Spring 2016

MIT CEEPR Newsletter

MIT Center for Energy and Environmental Policy Research

MASSACHUSETTS INSTITUTE OF TECHNOLOGY

MIT CEEPR

MIT Center for Energy and Environmental Policy Research

Hailed by many as a watershed moment in international climate cooperation, the Paris Agreement adopted late last year aspires to set the international community on a path towards decarbonization before mid-century. Effective, coordinated and economically sensible policies will prove more important than ever to achieve this ambitious target with a minimum of unintended consequences, such as spillover effects and competitive distortions. Claims that the Paris Agreement heralds an end of conventional energy sources are premature, however, as a recent MIT CEEPR Working Paper (featured in this newsletter) demonstrates. Still, if the climate pledges submitted by a majority of countries around the world are fully implemented, they will further accelerate disruptive forces already underway in different parts of the energy sector, with attendant economic and policy challenges that are not yet fully understood. Another MIT CEEPR Working Paper (also featured in this newsletter) highlights the impacts of uncertainty in low-carbon power systems, justifying the introduction of capacity remuneration mechanisms. Economically superior policies such as carbon pricing are only being deployed haltingly in most parts of the world, forfeiting their cost-saving potential in favor of cruder or more expensive policies such as subsidies and performance standards. Highlighting the cost and benefit of alternative policy options for energy and environmental goals has featured centrally in the research undertaken at MIT CEEPR, as was in evidence at a recent high-level event on emissions trading in North America (described in this newsletter). But more work remains to be done, and MIT CEEPR is poised to meet the challenge.

CONTENTS

RESEARCH

3 Energy Scenarios: The Value and Limits of Scenario Analysis

4 Will We Ever Stop Using Fossil Fuels?

6 OPEC vs U.S. Shale: Analyzing the Shift to a Market-share Strategy

7 The Impact of Uncertainty on the Need and Design of Capacity Remuneration Mechanisms in Low-Carbon Power Systems

8 A Review of the Value of Aggregators in Electricity Systems

10 The E2e Project Awarded $5 Million Grant to Evaluate New Advanced Energy Monitoring System

EVENTS

11 2015 Fall Research Workshop

12 Emissions Trading in North America and Beyond: Taking Stock and Looking Forward

14 University Energy Initiative Symposium

PERSONNEL UPDATES

15 Notable Changes

PUBLICATIONS

15 Recent Working Papers

MIT Center for Energy and Environmental Policy Research
77 Massachusetts Avenue, E19-411
Cambridge, MA 02139 USA

Website: ceepr.mit.edu

MIT CEEPR Newsletter is published twice yearly by the MIT Center for Energy and Environmental Policy Research.

For inquiries and/or for permission to reproduce material in this newsletter, please contact:

Email ceepr@mit.edu
Phone (617) 253-3551
Fax (617) 253-9845

Image credits

Front cover images: Wind farm in Washington; Tulips in bloom by the Architect of the Capitol; Energy efficient windows by Lawrence Berkeley Nat'l Lab - Roy Kaltschmidt; Sunset at the Naval Petroleum Reserve in Casper, Wyoming; Interior and back cover images are individually sourced, public domain images by the U.S. DOE or other agencies of the federal government, or were photographed by Michael Mehling and Tony Tran.

Energy Scenarios: The Value and Limits of Scenario Analysis

by: Sergey Paltsev

Energy scenarios are a useful tool for industry experts, government officials, academic researchers and the general public to assist in policy-making, planning and investment decisions. Such scenarios provide projections on a wide range of issues, including production, consumption, trade, prices, investments, technology mixes, and many others. The need to transition to a low-carbon economy has added a new and challenging dimension to long-term energy scenarios development.

A recent MIT CEEPR Working Paper[1] authored by Sergey Paltsev, Senior Research Scientist with MIT CEEPR and Deputy Director of the MIT Joint Program, reviews the value and limits of energy scenarios and, in particular, assesses how new low-carbon goals are reflected in the latest projections. A relatively new dimension in modern energy forecasts, such policy objectives related to climate change mitigation join traditional factors such as technology development, demographic trends, and economic, political, and institutional considerations. They introduce additional variables regarding the coverage, timing, and stringency of policies to mitigate greenhouse gas emissions and air pollutants.

International decisions – such as the Paris Agreement – that articulate the need to mitigate climate change render energy projections particularly important, as they call for a future energy system based on a radically different fuel mix compared to historic energy developments. Mitigating energy-related greenhouse gas (GHG) emissions (which affect the global climate system) and air pollutants (which mostly impact local environments) results in substantial challenges and opportunities for current and future pathways for energy development. Industry experts and policy makers need to understand investment requirements as well as policy design options and their implications.

Low-emitting technologies will be necessary to mitigate climate change and air pollution, and such technologies are likely to drastically transform energy production and consumption patterns in coming decades. Responding to this challenge, many energy scenarios therefore not only provide estimates regarding future developments under a given or expected policy framework, but they also can yield insights on the required changes to the energy system in order to achieve certain climate and environmental targets.

Modern tools used for energy scenario development offer a good basis to estimate such systemic changes needed to achieve specified mitigation targets. Scenario analysis often includes energy paths consistent with different policies. In many cases, however, this leads to an increase in the uncertainty ranges of forecasts, whereas policy makers often prefer to see a discrete number instead of a range of outcomes. While academic literature embraces uncertainty, the wide range of outcomes leads to a prevalent perception by the general public that scenarios do not offer much more than a statement that "almost anything is possible".

When ascertaining the value and limitations of energy scenarios, it is generally easier to find the limits. This is not only true of energy projections, but also of any other prediction of the future: financial, economic or political. Forecasts of all sorts are usually not very successful at predicting sudden changes. A move to a low-carbon energy future requires a drastic change in energy investment and the resulting mix in energy technologies. If history is any guide, energy scenarios overestimate the extent to which the future will look like the recent past.

Dr. Sergey Paltsev, Senior Research Scientist

Still, an argument can be made regarding the value of improvements, simplifications, or inclusion of additional detail to strengthen the models underlying an energy scenario. Most energy scenarios offer plausible futures, rather than trying to identify the most likely future. The need for low-emitting technologies will shift the current technology mix, but the exact contribution of particular technologies and the timing of this shift depend on many economic and political variables. Such uncertainty about the commercial availability of different technologies and their cost over time supports the conclusion that governments should not try to pick "winners", and instead focus policies and investment on targeting emissions reductions from any energy source. Energy scenarios may not provide the exact projections, but they are the best available tool to assess the magnitude of challenges that lie ahead.

[1] Sergey Paltsev (2016), "Energy Scenarios: The Value and Limits of Scenario Analysis." *CEEPR WP-2016-007*, MIT, April 2016.

