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MIT CEEPR Newsletter

MIT Center for Energy and Environmental Policy Research

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MIT Center for Energy and Environmental Policy Research

Around the globe, the energy landscape has remained turbulent since our last newsletter went to press. A steep price decline in world oil markets is affecting both conventional and unconventional producers across their supply chains, with important economic and geopolitical ramifications. Renewable energy continued to grow at a remarkable pace, and added nearly half of all new installed electricity generating capacity in the U.S. last year – further increasing the pressure to find regulatory models that properly value the costs and benefits of these variable energy sources while guaranteeing the continued stability and affordability of our electricity supply. Through a series of publications and events, CEEPR has remained engaged on these issues. Recent Working Papers have addressed topics as diverse as the effectiveness of car allowance rebate programs, financial arbitrage in wholesale electricity markets, or the international climate negotiations. Events on carbon pricing and the price and geopolitical implications of unconventional oil and gas afforded timely opportunities for discussion. Several visiting scholars enriched the CEEPR community with their insights. The upcoming months will remain equally busy, as we prepare for our annual research workshops and a series of exciting research projects. We hope you will continue to be an active participant, and look forward to seeing you at CEEPR!

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A Strategic Perspective on Competition in International Natural Gas Markets

by: Robert A. Ritz

Natural gas increasingly plays an important role in energy policy—as well as geopolitics. The U.S. shale gas "revolution" has already had large knock-on effects across energy markets and economies worldwide, and the U.S. itself looks set to become a major exporter of liquefied natural gas (LNG) over the coming years.

In Europe, concerns about "energy security" have re-emerged due to the political conflict between Russia and Ukraine, and the European Commission in April 2015 launched an anti-trust case against Gazprom based on its alleged dominant market position in parts of Central and Eastern Europe. But while such natural gas issues receive much attention in public debate, they are under-researched in the academic literature.

Robert Ritz's ongoing research at the Energy Policy Research Group (EPRG) at Cambridge University aims to fill some of these gaps. This research program was an important part of his 4-week visit to CEEPR in April 2015, at the invitation of Michael Mehling. It resulted in a seminar presentation to the Joint Program on the Science and Policy of Global Change at MIT, as well as a discussion at the CEEPR/MITEI Oil & Gas Symposium on April 22, 2015.

A recent working paper by Ritz presents a game-theoretic model of competition in natural gas markets, with an emphasis on the strategic interaction between pipeline-based sellers, such as Russia and Norway, and exporters of LNG, such as Qatar, Australia, and Nigeria.[1] While these two organizational technologies increasingly compete head-to-head, they are also fundamentally different. Gas pipelines have a very high degree of "asset specificity"; once built, they are physically bound to a particular route, with no alternative use. By contrast, LNG is transported by tanker, giving exporters a choice of markets for any cargo. As a result, piped gas is more strongly committed to a particular export market.

Russian President Vladimir Putin and Chinese Vice Premier Zhang Gaoli at the Power of Siberia pipeline construction launch on September 1, 2014. Source: *Gazprom / RIA Novosti / Alexey Nikolsky*

Ritz argues that this greater commitment gives piped gas a competitive advantage over LNG in their common export markets, notably in Europe. The reason is that a pipeline producer, such as Gazprom, can strategically over-expand its capacity investment and market share in Europe because it realizes that LNG exporters, such as Qatar, have the "outside option" of instead diverting sales to Asia (or other export markets). In contrast to most policy discussion, the analysis suggests that Gazprom's traditional focus on Europe may be a source of strength; it also suggests that European gas buyers have actually benefitted from this, with greater gas consumption, lower prices, and better "energy security."

The same logic can be used to evaluate Russia's evolving gas export strategy. In May 2014, Russia and China agreed on the "Power of Siberia" deal, reportedly worth $400 billion over 30 years. Not long after, in November 2014, they moved closer to the "Altai" agreement, which involves piped gas from Western Siberia that has so far gone to European consumers. Some analysts expect Russia to thus become the new "swing producer" between Europe and Asia. The model suggests that, from a strategic point of view, the Altai deal may be less attractive to Russia—because it risks undermining Gazprom's traditional commitment to the European market, and its resulting competitive advantage over LNG.

Looking ahead, the entry of the U.S. into the global gas scene and the rapid evolution of natural gas markets and regulatory policy in Asia suggests that the need for research will not diminish any time soon.

[1] Ritz, Robert A. (2015), "Strategic Investment and International Spillovers in Natural Gas Markets." *Working Paper 15-05*, Energy Policy Research Group, University of Cambridge, February 2015.

The Geoeconomics of the South Stream Pipeline

by: Antto Vihma

Natural gas trade has developed into an object of contestation between the EU and Russia. This unfortunate reality is in direct opposition to the European post-Cold War vision, in which energy trade was thought of as the glue that would bind the two regional powers together in peaceful and prosperous trade relations, a positive circle of mutual interdependence. The initial optimistic agenda met obvious difficulties as Russia gradually hardened its stance, favouring an increasingly strategic view on its energy reserves.

