Counter to the norm, consumers in electricity markets do not respond significantly to increasing marginal costs or residential tariffs. According to Puller, thought must therefore be given to the price signals sent by bills and tariffs, which are difficult to control and communicate effectively, and which differ depending on the role of regulation in a given electricity market.

As the workshop concluded, participants were once again left with an appreciation for the evolving complexities in the energy sector and the need for balanced and objective research to craft sound, pragmatic policies.

UPCOMING WORKSHOPS
April 27-28, 2017, Cambridge, MA
July 2017, Paris *(to be confirmed)*
November 16-17, 2017, Cambridge, MA

Transatlantic Perspectives on Energy Storage: Technology, Policy and Finance

by: Maximilian Blaschke and Fiona Paine

Energy storage will play a critical role in enabling the transition to low-carbon electricity systems, providing capacity, energy, and ancillary benefits to help secure a stable and reliable power supply. But even as the technology horizon evolves, the value of different storage technologies remains uncertain, as do suitable market and policy frameworks to promote their efficient deployment. On October 21, therefore, the MIT Center for Energy and Environmental Policy Research (CEEPR) and the Technical University of Munich (TUM) Center for Energy Markets (CEM) convened a group of researchers, policy makers and industry leaders for a full-day symposium on energy storage and its technology, policy and business implications.

Yet-Ming Chiang, Professor of Materials Science and Engineering at MIT, kicked off the symposium by discussing energy storage technology. Lithium-ion batteries are currently favored as the dominant storage system for transportation and grid applications, he explained, but the price of lithium-ion technology has not decreased as much as predicted. One approach to lessen battery costs is to reduce the amount of non-energy-storing materials used to thicken the battery electrodes, and he proceeded to describe work underway at 24M, a company he helped establish, to bring storage costs below 100$/kWh.

Marcus Müller, a Project Manager and Ph.D. Candidate at TUM , proceeded to highlight the adaptability of lithium-battery technology for different uses. He and his team decided to simulate a variety of applications, system configurations, and aging processes to calculate the value of energy storage in different scenarios, finding that stacking of battery applications does not necessarily harm their performance metrics, but can yield additional economic value through an increase in utilization.

Michael Aziz, Professor of Materials and Energy Technologies at Harvard University, presented organic aqueous flow batteries as an alternative technology option. Replacing metal components with organic quinones shows promise for large-scale electrical storage, although research is ongoing and a wide range of battery chemistries remains to be explored. A second discussant, Stefan Andreas Meyer of Kreisel Electric, closed the first session by highlighting the opportunities for innovative packing of battery solutions in transportation environments.

Introducing the second session on the business implications of energy storage, Kristin Brief of Ambri provided an introduction to her startup's design for liquid metal battery storage. The technology was originally developed at MIT and is based on three separated layers of liquid metal operating in high temperature environments. These batteries exhibit negligible capacity losses even after a high number of charging cycles and an ability to hold their charge for exceptionally long periods.

"Energy storage could be the solution for nearly every problem we face today."

She was followed by Sandeep Dudhwewala of National Grid, an electric utility, who acknowledged that storage will play a key role in facilitating the broader trend towards decarbonization and decentralization across the electricity sector. New technologies will create challenges as well as opportunities, and storage may eventually become a standard option for utilities. Before it is implemented at a large scale, however, costs must fall further, market rules have to be clarified, and regulations need to be adopted or improved. National Grid has taken steps to evaluate the business viability and potential of storage in a range of different applications and locations, from generation and transmission to distribution and end use.

A third panelist, Archan Padmanabhan of Tesla, offered additional insights into energy storage applications. Tesla has used its knowledge of energy storage from automotive and transportation applications to address grid and home level storage. Their current approach is a modular battery design that utilizes different chemistries for different applications. Batteries still face the challenge of high costs, but improvements are underway to increase the economic viability of battery storage technology.

During lunch, Massachusetts Energy Commissioner Judith F. Judson reported on current projects and policy strategies for energy storage systems in her state. New clean energy legislation signed in August 2016 requires utilities to solicit and procure long-term contracts for clean energy generation, and authorizes the state to explore an energy storage procurement mandate. Future steps for the state of Massachusetts include funding demonstration projects and clarifying the regulatory status of energy storage.

David Wozabal, professor at the Technical University of Munich, introduced the following session on the economics of energy by focusing on how energy storage could become profitable in Germany. Currently, he explained, storage capacity in Germany

is largely centered around pumped hydro facilities. Other systems, such as grid-integrated vehicles, would be unable to provide significant revenues within the current market design and regulatory framework. Based on his research, grid-integrated vehicles do not appear to be a promising storage option because they require additional investment and involve uncertainties – such as driving patterns – that will affect revenue flows.