Will We Ever Stop Using Fossil Fuels?

by: Victoria Ekstrom High

The Galveston Bay petroleum refinery at night in Texas City, Texas. Source: *Marathon Oil*

On the heels of a historic climate agreement in Paris, a new study published in the Journal of Economic Perspectives sheds light on the world's ability to stop using fossil fuels. Its conclusion: fossil fuel consumption is likely to continue growing without clear and decisive global action to introduce an adequate price on greenhouse gas emissions and increase research and development spending toward clean energy technologies. The study[1] was co-authored by Thomas Covert and Michael Greenstone at the University of Chicago, and Christopher R. Knittel at the Massachusetts Institute of Technology.

As Greenstone, the Milton Friedman Professor in Economics at the University of Chicago and Director of the Energy Policy Institute at the University of Chicago (EPIC), explains, "counting on the fickle finger of fate to point the way to cheaper low-carbon energy sources without market and policy forces pushing us there mistakes hope for a strategy." In measuring their impacts on warming, the study finds that burning the fossil fuel reserves known to us today would increase global temperatures by 10°F to 15°F. What is more, those numbers do not account for advances in fossil fuel extraction techniques that could make resources we cannot even extract today economically accessible, such as oil shale and methane hydrates, potentially adding another 1.5°F to 6.2°F of warming.

The economists explored whether market forces alone would cause a reduction in fossil fuel supply or demand. By studying the history of fossil fuel exploration and technological progress for both clean and dirty technologies, they reached the conclusion that it is unlikely that the world will stop primarily relying on fossil fuels any time soon. As one piece of evidence, the economists studied the amount of reserves in the ground over the last three decades compared to world consumption. For the last 30 years, known reserves of oil and natural gas have grown at least as fast as consumption. As a result, the world has always had 50 years of future oil and natural gas consumption stored as reserves in the ground. This was equally true in boom years (when prices were high) and bust years.

Technological progress, such as the development of hydraulic fracturing and the ability to extract oil from tar sands, is at least partially responsible for a long-term pattern of consistent worldwide growth in fossil fuel reserves. Looking at the average growth rate of these reserves, the study shows that both oil and natural gas grew at a steady rate of 2.7 percent. While coal reserves fell consistently through the late 1990s to 2008, they too have since taken a fairly consistent turn upward; there are roughly more than 100 years of coal reserves currently.

"As long as markets fail to account for the environmental damages from using fossil fuels, there always will be incentives to develop new techniques to more efficiently access these resources," says Thomas Covert. "It seems unlikely that our technological abilities to recover fossil fuels should stop improving any time soon. With continually improving technology, the world will likely be awash in fossil fuels for decades and perhaps even centuries to come."

The study's authors also found that technology improved significantly in cleaner energy sources. This is encouraging, because cheaper clean technologies would reduce demand for fossil fuels. Unfortunately, the trends in clean technology progress are not yet strong enough. For example, the levelized cost of solar power fell from nearly $450/MWh in 2009 to $150/MWh in 2014. Though the downward trend continues today, the cost of natural gas fired power is still cheaper, even when accounting for the cost of climate-related damages.

The story is similar when looking at alternatives to fossil fuels in the transportation sector: namely, battery-powered electric vehicles. At the current battery cost of $325 per kWh, the authors find that the price of oil would need to exceed $350 per barrel before an electric vehicle would have a lower cost of ownership than an equivalent gasoline powered vehicle. Unfortunately, oil traded at an average of $49 per barrel during 2015 and is currently trading below $30 per barrel. Thus, batteries need to be much cheaper before electric vehicles could cause reductions in demand for fossil fuels.

"While alternative sources of energy and energy storage technologies have vastly improved, lowering costs, they still have a long way to go before they are cost competitive with fossil fuels," says Christopher Knittel, the William Barton Rogers Professor of Energy Economics at the MIT Sloan School of Management and Director of the MIT Center for Energy and Environmental Policy Research. "To change this, governments should put a price on carbon emissions and start injecting more money towards the basic R&D that is critical to making these technologies more cost competitive."

[1] Thomas Covert, Michael Greenstone, and Christopher R. Knittel (2016), "Will We Ever Stop Using Fossil Fuels?." *CEEPR WP-2016-003*, MIT, February 2016.

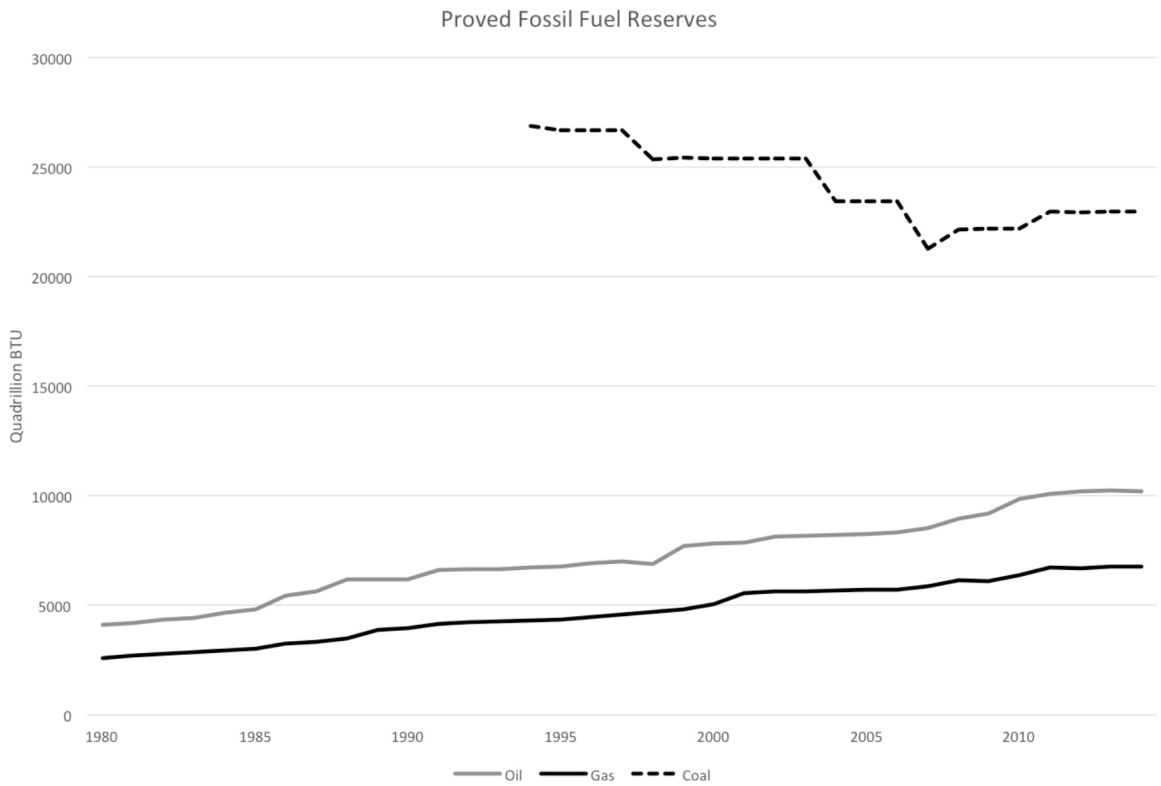
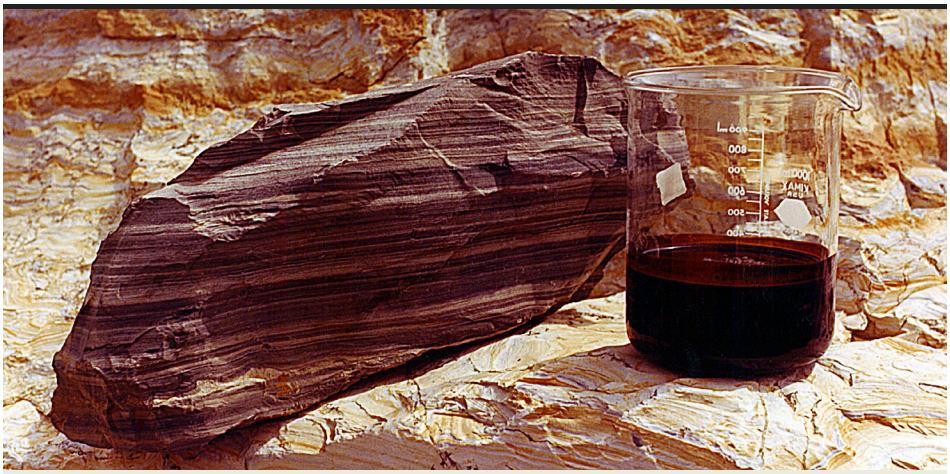