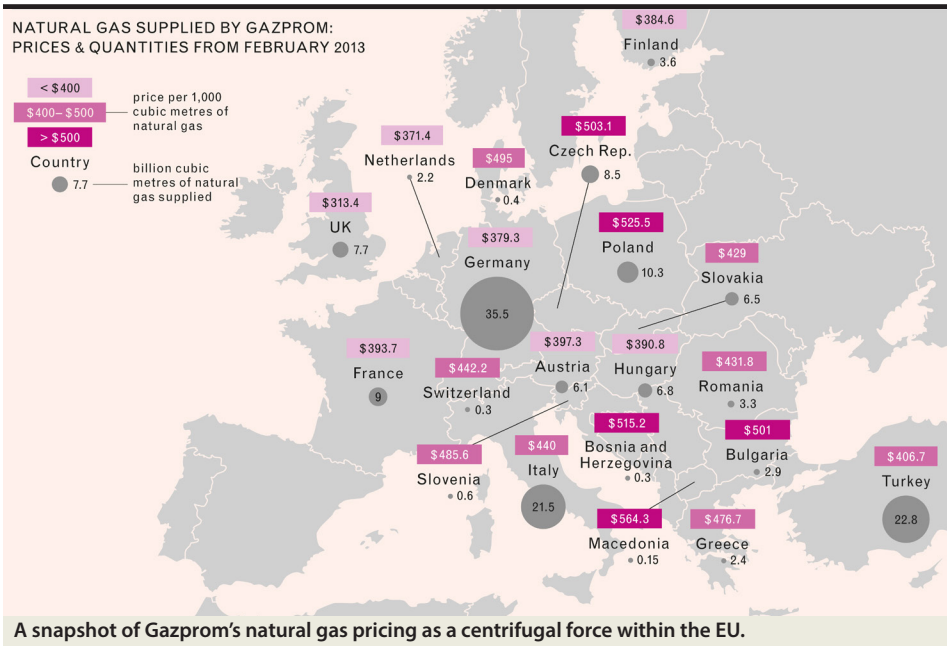
From December 2014 to February 2015, CEEPR hosted Visiting Scholar Dr. Antto Vihma, a Senior Research Fellow with the Finnish Institute of International Affairs. In a forthcoming CEEPR Working Paper, Dr. Vihma traces the process of South Stream pipeline construction and analyzes it from a geoeconomic perspective. Geoeconomics is a rising framework for foreign policy analysis, rivaling both economic liberalism and traditional geopolitics as a paradigm of foreign and economic policies of states. It challenges the liberal interdependency paradigm by underscoring the strategic interests – zero-sum interests that do not function in the logic of commerce – in economic relations between states. But it also departs from geopolitics, highlighting softer, economic means of foreign policy, something that traditional geopolitics often overlooks.

South Stream was aimed at bringing up to 63 billion cubic meters of natural gas each year across the Black Sea to the Balkans and finally to Austria and Italy. Gazprom announced the project in June 2007, but to the surprise of many analysts, politicians and partner companies, cancelled it in December 2014. From the outset, mainstream commentators suggested that the project was motivated by geoeconomics – a strategic advantage rather than commercial viability. Russia stood to increase its leverage over Ukraine and re-invigorate its influence in South-Eastern Europe, whereas the European Commission repeatedly expressed concerns about its compatibility with EU common energy market rules, initially without success.

Through process tracing, the Working Paper concludes that South Stream was a strategic priority for Russia that became a victim of Russian adventurism in Ukraine. In Spring 2014, Russian leadership calculated that it could advance two European strategies simultaneously: a geoeconomic one (constructing South Stream) and a geopolitical one (military campaign in Ukraine). Here, President Putin – frequently described by political commentators as a master strategist – made a critical miscalculation. Once the Ukrainian conflict began, however, the EU was able to harden its line on South Stream. The global energy context, including cheap coal prices, expansion of renewable energies, and greater availability of liquefied natural gas, cannot fully account for the assertiveness of the EU Commission and the allegiance of Member States in the South Stream case.

The South Stream case study highlights the incompatibility of geoeconomic and geopolitical strategies. Europe's dependence on Russia for gas has been widely viewed as limiting the scope of the European response to Russia's military aggression in Ukraine. What has not been adequately analyzed, however, is the harm to Russian geoeconomic influence caused by Russia's geopolitical intervention in Ukraine. In the past, Russian geoeconomic activity has been highly successful as a centrifugal, dividing power within the EU. The geopolitical campaign in Ukraine, by contrast, has been a centripetal force, resulting in increased EU unity, as manifested by the South Stream case.

Although contemporary analysts are keen to invoke von Clausewitz, it seems that descriptions of geoeconomics as a continuation of war by other means are analytically poor and potentially misleading. The means of geopolitical power projection and tools of geoeconomic power have notably different effects in the contemporary, interconnected world.



A snapshot of Gazprom's natural gas pricing as a centrifugal force within the EU.
Source: *Vihma 2015, forthcoming*

OPEC's Pricing vs the Carbon Tax

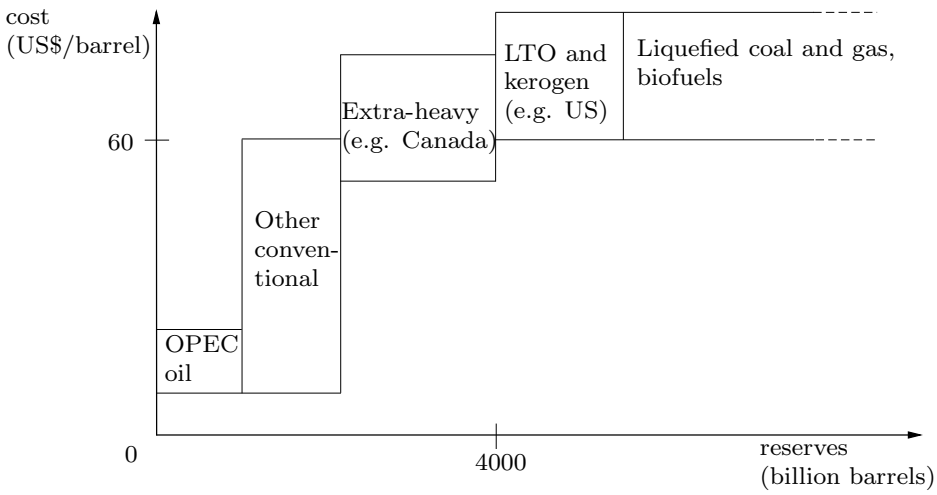
by: Saraly Andrade de Sá and Julien Daubanes

Most experts share the same explanation for last year's oil price drop. Faced with rapidly improved and abundant competing resources, the OPEC cartel was protecting its market shares. In the words of *The Economist* (December 6, 2014), the tactic was to "let the price fall and put high-cost producers out of business".