Jesse Jenkins, a Ph.D. candidate at MIT, continued by breaking down the various applications of energy storage and assessing their value. First, supply and demand in the grid must be balanced in nearly real time, and storage has the greatest accuracy and fastest response times for attendant frequency regulation. While the regulation market is a high-value market, it is small and quickly saturated. Second, energy storage can be of use in network capacity deferral. A small reduction in peak demand could avoid exceeding distribution network constraints and allow a moderate increase in load without requiring network improvements. However, the "peakiest" load hours could also be addressed at lower cost by demand or price response. Third, energy storage may be useful under a CO_2 limitation scenario, acting as a substitute for peaking power plants, but it still appears to be a weak substitute for nuclear and other base resources.

Thomas Greve of the University of Cambridge highlighted uncertainties and information asymmetries in the energy system, and reminded the audience of the usefulness of markets. He discussed current auction designs as an option to price storage in a way that allows it to become a viable service. In addition, futures and risk markets could allow energy price hedging.

Continuing the discussion of energy storage, Ted Loch-Temzelides, a Professor of Economics at Rice University, discussed variables to consider when implementing energy storage systems, including location, supply variability, and interaction of storage with nuclear energy. Energy storage across time scales is also an issue. Seasonal fluctuations of energy supply from wind and solar may necessitate energy storage over months, not just minutes or days. In the specific case of Texas, with a substantial installed wind power capacity, storage systems have to fulfill different use-cases to help meet demand. Transmission lines used to transport energy to the location of storage systems will only be used 25-30% of the time, since windless periods prevent higher utilization and therefore require storage systems to also bridge demand during these periods.

Commissioner Judith F. Judson of the Massachusetts Dept. of Energy Resources.

An event organized by MIT CEEPR jointly with TUM CEM and the Transatlantic Climate Bridge in October 2016 convened leading experts and decision makers from the public and private sector for an informed debate on the state of energy storage.

In the final session of the day, focused on the policy needs and implications of energy storage, Stephen Pike of the Massachusetts Clean Energy Center discussed funding for energy storage and various market discovery efforts. Christopher Parent of the regional transmission system operator ISO New England followed with a presentation of how new storage is integrated into the grid, and the conditions that apply. Jason Burwen of the Energy Storage Association (ESA) discussed alternative market design considerations for energy storage, followed by his counterpart Helena Teschner of the German Bundesverband Energiespeicher, who addressed market design and the regulatory framework in Germany.

The lively discussions throughout the day highlighted that, while energy storage has been rapidly growing as an area of interest, vast unfulfilled potential remains and many challenges have yet to be solved.

Efficiency and Equity in Today's Environmental Policy

by: Samuel Stolper

The economics rationale for environmental regulation is simple and strong: private decisions about how much to pollute lead to socially undesirable levels of pollution. We need policy to correct this flaw in markets. The question is, which policies? A government's challenge is to balance environmental quality with a fair and healthy economy. In my work, I try to inform the pursuit of that balance, by studying the varied impacts of energy and environmental policy.

I'm especially interested in issues of equity. Environmental problems often disproportionately affect poorer and more vulnerable segments of society – the obvious example is climate change. Furthermore, the policies designed to address such problems sometimes themselves have unattractive distributional properties. A couple of my ongoing research projects speak directly to these challenges.

Dr. Samuel Stolper is a CEEPR Postdoctoral Associate at the MIT Energy Initiative and the MIT Dept. of Economics focusing on the environmental and economic impacts of policy regulations.

The first of these projects (*Who Bears the Burden of Energy Taxes? The Role of Local Pass-Through*)[1] focuses on the distributional impacts of automotive fuel taxes. Fuel taxes are used by dozens of countries and are seen as potential levers by which to meet international targets for greenhouse gas emission reductions. However, they (and related policies) are often thought to be regressive – that is, relatively worse for poorer households.

The logic of this presumption is that relatively poorer households spend a greater proportion of their budget on energy, so their effective tax rate is correspondingly higher. But this logic assumes that all households experience the same price change as the result of a tax hike. In my analysis of the Spanish automotive fuel market, I find that richer areas see the price of retail fuel jump systematically more than poorer areas, for the same tax hike. That finding suggests that the alleged regressivity of energy taxes may be overstated. In the particular setting of Spain, adjusting welfare calculations to reflect observed pass-through patterns reveals state diesel taxes to be progressive.

A second project in which I'm engaged (*Can Environmental Policy Reduce Infant Mortality? Evidence from the Ganga Pollution Cases*)[2] is an evaluation of environmental policy in the developing-country context. From a distributional perspective, nations like India and China have some of the worst environmental quality in the world and are predicted to be disproportionately burdened by climate change. But they are also the places where energy usage and economic activity are slated to rise most. In these nations, successful environmental policy means reducing pollution without compromising the growth to which citizens are entitled. Along with co-workers, I am examining what drives successful policy in the specific context of industrial water pollution into India's rivers.