Figure: Reserves of oil, natural gas, and coal over time. Source: *BP Statistical Review of World Energy, 2015*

OPEC vs U.S. Shale: Analyzing the Shift to a Market-share Strategy

by: Alberto Behar & Robert A. Ritz



A block of oil shale (marlstone) and a beaker of oil (kerogen). Source: *U.S. Department of Energy*

In 2014, global oil supply overtook demand and the oil price started to decline. In its November 2014 meeting, OPEC decided not to reduce supply and prices fell further. Oil-market analysts interpreted this as the formal decision to squeeze higher-cost U.S. shale oil production out of the market. It also stood in contrast with OPEC's coordinated cut during the Global Financial Crisis and Saudi Arabia's role as a "swing producer" which seeks to accommodate changes in demand or production by other players. In its December 2015 meeting, OPEC reiterated its commitment to a "market-share" strategy. Many have opined on whether or not OPEC's moves are sensible.

In a recent MIT CEEPR Working Paper[1], Alberto Behar, an economist at the International Monetary Fund's Middle East and Central Asia Department, and former CEEPR Visiting Scholar Robert A. Ritz of the Energy Policy Research Group at the University of Cambridge, seek to understand the fundamental market factors that induced the shift in OPEC's strategy. In their model, OPEC has a degree of market power and competes against a set of non-OPEC producers who act as price-takers. OPEC has a choice between two strategies. The first strategy, "accommodate", is to maximize profits via a high oil price, which allows higher-cost non-OPEC producers to remain profitable. The second strategy, "squeeze", is to drive up production and drive down price, thereby inducing high-cost producers, specifically U.S. shale, to exit the market. The model shows that either of these two strategies can be *optimal* for OPEC depending on market demand and supply fundamentals.

The theory shows that the market-share strategy becomes relatively more attractive for OPEC given: (i) slower global oil demand; (ii) greater U.S. shale oil production; (iii) reduced cohesiveness within OPEC; and (iv) higher output in other non-OPEC countries. A regime switch from accommodate to squeeze becomes optimal when U.S. shale grows beyond a specific point. The model can rationalize OPEC's decision to raise output in the face of weaker demand, and explain a large drop in the oil price. Unlike classic "limit pricing" in industrial-organization theory, the market-share strategy in the model does *not* rely on a later period with again-higher prices in which OPEC can recoup "lost" profits.

The empirical analysis shows how the model rationalizes the oil market in the period preceding the price collapse as a high-price accommodate scenario; OPEC optimally *chose* not to squeeze U.S. shale despite having sufficient spare capacity to do so. Next, it shows how changes in market conditions can prompt a rational decision by OPEC to squeeze U.S. shale out of the market. Finally, the model generates squeeze equilibria when calibrated to forecasts of future data that yield higher OPEC output and lower oil prices.

The model exposes the fallacy of interpreting a fall in OPEC's revenues or profit as evidence that a market-strategy is necessarily misguided. The simple point is that the relevant comparison is not how profits compare to an earlier period, but rather how they would compare to pursuing a different strategy today—for which profits could be even lower.

It remains to be seen whether the initial logic of the squeeze will play out and vindicate the OPEC strategy. As of early 2016, the squeeze appears to have been less successful than OPEC might have calculated: a substantial decline in U.S. shale output does not (yet) appear imminent, and the squeeze has perhaps been more costly than anticipated given the continued decline in oil prices. One potential reason is that the costs of U.S. shale may have fallen more strongly than might have been anticipated. It is also possible that the attempted squeeze and the re-entry of Iran have reduced cohesiveness within OPEC so much that it reluctantly yet rationally persists with the squeeze.

The paper does not pretend to forecast the future of the industry but rather to provide a coherent economic framework to think about the key drivers of such regime switches, including the one that took place at the end of 2014.

[1] Alberto Behar and Robert A. Ritz (2016), "OPEC vs U.S. Shale: Analyzing the Shift to a Market-share Strategy." *CEEPR WP-2016-006*, MIT, March 2016.

The Impact of Uncertainty on the Need and Design of Capacity Remuneration Mechanisms in Low-Carbon Power Systems