Indeed, an oil price sufficiently high, for sufficiently long, triggers huge investments in other fuels' development, a fact already experienced in the 1970s. Today's long-run unit cost curve for liquid fuels becomes flat around $60. At this price, not only Canadian, Russian and Venezuelan resources start to break-even, but also most of U.S. shale oil, and virtually unlimited capacities of synthetic fuels; production flexibility further confers a special role to shale oil.

For many analysts, OPEC makes the oil price, determining the profitability of other energy sources. The reason is that despite its less-than-40-percent market share, the cartel controls the quasi-entirety of currently exploitable production capacities. Therefore, the everyday balance of oil supply and demand relies on the "call on OPEC", and the oil price strongly responds to the cartel's production.

In a recent CEEPR working paper, Saraly Andrade de Sá and Julien Daubanes combine empirical estimates to establish that the demand for OPEC's oil exhibits a less-than-one demand elasticity, in contradiction with the widely-used approach to OPEC's market power.[1] This very low demand elasticity implies that OPEC's profits increase with price, yet to the extent that it does not trigger the entry of aforementioned competing resources; those resources would largely eat into OPEC's market shares. When the oil price was higher, OPEC Secretary General Abdalla El-Badri already referred to the potential "destruction as far as demand [was] concerned" (May 3, 2012).



Break-even prices for main liquid fuels. Source: *International Energy Agency*

In the jargon of industrial economists, OPEC practices "limit pricing": it seeks, albeit through trial and error, to induce the highest price that deters resources like shale oil, setting extraction accordingly. The authors' model shows that "limit pricing" is not only a short-run strategy, but may be optimal in the long run for OPEC, despite the cartel's reserve constraint.

The oil price drop initiated by OPEC in June 2014 is often celebrated as good news by business analysts. However, OPEC's limit-pricing behavior is bad news for environmental policy makers; the authors point out that the effect of carbon taxation does not obey the usual logic in the face of "limit-pricing" suppliers. For example, taxing OPEC's oil leaves unaffected the cartel's supply level which deters competing resources. Surprisingly, this is so despite the fact that the organization's revenues may be eroded. Yet carbon taxation also penalizes carbon substitutes to OPEC's oil, causing two effects of opposite directions.

The good effect concerns the aforementioned resources (shale oil, liquefied gas…) that largely threaten OPEC's market shares: as those resources are penalized, the cartel can afford a price rise, hence cutting its oil supply.

The bad effect concerns all other carbon substitutes to OPEC's oil, which currently meet some fraction of the energy demand (non-OPEC oil, coal and gas for some uses…). Their market shares are limited because their production exhibits rapidly decreasing returns to scale; for OPEC, they are not worth deterring. When penalized, these substitutes' market shares are abandoned to OPEC, which takes them over with more oil. A limit-pricing OPEC completely replaces these carbon resources, implying ambiguous effects on total carbon emissions.

While the ability of the carbon tax to reduce carbon emissions should be expected to be largely weakened by OPEC's pricing, one basic environmental policy remains very effective: it is to promote non-carbon substitutes to eat into the cartel's business.

[1] Andrade de Sá, S., and J. Daubanes (2015), "Limit Pricing and the (In)Effectiveness of the Carbon Tax." *CEEPR WP-2015-004*, MIT, April 2015.

When Financial Trading Only Makes Things Worse

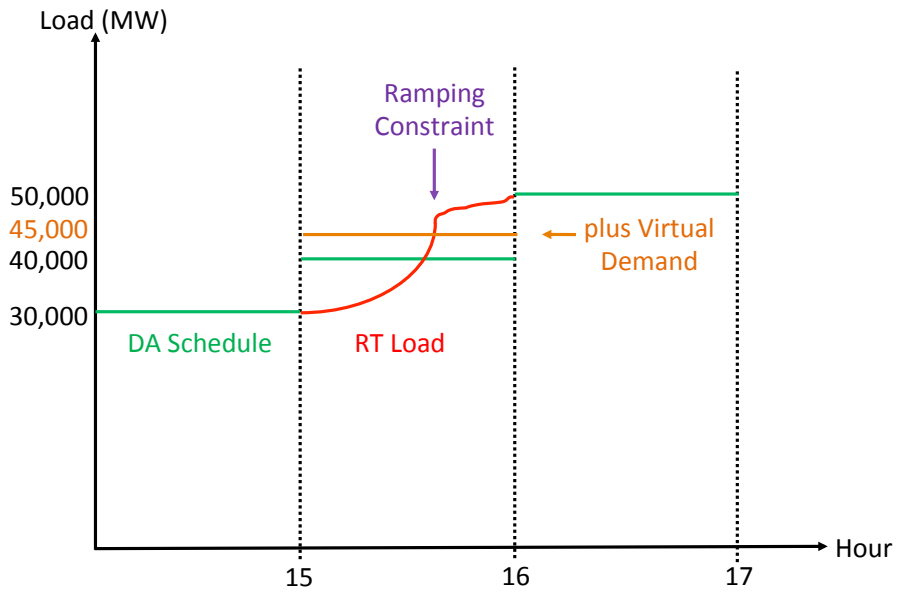
by: John E. Parsons

The role of financial traders in commodity markets is controversial. Advocates argue that they improve the pricing to better reflect information about expected demand and supply. Detractors complain that they often manipulate prices or otherwise move the market away from the fundamentals of supply and demand. The U.S. Federal Energy Regulatory Commission (FERC) in recent years has vigorously prosecuted a number of cases against financial traders in wholesale electricity markets, and controversy has swirled about whether these prosecutions have hurt or helped the operation of the markets.