To complement my research, I place great emphasis on teaching and communication of knowledge in economics and public policy. This coming spring, I will teach 14.42 Environmental Economics and Policy at MIT. In September 2017, I will join the faculty of the University of Michigan's School of Natural Resources and Environment, teaching the Economics of Climate Change. I also write blog articles for Harvard-based Sense and Sustainability, which develops leadership skills and provides online content related to the topic of sustainability.

[1] This paper is available at: https://goo.gl/op4N4O

[2] This paper is available at: https://goo.gl/Jg3IKR

Notable Changes

In June, CEEPR welcomed **Professor Stefan Weishaar**, of the University of Groningen in the Netherlands, as a Visiting Scholar. Professor Weishaar's work focuses on the operation of markets and regulatory instruments and applies a law and economics methodology to energy and climate policy, competition law, procurement law and market integration. During his year-long visit with CEEPR, Professor Weishaar will pursue research on electricity leakage and linking, carbon market stabilization measures and their implications for linking, and absolute versus intensity-based caps for carbon emissions target setting.

In July, **Leila Safavi** joined CEEPR as a Research Associate. Continuing MIT CEEPR's relationship with the E2e joint initiative between UC Berkeley's Energy Institute at Haas and the Energy Policy Institute at the University of Chicago, Leila will work on research projects related to energy efficiency.

With the start of a new semester in September, CEEPR hired additional personnel to expand our research capacity under the guidance of Professor Christopher Knittel. **Dr. Samuel Stolper** joined CEEPR as a Postdoctoral Associate, with a research agenda focused on the environmental and economic impacts of policies in a range of issue areas (see Dr. Stolper's profile in this Newsletter issue for more details).

CEEPR has also appointed **Dr. Ignacia Mercadal** as a Postdoctoral Fellow. She will focus on energy economics and industrial organization. Her research to date has focused on restructured electricity markets and, in particular, the role of financial traders and arbitrage on market efficiency.

Professor Knittel has also appointed two additional MIT graduate students as CEEPR Research Assistants. **Elizabeth Murphy** will work on the upcoming MIT *Mobility of the Future* study, an interdisciplinary examination of how complex interactions between engine technology options, fuel options, refueling infrastructure, consumer choice, public transit options, new transportation modalities, and government policy might shape the future landscape for mobility. In addition, **Seth Wong** will work on a research project that looks into the growing need for electricity storage in the grid due to the increasing amount of intermittent renewable energy being added into the system. A particular focus of the project will be on the optimal placement of solar and energy storage within the local utilities grid while taking the shifting of prices and grid costs into account.

Finally, October has also seen a transition in CEEPR's management team. **Joshua Hodge**, former Deputy Executive Director of both CEEPR and the MIT Joint Program on the Science and Policy of Global Change, has joined CEEPR full-time as its new Executive Director. He brings with him extensive leadership experience in the energy sector, including as head of the Commodities Research and Forecasts business at Thomson Reuters, and as Managing Director, North America at Point Carbon. His predecessor **Michael Mehling** has been appointed Deputy Director, and will focus on content and programming with a reduced effort level at CEEPR while he serves as a Visiting Professor at Strathclyde University in the UK.

Recent Working Papers

WP-2016-014
Lower Oil Prices and the U.S. Economy: Is This Time Different?
Christiane Baumeister and Lutz Kilian, October 2016

WP-2016-013
Socialism for Red States in the Electric Utility Industry
Richard Schmalensee, September 2016

WP-2016-012
Tight Oil Development Economics: Benchmarks, Breakeven Points, and Inelasticities
Robert L. Kleinberg, Sergey Paltsev, Charles K,. Ebinger, David Hobbs, and Tim Boersma, August 2016

WP-2016-011
Carbon Market Stabilisation Measures: Implications for Linking
Fitsum G. Tiche, Stefan E. Weishaar, and Oscar Couwenberg, August 2016

WP-2016-010
A Theory of NGO Activism
Julien Daubanes and Jean-Charles Rochet, July 2016

WP-2016-009
Multilateral Linking of Emissions Trading Systems
Michael Mehling and Benjamin Görlach, May 2016

All listed and referenced working papers in this newsletter are available on our website at ceepr.mit.edu/publications/working-papers

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A panel discussion during an MIT CEEPR event, *Predicting the Unpredictable – Handling Uncertainy in Energy Economics and Management*, with EnBW at the European School of Management and Technology in Berlin on September 8, 2016.