by: Fernando J. de Sisternes & John E. Parsons

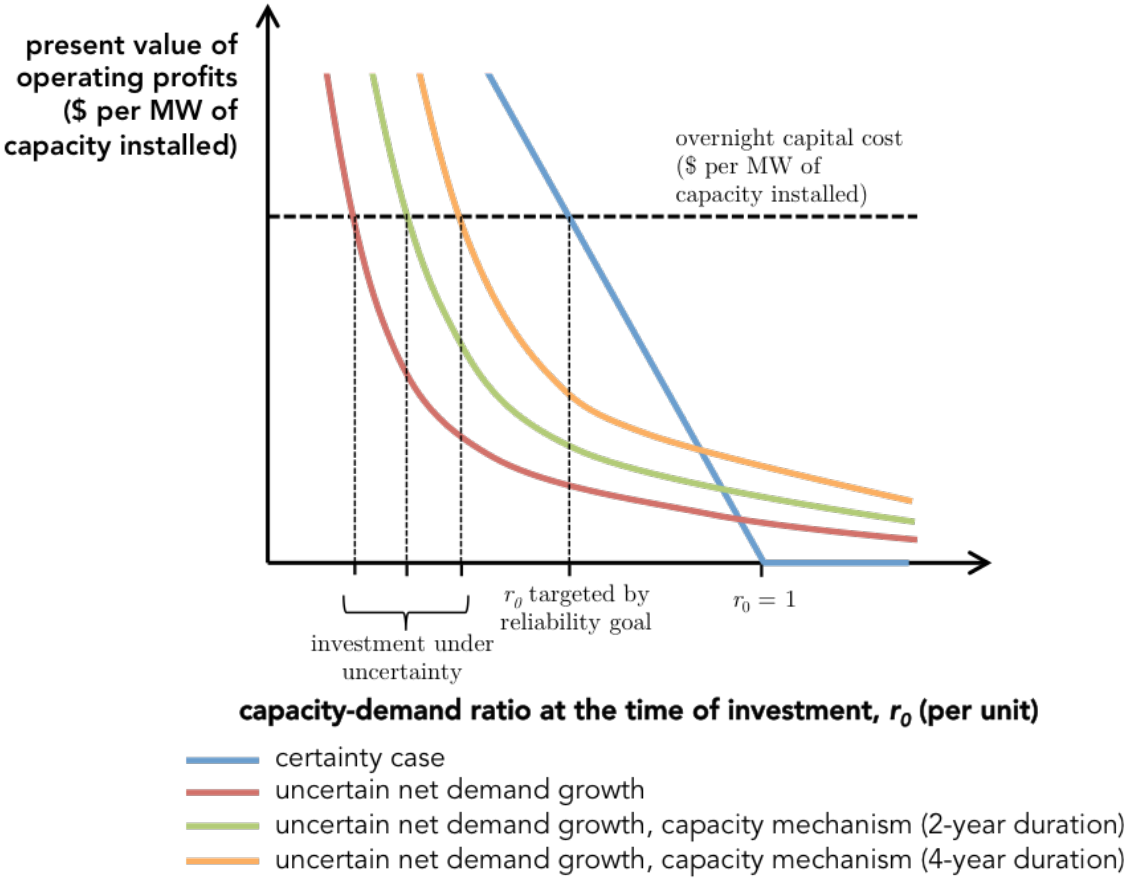


Illustration of the effect of introducing a price-based capacity mechanism with different contract durations, shifting the capacity-demand ratio towards the targeted reliability goal.

Future decarbonization pathways in the U.S. and in Europe rely heavily on a large-scale deployment of intermittent energy resources —including wind and solar power. Intermittent energy resources increase the volatility of energy supply as well as the associated market clearing prices, creating uncertainty around when the system will experience "scarcity"— the very few hours of the year when capacity is strained exhibiting prices high-enough to cover a large portion of the capital and fixed operation and maintenance costs incurred by all types of installed generation capacity. Additional uncertainty is introduced by uncertain growth in demand and uncertain growth in renewable capacity—primarily driven by uncertain energy policies—which together lead to uncertain growth in net demand.

The combined volatility of demand and renewable generation has been identified as one possible cause for underinvestment in thermal generation capacity. However, a rational investor with perfect information about how the net demand and its growth are distributed—and therefore perfect information on its volatility—would have little trouble estimating its expected earnings over the life of the asset as it occurs in many other markets. In reality, it takes time to fully understand the underlying process characterizing net load uncertainty, and it is the limited knowledge about this process, based on historical experience, that informs investment decisions. Therefore, it is not the volatility per se that is problematic, but the uncertainty on the underlying parameters and processes characterizing that volatility—one learns faster about the average of the underlying distribution than about the tails of that distribution.

A recent CEEPR working paper[1] by John Parsons and Fernando de Sisternes

highlights the central role that uncertainty around the distribution and growth of the net load plays in the case for introducing capacity remuneration mechanisms (CRMs, or capacity mechanisms) and in determining their optimal design. Capacity mechanisms are a tool that shifts the structure of profits from one where all revenues are earned exclusively through the marginal cost of energy supplied to another in which the same total revenue is paid for capacity across a broader number of hours. A capacity mechanism can be a useful element of market design, as it can offer a way for society to provide ex ante a rational signal about its short-and long-term demand for security of supply and to commit to paying for that supply on reasonable terms, which would partially resolve the uncertainty about the future net load.

Using a stylized example, this working paper describes how uncertainty increases the risk investors take financing new generation so that a higher likelihood of near term profits is required for new investments to take place. The paper reviews existing forms of capacity mechanisms and discusses how each of them addresses the uncertainty component of the security of supply problem, highlighting the role that contract durations play in increasing the optimal capacity in equilibrium, enhancing the system's security of supply.

The paper also stresses the importance that capacity mechanisms be technology neutral to guarantee access to all generation technologies—conventional and renewable—as well as energy storage, and that they introduce penalties for non-performance to ensure that resources are only compensated for the capacity they actually provide when it is needed the most. Failing to do so would imply a hidden subsidy to the limited set of technologies qualifying for the capacity mechanism, and produce an inefficient generation mix.

Most zero emissions technologies—e.g., wind, solar PV, nuclear, energy storage—are capital intensive assets with zero or almost-zero variable costs. As power systems embark in the process of deep decarbonization and the focus on competition in generation shifts from variable costs to capital costs, the design of market-based capacity mechanisms will become a critical element to guarantee the optimal deployment of capacity and operation of resources.

[1] Fernando J. de Sisternes and John E. Parsons (2016), "The Impact of Uncertainty on the Need and Design of Capacity Remuneration Mechanisms in Low-Carbon Power Systems." *CEEPR WP-2016-004*, MIT, February 2016.

A Review of the Value of Aggregators in Electricity Systems

by: Scott Burger, Jose Pablo Chaves-Ávila, Carlos Batlle, & Ignacio J. Pérez-Arriaga

Electricity systems are currently facing significant changes as a result of the deployment of information and communication technologies (ICTs), power electronics, and distributed energy resources (e.g., gas-fired distributed generation, solar PV, small wind farms, electric vehicles, energy storage, and demand response). Given the small scale of these technologies, many industry stakeholders claim that aggregators can create economic value by enabling DERs to provide these services at scale.

Citing the untapped value of aggregators, regulators and policy makers in both Europe and the United States are debating the role of aggregators. In Europe's liberalized retail markets, the debate is centered around the functioning of retail markets, the ability of retailers to deliver desired levels of consumer engagement and value-added services, and the value or disvalue of superimposing third party aggregators over these retailers. On the other hand, new independent aggregators are highly active in U.S. markets, and stakeholders are attempting to design market rules to ensure these aggregators flourish due to true value creation as opposed to regulatory arbitrage. This debate has implications for a wide range of questions, such as: should the power system accommodate many aggregators or only one centralized aggregator? Who can or should be an aggregator (transmission and distribution system operators, retailers, third parties, etc.)? What market design elements may need to be adapted or adopted to accommodate DERs? What is the "best feasible level of unbundling"?