Recently, Dr. John Parsons, a CEEPR affiliate and faculty member in the Finance Group at MIT's Sloan School of Management, worked as a Visiting Scholar in FERC's Division of Analytics and Surveillance (DAS) to study financial trading in U.S. electricity markets. Working with four colleagues in DAS, Dr. Parsons completed a study of a unique type of financial trading known as Virtual Bidding. That study has been issued as CEEPR Working Paper 2015-002, "Financial Arbitrage and Efficient Dispatch in Wholesale Electricity Markets."[1] The research helps understand certain situations in which virtual bidding not only fails to improve system performance, but also adds to system costs.

Virtual bidding is a type of financial trade that is unique to organized electricity markets. A bidder can speculate on the spread or difference between the Day-Ahead and the Real-Time hourly prices at a certain location. Virtual Bids are placed in the Day-Ahead auction, and they clear like all other bids. Virtual demand bids clear if the price bid is greater than the auction clearing price, while virtual supply bids clear if the price bid is less. The bidder earns a gross cash payoff on a cleared bid equal to the price spread: demand bids earn the Real-Time price less the Day-Ahead price, while supply bids earn the reverse. The bidder also pays some costs, so the net cash payoff is less than the spread. The payoff is always cash: the bidder never actually takes power, and never actually supplies power. Consequently, financial players can enter the market using these bids.

The Inability of Virtual Bidding to Solve the Ramping Problem



The green lines in the figure shows the Day-Ahead dispatch schedule for three successive hours, assuming no virtual bidding. Generation awards in the Day-Ahead market are for a block of power. There is no granularity below the hourly time scale. The red line in the middle hour shows how load evolves through the hour when the Real-Time market schedule is developed. The high ramp rate in the middle of the hour exceeds the capacity of the units dispatched in the Day-Ahead market and forces the system operator to reach for other resources with the capacity to ramp quickly. This is what causes the infrequent, but extremely severe price spikes in the Real-Time market. The orange line shows the impact of virtual demand bids. The total generation award in the hour is increased. However, like all bids into the Day-Ahead market, virtual bids only express demand at an hourly granularity. The virtual demand increases the total generation award for the hour, but does not specify the need for the sharp ramp capacity. The added generation may not be alleviate the ramping constraint. In fact, in many circumstances, increases the level of generation awarded can reduce the ramping capacity, exacerbating the problem.

The promise of virtual bidding is that it improves the pricing and dispatch of generation. For example, in order to optimize the commitment of thermal generation, system operators need to forecast the amount of wind generation that will flow the next day. One tool at their disposal is the Day-Ahead offers by wind generators themselves. However, these generators have historically underbid the quantity of generation they end up supplying into the Real-Time market. Financial traders have noticed this, and they make virtual supply bids into the Day-Ahead market which reflect their estimates of the shortfall. As a result, the cleared physical supply in the Day-Ahead market more accurately forecasts the actual physical supply in the Real-Time market.

Unfortunately, this promise is not always realized. Virtual bidding can shape the aggregate level of supply and demand at a given location in a given hour. So long as the system problems crystallize to a shortage or surplus of aggregate supply or demand at a given location and given hour, then virtual bidding has the potential to improve the situation.

Unfortunately, the unit commitment and optimal power flow problems that these wholesale market auctions are used to solve are much more complex than is acknowledged in the metaphor of an aggregated supply curve and an aggregated demand curve. The true unit commitment problem has to confront many fixed costs and discrete choices created by things like ramping constraints which raise the computational complexity enormously. The true optimal power flow problem needs to respect an array of complex power flow constraints such as thermal limits on the network cables and voltage limits. These complexities sometimes undermine the effectiveness of virtual bidding.

The paper uses the problems experienced in the California market as a case study to help illustrate the problem. California's new market design began operation in 2009, and immediately it exhibited a peculiar pricing anomaly.

On average, the Real-Time price was higher than the Day-Ahead price. This was due to a very few hours, less than 1% of all hours, when for a short interval of perhaps 5-minutes or so the load was ramping up at an extremely fast rate that exceeded the ramping capability of most of the units that had been dispatched in the Day-Ahead market. In the other 99% of the hours, the Day-Ahead price actually exceeded the Real-Time price by a small amount. During those 1% of hours when load was ramping very quickly, there was no general shortage of supply. Many of the units that had been dispatched for that hour had extra capacity. But they did not have the capacity to ramp up quickly enough to take advantage of that capacity within the 5-minute interval that it was required. Therefore, the system operator had to turn to other, expensive units and raise the price dramatically.

This price anomaly was an opportunity exploited by financial traders who placed a large quantity of profitable virtual demand bids. Unfortunately, this did not improve system operation. In 99% of the hours, the Day-Ahead price was already above the Real-Time price, and the virtual demand bids only increased the Day-Ahead price yet further. In 1% of the hours, the virtual demand bids increased the total supply scheduled, raising the Day-Ahead price. Unfortunately, this increased supply often did nothing to solve the ramping problem and the system operator was still forced to turn to other, expensive units. Because virtual bids can only be placed for a full hour of generation, which the system was not short of, and not for the short 5-minutes of ramping capacity that the system actually needed, the virtual bids could not effectively solve the problem. Instead, virtual bidding simply added to total system cost, while also producing profits for financial traders that would have to be paid by customer charges.