In a recent MIT CEEPR Working Paper[1], a team of authors from the Massachusetts Institute of Technology and Comillas Pontifical University review the economic and power systems literature to clarify ongoing debates about the value of aggregators, establishing an economically grounded "rational template" with which to analyze the role of aggregators in power systems. Based on their review, the authors argue that, in a hypothetical world with "perfect" information, economically rational agents, and "perfect" regulations,

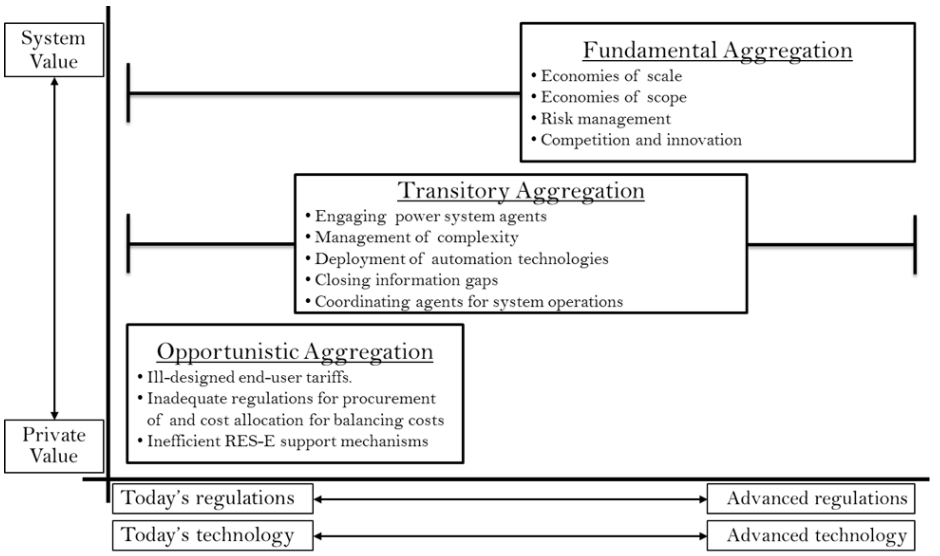


Figure 1: Value of aggregators based on technology and regulatory contexts.

aggregators will only create value by capitalizing on economies of scale and scope and by managing risks (these are termed "fundamental values" by the authors). They further note that maximizing the benefits of these sources of value could lead to a single, centralized aggregator, which might harm other power system objectives such as competition, agent engagement, and innovation; thus, the role of aggregators would be determined by analyzing the tradeoffs between fundamental values and the value of competition. Recognizing that such a hypothetical, perfect world is far from current realities, they identify "transitory" values of aggregation that may exist as power system technologies and regulations advance. Finally, they identify a number of regulations and market designs that create "opportunistic" aggregations; these opportunistic aggregations impair as opposed to enhance power system economic efficiency. Figure 1, above, summarizes these findings.

Fundamental value stems from factors inherent to the act of aggregation itself. While regulation and policy may influence whether or not this value is captured and by whom, the value itself is regulation, policy, and agent-independent. In the context of the power system, aggregation may create fundamental value through capitalizing on economies of scale and scope and by mitigating uncertainty. These fundamental values give the aggregator characteristics of an economic club, and, if considering only economic factors, may lead to a market structure with a monopolistic aggregator, harming competition. Furthermore, competition amongst aggregators may create value through driving agent engagement (enabling the participation and optimization of DERs), and potentially mitigating market power. Where sufficient data does not exist to balance the described value streams, regulators and policy makers should reduce entry barriers for new aggregators, allowing market forces to provide the efficient balance of competing or monopoly aggregators.

Aggregators may create value to the power system transitions from the near future scenario to the reference future scenario. Transitory value is not necessarily inherent to aggregation, but may be unlocked by aggregation. Transitory value, by definition, may exist only for a period of time until superior solutions emerge. In their analysis, the authors highlight that transitory value comes from closing information gaps (i.e. related to price signals, complexity of power system) as well as agent engagement. Closing information gaps may have very large impacts in the near term. Indeed, today's aggregators (both third party aggregators and retailers) pass on price signals to end consumers, enabling more efficient energy consumption. Further, these aggregators are providing automating technologies that have the potential to increase network utilization, decrease total costs, and increase consumer engagement in the near and long term.

Finally, opportunistic aggregation may emerge as a response to regulatory flaws. This opportunism may create private value without increasing the economic efficiency of the system; furthermore, this opportunism may restrict competition, especially for small agents. The study's authors highlight a number of regulations that create opportunistic aggregations – i.e. aggregations that harm overall system efficiency. Rules related to the procurement of balancing services (i.e. penalties beyond imbalance payments and symmetric bidding requirements), rules regarding the allocation of balancing costs to agents (i.e. allowing portfolio balancing and using dual imbalance pricing), and inconsistent locational price signals and network charges all create opportunities for regulatory arbitrage and opportunistic aggregations.

Where aggregation creates fundamental or transitory value, regulators or policy makers may want to take steps to remove barriers to its realization or to encourage it outright. However, where aggregation only leverages opportunistic value or regulatory arbitrage, regulations should be modified (unless this fact is explicitly acknowledged and desired as a form of subsidy). The foregoing review thus serves to highlight the tradeoffs between the values that aggregators may provide to the system.

[1] Scott Burger, Jose Pablo Chaves-Ávila, Carlos Batlle, Ignacio J. Pérez-Arriaga (2016), "A Review of the Value of Aggregators in Electricity Systems." *CEEPR WP-2016-001*, MIT, January 2016.

The E2e Project Awarded $5 Million Grant to Evaluate New Advanced Energy Monitoring System

by: Raina Gandhi

The E2e Project is in the process of launching the largest demonstration and evaluation of an innovative energy monitoring system for industrial facilities. The project will provide industrial customers and policymakers data-based evidence on whether advanced energy monitoring is a cost-effective approach to save energy and reduce greenhouse gas emissions. This research project is being carried out in partnership with a private company, Lightapp Technologies, and is supported by a $5 million research grant from the California Energy Commission.

The grant was awarded as part of the CEC's Electric Program Investment Charge (EPIC), an ambitious effort to develop and demonstrate the next generation of energy technologies to address California's clean energy goals.

E2e's partner, Lightapp Technologies, has developed a software-based, optimized energy management system for industrial facilities. This innovative approach to energy management relates electricity consumption within specific plant systems to the production outputs of those systems. Lightapp's software collects data from shop-floor sensors, manufacturing software systems and external data such as weather, and creates reports that will enable users to discover, analyze, and share data about how they consume energy—and, more importantly, how they might use it more efficiently. The reports also identify specific ways to lower consumption through operational changes, repairs, and capital investments.

"Lightapp's mission is to enable decision makers at all levels in the industrial sector to make financially driven decisions about their energy and operations" said Elhay Farkash, CEO at Lightapp. "We are excited to partner with E2e to roll out our new technology to industrial facilities in California and show that by simplifying energy management through software, manufacturers can improve bottom line results and enhance throughput performance."

A bottling line run by an air compression system. These systems account for up to 10% of the electricity used by the plant.

For this project, E2e and Lightapp will test Lightapp's energy-monitoring system in one hundred Californian industrial facilities. The project will focus on the facilities' compressed air systems. Compressed air systems do everything from running bottling lines at breweries to powering tools in automotive factories. Air compressors and the equipment they drive account for around 10 percent of the electricity used by manufacturers. In some plants, compressors use more electricity than any other kind of gear. With a leaky compressor valve, money is literally disappearing into thin air. If successful, the technology can be used throughout a facility and measure energy consumption in every part of the manufacturing process.

E2e will structure the evaluation as a randomized controlled trial, where randomly chosen facilities will be recruited to participate and receive Lightapp's analytical software. This arrangement will enable the faculty researchers - Catherine Wolfram (UC Berkeley), Michael Greenstone (University of Chicago), and Christopher Knittel (MIT) - to precisely measure the impact of the new technology and analytics on industrial facilities' electricity consumption. By including a sampling of facilities from different industrial sectors, the researchers also hope to identify which types of facilities are more likely to adopt the new technology and gather information on potential barriers to adoption.

This project aims to generate rigorous and reliable evidence on the effectiveness of an industrial energy-management system. If successful, the findings can be used to encourage thousands of manufacturers worldwide to deploy energy management systems to save energy, lower costs, and reduce carbon emissions.

2015 Fall Research Workshop

by: Fiona Paine & Olivia Zhao

Dr. Ann Wolverton, an Economist at the U.S. EPA, gives a talk to over 80 attendees at the 2015 Fall CEEPR Research Workshop in Cambridge, Massachusetts.

Held in Cambridge, Massachusetts on November 19 and 20, the 2015 Fall Research Workshop brought together over 80 participants for a lively discussion of relevant issues in the broader energy and environmental policy arena.

The first day started off with Mark Finley of BP, who outlined highlights from the latest installment of the BP Statistical Review of World Energy. He focused on the central themes that shaped the energy sector in 2014, notably the shale gas revolution, the rebalancing of the Chinese economy, and an increased focus on climate change and renewable energy. Next, Julien Daubanes of ETH Zurich took a more theoretical view, drawing on a recent MIT CEEPR Working Paper to argue that OPEC is practicing limit pricing, with significant effects on carbon and climate policy.

Ann Wolverton of the U.S. Environmental Protection Agency (EPA) described the work of the Interagency Working Group on Social Cost of Carbon, reviewing the models used to calculate the social cost of carbon as well as the underlying assumptions. Frances C. Moore of the University of California, Berkeley followed with a presentation relating growth impacts and the social cost of carbon. By using a new model that takes into account the effects of temperature change due to carbon emissions on growth, Moore calculated a substantially higher social cost of carbon due to a lower discount rate.

Following a lunch discussion of the recently unveiled MIT Plan for Action on Climate Change introduced by Henry D. Jacoby of the MIT Sloan School of Management, the first afternoon session provided insights into the strengths and limitations of climate models and scenarios. Robert Pindyck of the MIT Sloan School of Management drew on a recent MIT CEEPR Working Paper to argue that substantial uncertainties about key parameters undermine the value of integrated assessment models. Sergey Paltsev of the MIT Joint Program on the Science and Policy of Global Change countered, drawing on examples to suggest that integrated assessment models offer useful policy guidance despite the uncertainties.

The final session of the first workshop day focused on electricity market design and the role of capacity payments. Carlos Batlle of the Institute for Research in Technology (IIT) at Comillas Pontifical University, Madrid, drew attention to the shortfalls in European electricity market integration as various EU Member States proceed to unilaterally implement non-market approaches. John Parsons of the MIT Sloan School of Management discussed the implications of recent proposals to increase natural gas pipeline capacity into New England. William Hogan of Harvard University concluded the first day with a dinner presentation on the implications of the EPA's Clean Power Plan for U.S. utilities.

The second day opened with a presentation from Arthur van Benthem of the University of Pennsylvania, who demonstrated that emissions standards increase demand and prices of used cars, with an unintended effect of promoting emissions leakage. Similarly, Matthew Zaragoza-Watkins of MIT CEEPR identified a measurable, but limited impact of new standards in promoting pre-buying behavior, which can result in delayed capital turnover and increased emissions after implementation.

Lucas Davis of the University of California, Berkeley then examined how clean energy tax credits have been distributed across American households, finding that higher income families have disproportionately benefited from clean energy credits. Christopher Knittel of MIT CEEPR and the MIT Sloan School of Management closed the day by discussing recent work simulating the effect of greenhouse gas reduction policies on innovation, concluding that overly generous incentives can focus innovation in less productive areas.

UPCOMING WORKSHOPS
July 7-8, 2016, Paris, France
September 8-9, 2016, Berlin, Germany
November 17-18, 2016, Cambridge, MA

Emissions Trading in North America and Beyond: Taking Stock and Looking Forward

by: Gunther Glenk & Michael Mehling

With the recently adopted Paris Agreement, the international community has committed to an ambitious pathway towards decarbonization of the global economy. Cost-effective policy approaches will be critical to minimize the welfare impacts of climate change mitigation, and emissions trading is favored in economic theory because it offers compliance flexibility to participating entities. In practice, however, the implementation of this policy instrument is complex and raises important questions.

An event organized by MIT CEEPR jointly with the governments of Québec and Germany convened leading decision makers from the public and private sector and researchers for an informed debate on the past and future of emissions trading in North America.

Against the backdrop of a recent U.S.-Canada Joint Statement on Climate, Energy, and Arctic Leadership that emphasized the role of carbon trading in North American climate cooperation, the MIT Center for Energy and Environmental Policy Research (MIT CEEPR) convened a timely high-level event on the prospects for emissions trading and carbon market linkage in Canada and the United States. In partnership with the Government of Québec and the Consulate General of the Federal Republic of Germany, this event brought together over 80 invited participants on the MIT Campus on April 11, including state legislators and cabinet members, senior public officials, and representatives from industry, civil society and academia.

Christopher R. Knittel, the William Barton Rogers Professor of Energy Economics in the MIT Sloan School of Management and Director of MIT CEEPR, opened the event by recalling CEEPR's strong legacy in the economic analysis and intellectual foundation of emissions trading as a policy instrument. Helmut Landes, Germany's Deputy Consul General in Boston, provided welcoming remarks on behalf of his country and highlighted the importance of robust knowledge-based engagement in international relations, as evidenced by the success of the recent Iran nuclear negotiations brokered by MIT's Ernest Moniz.