Dr. John Parsons, a CEEPR affiliate and faculty member in the Finance Group at MIT's Sloan School of Management, worked as a Visiting Scholar in FERC's Division of Analytics and Surveillance to study financial trading in US electricity markets. Working with four colleagues in DAS, Dr. Parsons completed a study of a unique type of financial trading known as Virtual Bidding.

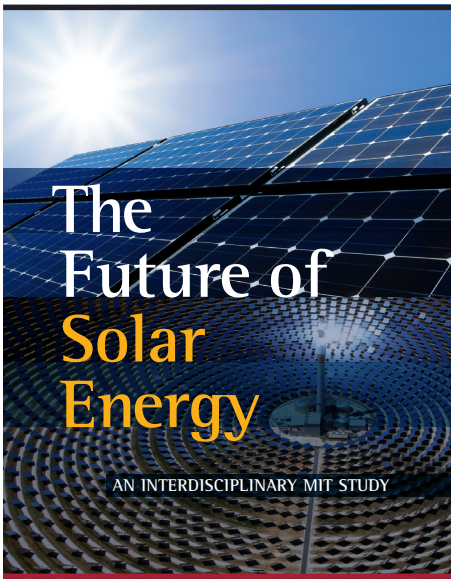
The research generalizes this illustrative example, and shows how the underlying problem with virtual bidding can manifest itself in different situations. It explains how the usual diagnostic of convergence can sometimes fail to accurately reflect whether or not virtual bidding is improving system performance. The research emphasizes that task of evaluating the costs and benefits of virtual bidding is a very demanding one.

Dr. Parsons' colleagues at FERC's Division of Analytics and Surveillance who co-authored this research are Cathleen Colbert, Jeremy Larrieu, Taylor Martin, and Erin Mastrangelo .

[1] Parsons, J. E., C. Colbert, J. Larrieu, T. Martin, and E. Mastrangelo (2015), "Financial Arbitrage and Efficient Dispatch in Wholesale Electricity Markets." *CEEPR WP-2015-002,* MIT, February 2015.

The MIT Future of Solar Energy Study Released

by: Michael Mehling



On May 5, 2015, the MIT Energy Initiative (MITEI) released a comprehensive new study titled *The Future of Solar Energy*.[1] As with earlier installments of the highly regarded MIT "Future of ... " report series, several CEEPR faculty and research affiliates were involved in the elaboration of the study, contributing economic and policy insights to a multidisciplinary, multi-year research effort. Former CEEPR Director Richard Schmalensee, a Professor of Economics and Management at the MIT Sloan School of Management, served as the study's chair.

Although it currently provides only 1% of electricity generated globally, solar energy is seen to enjoy a bright future in the 332-page study. No other technology, its authors say, has the scalability and broad distribution to displace carbon emissions from energy generation by mid-century – an essential element of any serious strategy to mitigate global climate change. "Given the vast resource and its intrinsic zero-carbon nature, it seems inevitable that solar is going to play a key role in future energy systems", said MITEI's Director Robert Armstrong during a launch event at the National Press Club in Washington DC.

But the study also identifies serious obstacles on the path towards greater solar penetration, both in terms of technological innovation and enabling regulatory frameworks. Across the study's ten chapters, the authors draw on their extensive discussion of solar technology, its economic and business implications, and public policy challenges to formulate a series of recommendations. Ultimately, they conclude that any policies related to solar energy should focus on one central objective: to build the foundation for a substantial scale-up of solar generation in the near- and medium term.

Solar module prices have fallen dramatically in recent years, although balance of system (BOS) costs – such as the cost of inverters and other hardware, installation, and marketing – have followed less rapidly. Coupled with decreasing policy support in the U.S. and elsewhere, accelerated growth in solar energy is thus not inevitable.

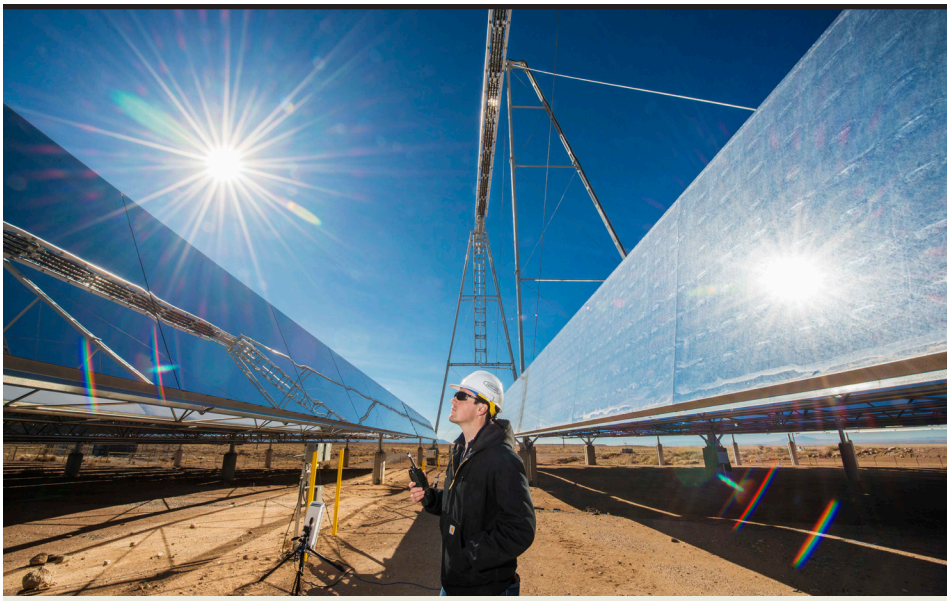
> ***"The main goal of U.S. solar policy should be to build the foundation for a massive scale-up of solar generation over the next few decades."***

At the launch event, Francis O'Sullivan, one of the study's authors, cautioned that "the economics of solar face some important challenges." In particular, renewable energy penetration in competitive electricity markets tends to depress wholesale prices, which also lowers the return on investment accruing to solar investors. According to O'Sullivan, this underscores the need for continued cost reductions: "We need to focus on driving costs lower and lower".

While technologically mature, the

NREL's photovoltaic array at the National Wind Technology Center near Boulder, Colorado. Source: *US Department of Energy*

leading technology for solar energy generation, wafer-based crystalline silicon (c-Si), has intrinsic properties that limit its potential for additional cost savings. Due to their thickness, for instance, they require a heavier substrate, affecting BOS costs. Current thin-film photovoltaic technologies offer opportunities to significantly reduce system costs, but many rely on scarce rare-earth elements, constraining their scalability. Instead of focusing on incremental cost reductions in conventional photovoltaic technology, public research and development efforts should therefore target transformative thin-film technologies that use safe, abundant materials and promise flexibility and low weight.



The molten salt test loop (MSTL) at Sandia National Laboratories' National Solar Thermal Test Facility in Albuquerque, New Mexico. The mirrors, based on AREVA's Compact Linear Fresnel Reflectors, focus sunlight to the top of the structure where molten salt is flowing. The resulting heat is stored and used later when the sun is not shining. Source: *US Department of Energy*

In another key recommendation, the study calls on public authorities to prepare for a variety of technical and economic challenges raised by growing penetration of variable solar generation. As the share of photovoltaic electricity increases, its ability to replace non-solar generation capacity diminishes, at the same time requiring a higher ramping rate from conventional electricity generation fleets. Diurnal and seasonal changes in solar energy output are predictable, moreover, but hourly photovoltaic electricity output varies with weather and is therefore imperfectly predictable. Finally, while distributed generation can lower line losses, the investments needed to maintain power quality in the distribution system outweigh such savings with growing penetration levels. All this suggests a need for large-scale energy storage, and thus for substantial innovation efforts to reduce the cost of storage technologies.

Unsurprisingly, the challenges of integrating an expanding share of solar photovoltaic generation also extend to the policy arena. Net metering, a widely used policy to support distributed solar energy, favors residential photovoltaic deployment by offering retail rates for generated electricity. Because retail rates bundle the cost of electricity with distribution network and other costs, however, they are considerably higher than the wholesale rates typically available for electricity from utility-scale installations. Also, net metering shifts network costs to ratepayers without renewable energy generation capacity.

> ***"Today's taxpayers and utility ratepayers are paying considerably more per kWh of solar output than they need to."***

"The cost shift is real, and that cost shift is going to produce a backlash against distributed generation," Schmalensee warned at the study's launch.

Net metering is only one of an extensive portfolio of measures adopted at the federal, state and local levels to support renewable energy. Given the absence of a price on carbon emissions, the study concedes the importance of continued policy support to build experience with manufacturing, deployment, and ways to overcome institutional barriers. By reducing BOS costs, current subsidies can help lay the foundation for an accelerated scale-up of solar energy as technologies improve and become more competitive. Still, because of their focus on investment rather than output, current subsidies – such as the federal investment tax credit and accelerated depreciation opportunities – favor the most expensive sources of solar electricity. Likewise, renewable portfolio standards enacted in a number of states impose siting restrictions on eligible generation, limiting the flexibility to deploy solar photovoltaic technology in locations with the most abundant solar resources. A reform of current subsidy mechanisms should therefore ensure greater solar generation per dollar of subsidy investment - as Schmalensee put it, "if we are about generation, we should reward generation."

[1] Schmalensee et al. (2015), "The Future of Solar Energy, An Interdisciplinary Study." MIT Energy Initiative, MIT, May 2015.

The full report is available at http://mitei.mit.edu/futureofsolar

Fugitive Vehicles Erode the Benefits of Air Quality Measures in Clean Air Act Non-attainment Counties

by: Matthew Zaragoza-Watkins

In the U.S., the transportation sector is the largest source of air pollution regulated under the Clean Air Act. Implementing optimal policies to reduce emissions, improve air quality, and increase welfare is no easy task. Administrative, political, and technological constraints often force policymakers to choose among "second-best" policies. Take, for example, the 1990 Clean Air Act Amendments, which require installation of emissions controls on all newly-sold light-duty vehicles, and which prescribe inspection and maintenance (I/M) programs to enforce durability requirements for vehicles circulating in regions out of attainment with National Ambient Air Quality Standards (NAAQS) for carbon monoxide and ozone. Even in concert, these partial regulations – partial, because each regulation only addresses a subset of vehicles and possible adjustment margins – do not closely approximate optimal control (i.e., Pigouvian taxes).