The morning sessions consisted of academic presentations by researchers and policy experts, whereas the afternoon sessions featured roundtable discussions with experienced leaders from public policy and the private sector. A retrospective of emissions trading around the world began the day, with Clayton Munnings of Resources for the Future (RFF) presenting his analysis of experiences with different approaches to carbon pricing. While the past two years have seen a surge in carbon pricing initiatives, the global dynamic still is concentrated around a small group of leaders. Above all, he argued, carbon pricing has yet to evolve from an insurance policy for regulators to the workhorse for abating carbon emissions before it can leverage its cost-reducing potential.

Michael Pollitt, a Professor of Business Economics at the University of Cambridge, continued with a presentation on the economic merits and feasibility of a global carbon market compared to alternative policy options. Considering the necessary alignment of governments to introduce a global carbon market, it may face political challenges; however, even incomplete linking of national and subnational carbon markets can result in sufficient arbitrage effects to achieve the desired economic benefits. Brian Murray, Director of the Energy Initiative at Duke University, and Michael Mehling, Executive Director of MIT CEEPR, offered comments on both presentations, drawing on recent experience with subnational emissions trading systems in North America, prospects for trading under the U.S. Environmental Protection Agency's Clean Power Plan, and observations of the political economy of carbon markets.

The second session addressed opportunities for carbon market linkage following of the 21st Session of the Conference of the Parties to the United Nations Framework Convention on Climate Change (UNFCCC) in Paris in late 2015. Benjamin Görlach, Senior Fellow and Head of Economics and Policy Assessment at the Ecologic Institute in Berlin, Germany, introduced the concept of linking carbon markets, defining it as acceptance of a carbon unit issued under one scheme for compliance purposes under another. With his presentation, he highlighted that linking quickly becomes very complex as each additional linked system will impact supply and demand dynamics, and potentially market integrity, in all other linked systems, requiring joint governance structures to sustain compatibility over time.

Stefan Weishaar, Professor of Law and

Economics at the University of Groningen, the Netherlands, and a Visiting Scholar at MIT CEEPR, expanded on the challenges of carbon market integration by highlighting the risks of electricity leakage. In certain linking scenarios, for instance in China, electricity generated within one jurisdiction might fall under carbon pricing, whereas electricity imported from outside the jurisdiction might not and would therefore, all things being equal, be produced and sold at lower cost.

Serving as discussant in the foregoing session, Jackson Ewing, Director of Asian Sustainability at the Asia Society Policy Institute in New York, however, highlighted that cooperation on carbon trading – especially among countries facing diplomatic stalemate on other issues – might be an area of shared interest and opportunity to foster mutual trust. Ruben Lubowski, Chief Natural Resource Economist at the Environmental Defense Fund, reminded the speakers that reducing leakage risks is one of many arguments favoring coordinated linking, but he also addressed some risks posed by recent proposals to develop a network of carbon markets with exchange rates between carbon asset categories.

At lunchtime, Marie-Claude Francoeur, Québec's Delegate to New England, recalled her role in the elaboration and adoption of emissions trading in Québec to remind the audience that political challenges can be overcome, concluding with optimism about future climate cooperation across North America. The first roundtable after lunch then offered varied perspectives from leading policy makers and experts, including Jean-Yves Benoît, Director of Carbon Markets at the Québec Ministry of Sustainable Development, the Environment, and the Fight Against Climate Change, and Co-Chair of the International Carbon Action Partnership; Christopher Knittel, Director of MIT CEEPR; Deborah Markowitz, Secretary, Agency of Natural Resources, State of Vermont, and Member of the Board of the Regional Greenhouse Gas Initiative; and Alex Wood, Executive Director of the Ontario Climate Change Directorate; with David Cash, Dean of the McCormack Graduate School of Policy and Global Studies at the University of Massachusetts Boston and former Commissioner of the Department of Environmental Protection, Commonwealth of Massachusetts, moderating. A lively exchange of views and discussion with the audience ensued.

In the second and final roundtable, the focus shifted to the perspective of those stakeholders principally affected by emissions trading, compliance entities and market facilitators in the private sector. This session featured Adam Auer, Director of Sustainability at the Cement Association of Canada; Brad Neff, Principal at the Pacific Gas & Electric Company (PG&E); Jean Nolet, President and CEO of Coop Carbone; Janet Peace, Senior Vice President for Policy and Business Strategy at the Center for Climate and Energy Solutions (C2ES); and Sandy Taft, Director of Environmental and Sustainability Policy at National Grid; with Katie Sullivan, Director for the Americas and Climate Finance at the International Emissions Trading Association (IETA), moderating. In the discussion, the group agreed on three priorities for future policy development: fostering confidence, providing certainty, and safeguarding competitiveness.

Public policy roundtable with (from left to right) Alex Wood, Deborah Markowitz, Christopher Knittel, Jean-Yves Benoît, and David Cash.

Mass. State Senator Barrett (D) engages with the policy roundtable participants.

Overall, these three issues proved to be recurring themes throughout the day. Lack of trust in market integrity and policy stability was repeatedly identified as a key challenge for emissions trading going forward. Both industry representatives and public policy makers acknowledged the importance of political certainty for short-, medium- and long-term investments. And finally, with only 12% of global GHG emissions covered by a carbon price, the threat of leakage remains very real as companies in some jurisdictions face higher costs than those operating in others, distorting competition and preventing a level playing field. Overall, the discussions throughout the day reflected a clear sense of momentum for emissions trading in North America and beyond, yet also underscored the need for further research and critical debate.

University Energy Initiative Symposium

by: Sarah Armitage

On April 29, 2016, the MIT Center for Energy and Environmental Policy Research (MIT CEEPR) convened a symposium for the leadership and management of major energy economics and policy research initiatives across the United States. Funded by the Alfred P. Sloan Foundation, the daylong conference facilitated a first-ever strategic discussion of current and emerging research priorities, funding opportunities, and effective communication and outreach practices among major energy initiatives. Participants included representatives from 14 university-affiliated energy initiatives and four independent research and funding organizations. The event was structured along three thematic sessions, each featuring brief kick-off presentations followed by a discussion with the audience, and a closing session that focused on identifying opportunities for future cooperation and stakeholder engagement.

The first session, on "Energy Policy Research Today – Evolving Research Themes, Methods, and Stakeholder Demands," addressed the intersection between academic research questions and questions of practical interest to policymakers. Priority research themes highlighted by participants included the role of energy efficiency in meeting climate targets; energy for development, especially large-scale energy infrastructure; environmental implications of hydraulic fracturing in oil and natural gas production; electricity storage and grid integration of renewable energy; and new modes of transport. Participants also highlighted the challenges associated with co-authoring research papers across disciplines, given the importance of discipline-specific journals in faculty promotion. Participants agreed that, unless interdisciplinary work is afforded greater credit, availability for cross-departmental research activities will be largely limited to research staff and tenured faculty.