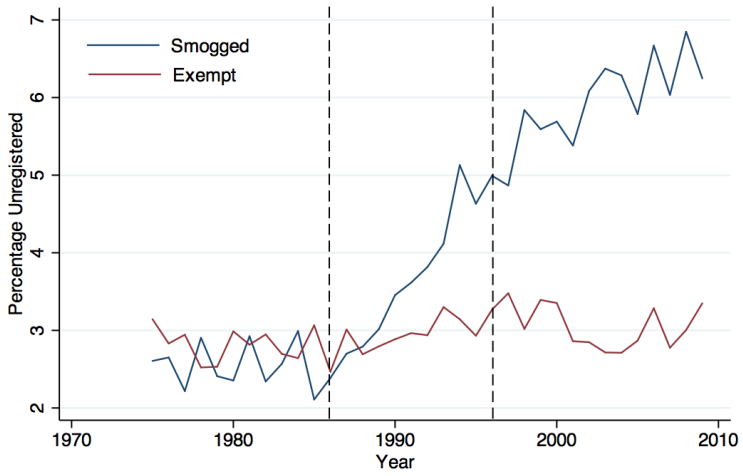
As is often true, behavioral responses create further challenges for policymakers. Costly new vehicle emission controls increase the relative value of older vehicles, causing motorists to operate older, higher-emitting vehicles for longer than they otherwise would – diminishing the net benefits of new vehicle standards. I/M programs are designed to "claw back" some of these emissions reductions by forcing motorists to choose between making costly emission-related repairs and scrapping their high-emitting vehicle (in I/M program areas vehicle registration is often tied to meeting emissions control standards). However, some motorists ignore emission control and registration requirements, choosing instead to operate "fugitive" vehicles. If emissions from these vehicles are substantial – either because they are frequently used or high-emitting or both – the benefits of I/M programs could be significantly eroded.

In new research, Matthew Zaragoza-Watkins estimates the impact of I/M programs on emissions from unregistered vehicles. Though the activity of unregistered vehicles is inherently unmeasured, Matthew overcomes this data limitation by exploiting a novel indirect measure of unregistered vehicles: frequencies of fatal traffic accidents reported in the Fatality Analysis Reporting System (FARS) – the universe of fatal traffic accidents in the United States since 1975. By comparing the frequencies of fatal traffic accidents involving registered and unregistered vehicles, and knowing the distributions of activity for registered vehicles, Matthew is able to infer activity among unregistered vehicles.

The figure below charts the share of fatal traffic accidents among vehicles that are and are not ever subject to I/M programs. Each dashed line signifies a national policy change, where a large number of counties were required to adopt I/M programs as part of a state-level plan to meet NAAQS. Prior to the first round of changes (i.e., the first dashed line), the lines track closely. Immediately following the first round of I/M programs, the lines begin to diverge.

Matthew's analysis corroborates that I/M programs have resulted in a three to four percentage point increase in the share of fatal traffic accidents involving unregistered vehicles, or a more than doubling of activity among unregistered vehicles in counties with I/M programs. Aggregating over all I/M areas, it is estimated that millions of high-emitting and unregistered vehicles are circulating in counties failing to meet NAAQS.

What is more, this small fraction of vehicles is likely contributing an outsized share of total vehicle emissions, diminishing the effectiveness of I/M policies meant to bring counties into compliance with NAAQS. To estimate emissions from unregistered vehicles, Matthew relies on the universe of emissions inspections performed in California since 1996. These data provide model-level distributions of emissions rates for vehicles failing an emissions test. These data show that vehicles often fail an inspection with emission rates that are an order of magnitude above the fleet-wide average, suggesting that in some counties unregistered vehicles may account for ten to thirty percent of total vehicle emissions.

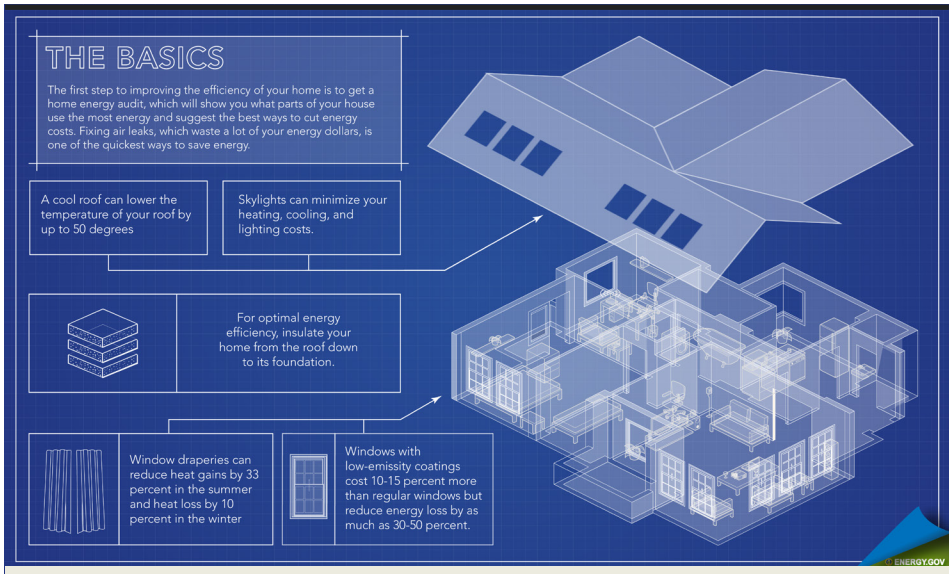


The share of fatal accidents among vehicles that are and are not subject to inspection and maintenance programs.