Under the title "Sustaining the Relevance of Energy Policy Research – Engaging Stakeholders and Reaching Intended Audiences", the second session raised questions about communication and outreach. Successful examples of public-facing research that resurfaced throughout the symposium included MIT's "Future of…" studies and collaborations between representatives from various disciplines to engage in new methodologies, such as machine learning or remote sensing. Speakers noted that the success of such projects stemmed from the complexity of the policy problems and policymakers' recognition of that complexity; the contributors' general agreement about project purpose and process; and the separation of the research process from public engagement activities. Beyond traditional white papers and policy briefs, participants also discussed the merits of other forms of public engagement, from popular press articles and op-eds, to social media and podcasts with on-campus speakers.

During this session, one speaker distinguished between "policy-reactive" and "policy-responsive" research, and others agreed that meaningful public engagement requires an ongoing, repetitive process that allows researchers and policymakers to gradually better understand each other's respective perspectives and knowledge interests, and that ultimately emphasizes research themes rather than narrowly focusing on "the questions of the day." In this respect, participants identified a tension between the quality of policy-oriented research and its timeliness and frequency, with legitimate roles for researchers at different ends of the spectrum between rigorous, in-depth analysis and more general commentary on issues of current interest or public demand. Participants also agreed about the importance of distinguishing between engagement and impact, and of developing appropriate metrics for each.

MIT CEEPR recently collaborated with the Alfred. P. Sloan Foundation to bring together leaders of U.S. energy and policy initiatives.

The third session, on "Securing Resources for Energy Policy Research – A Survey of Fundraising Strategies and Partnership Models," sparked discussion about resource challenges among research institutes with varied organizational structures. Participants highlighted several broader trends in the fundraising landscape: a relative shift to funding from individual philanthropists, and away from corporate funding; funders' diminishing interest in providing unrestricted research funding; and funders' encouragement of greater collaboration among grantees. Disruptive transformation in the energy sector as well as heightened sensitivity about academic independence call for new approaches to diversifying and disclosing sources of research funding.

During the closing session, participants discussed follow-on activities that could leverage their respective platforms and comparative advantages to create a "whole greater than the sum of the parts" among U.S. energy initiatives. Potential avenues included hosting journalists for short courses or longer fellowships to study energy systems and markets; workshops for Congressional staffers on key energy policy issues; and central repositories for working papers or other research dissemination. Participants also discussed establishing an ongoing platform for sharing ideas – and potentially resources – among university energy initiatives. The manifold challenges and opportunities highlighted during the symposium will provide ample reason for continued dialogue and collaboration.

Notable Changes

In January, CEEPR hired **Sarah Armitage** as a Research Assistant. With Christopher Knittel, she is working on a project that examines the distributional impact of CAFE standards. Using a model to show that CAFE standards create an implicit subsidy for fuel-efficient vehicles and an implicit tax for fuel-inefficient vehicles, the project characterizes the pattern of ownership of these vehicles, by income level and other demographic characteristics. In another project, she is working to assess the impact on local mortality rates of coal-fired power plants.

At the end of January, CEEPR welcomed **Gunther Glenk** as an MIT Visiting Student. Gunther, a Master's student from the Technical University Munich School of Management, conducted economic research work on wind energy in Germany and on the risk-reducing effect of energy storage on renewables investment.

In March, Christopher Knittel and Stephen Zoepf invited **Joerg Hauke** to MIT as an MIT Visiting Student through the end of September. Joerg, a graduate student from ETH Zurich, will conduct research work on transportation mode choice and the evolution of ride and car sharing as a viable means of mobility.

Finally, in May, CEEPR is pleased to welcome two new MIT Visiting Scholars to Cambridge. **Dr. Sergio Franklin** joins CEEPR from the Superintendência de Seguros Privados (SUSEP) in Brazil. Dr. Franklin will collaborate with CEEPR faculty and pursue research on real options, multivariate stochastic processes (big data), copulas and credit risk, insurance and catastrophe economics.

In addition, **Dr. Thomas Brewer**, a Senior Fellow at the International Center for Trade and Sustainable Development in Geneva, Switzerland, and Professor Emeritus at the McDonough School of Business, Georgetown University, will be spending time at CEEPR as a visiting scholar. Professor Brewer will work on policy options to address environmental impacts from international shipping.

Recent Working Papers

WP-2016-008
Absolute vs. Intensity-based Caps for Carbon Emissions Target Setting: An Obstacle to Linking the EU ETS to a Chinese National ETS?
Yingying Zeng, Stefan E. Weishaar and Oscar Couwenberg, April 2016

WP-2016-007
Energy Scenarios: The Value and Limits of Scenario Analysis
Sergey Paltsev, April 2016

WP-2016-006
OPEC vs U.S. Shale: Analyzing the Shift to a Market-share Strategy
Alberto Behar and Robert A. Ritz, March 2016

WP-2016-005
Electricity Services in a More Distributed Energy System
Ignacio J. Pérez-Arriaga, Scott Burger, and Tomás Gómez, March 2016

WP-2016-004
The Impact of Uncertainty on the Need and Design of Capacity Remuneration Mechanisms in Low-Carbon Power Systems
Fernando J. de Sisternes and John E. Parsons, February 2016

WP-2016-003
Will We Ever Stop Using Fossil Fuels?
Thomas Covert, Michael Greenstone, and Christopher R. Knittel, February 2016

WP-2016-002
The Local Economic and Welfare Consequences of Hydraulic Fracturing
Alexander W. Bartik, Janet Curie, Michael Greenstone, and Christopher R. Knittel, February 2016

WP-2016-001
A Review of the Value of Aggregators in Electricity Systems
Scott Burger, Jose Pablo Chaves-Ávila, Carlos Batlle, Ignacio J. Pérez-Arriaga, January 2016

WP-2015-016
A Global Carbon Market?
Michael G. Pollitt, December 2015

WP-2015-015
Lessons Learned from Three Decades of Experience with Cap-and-Trade
Richard Schmalensee and Robert N. Stavins, December 2015

WP-2015-014
The Geoeconomics of Russian-EU Gas Trade: Drawing Lessons from the South Stream Pipeline Project
Antto Vihma and Umut Turksen, November 2015

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

MIT CEEPR

MIT Center for Energy and Environmental Policy Research
Massachusetts Institute of Technology
77 Massachusetts Avenue, E19-411
Cambridge, MA 02139-4307

Website: ceepr.mit.edu

A panel discussion during an MIT CEEPR event on Emissions Trading in North America on April 11, 2016.