Evaluating Energy Efficiency Programs and Policies

by: Raina Gandhi

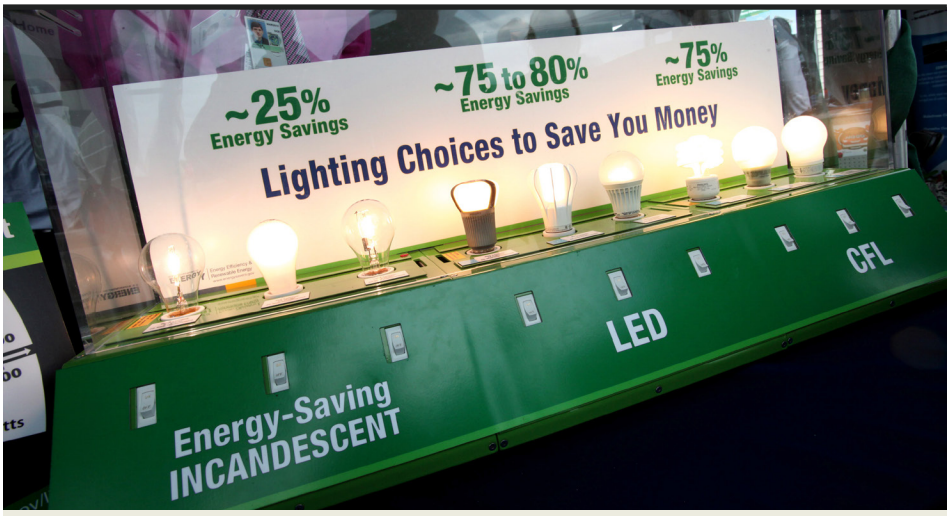
The E2e Project, a joint initiative between CEEPR at MIT, the Energy Policy Institute at the University of Chicago, and the Energy Institute at UC Berkeley's Haas School of Business, is focused on understanding one of the most perplexing energy puzzles of our time: the energy efficiency gap, or the gap between the levels of energy efficiency investment that appear to be cost effective based on ex-ante predictions and the levels of investment and savings actually observed. E2e is led by Chris Knittel at MIT, Michael Greenstone at the University of Chicago, and Catherine Wolfram at UC Berkeley. In addition, Raina Gandhi is the resident E2e Research Assistant at CEEPR. Initially funded by the Alfred P. Sloan Foundation, the E2e Project has recently received an additional $1.5 million in support from Sloan for the next three years.



E2e is currently evaluating returns from the Federal Weatherization Assistance Program.

The E2e Project uses randomized controlled trials to credibly and rigorously evaluate the impact of different policies and programs. These trials are used widely by researchers in other areas, particularly in medicine, but their potential to measure energy efficiency impacts is just beginning.

E2e's research to date has found that most analyses overstate the energy savings available from energy efficiency investments in the residential sector (Fowlie, et al., 2015; Davis, et al., 2014), and that a lack of information is likely not the only barrier to energy efficiency investment in several domains, including automobiles (Busse, Knittel and Zettelmeyer, 2013; Allcott and Wozny, 2012) and home appliances (Allcott and Taubinsky, 2014). Existing research suggests that though behavioral insights and tools are low-cost means to increase energy efficiency, the gains are small, but real (Allcott, 2014). New evidence indicates that there are substantial unobserved costs that are not included in traditional engineering analyses, and that these costs may indeed be important (Allcott and Greenstone, 2012; Fowlie, et al., 2015; Houde and Aldy, 2014). Finally, we are gaining increasingly precise estimates of the rebound effect, or the increase in energy consumption due to the decline in the price of energy services, in different contexts (Fowlie, et al., 2015; Borenstein, 2015; Davis, et al., 2014; Gillingham, et al., 2014).



E2e is also assessing if energy education affects energy bill management in low-income households.

Some examples of current projects include evaluating energy savings due to energy efficiency programs for K-12 schools in California; testing how car buyers respond to mileage information when it's presented differently; assessing whether energy education can help low-income households manage their energy bills; evaluating the returns from the Federal Weatherization Assistance Program; and more.

The E2e Project has also just received a $5 million grant from the California Energy Commission in partnership with Lightapp Technologies to conduct an evaluation to measure the savings from and market opportunity for optimized energy management systems. The E2e Project is actively looking for new research ideas and opportunities for fruitful, mutually-beneficial partnerships.

Unconventional Oil & Gas: Price Impacts and Geopolitical Implications

by: Michael Mehling

On April 22, 2015, CEEPR and the MIT Energy Initiative (MITEI) convened a symposium to address the latest developments in unconventional hydrocarbon exploration, its effects on oil and natural gas markets, and broader geopolitical implications. A small group of distinguished participants from academia, industry, and public policy joined in a candid, in-depth discussion of some of the most pressing issues currently facing the oil and gas sector.

For the first session on "Impacts on Markets & Prices: A New Equilibrium?", Lutz Kilian of the University of Michigan drew on an ongoing research project with multiple vector autoregressive forecasting models to provide insights on the decline in oil prices since June 2014. A breakdown and analysis of observed forecasting errors served to better understand the (positive) supply and (negative) demand shocks responsible for the decline, and also helped identify different scenarios and their effect on oil prices going forward. Drawing on his earlier work with Morris Adelman at MIT, Michael Lynch of Strategic Energy & Economic Research Inc. followed with an exploration of how Adelman's work might apply to current trends in oil and gas markets. Through a series of examples, he demonstrated the continued strength of one of Adelman's central postulations: the perennial conflict between diminishing returns and increasing knowledge of hydrocarbon resources and their extraction will always provide a competitive floor for world oil prices. Matthew Partridge of Statoil and MIT's John E. Parsons served as discussants for both presentations, inter alia questioning the potential of futures prices to help predict short- and long-term oil price trends.

For the second session, titled "Evolving Supply-side Dynamics: Unconventional Oil and Gas", Robert Kleinberg of Schlumberger and Philippe Frangules of IHS examined the disruptive role of shale gas and tight oil in the hydrocarbon sector. Frangules shared IHS' forecasts for oil prices and production levels, drawing attention to factors that make it harder to predict how the market will recalibrate after the current decline. For instance, the ability of producers faced with cash-flow constraints to allocate capital to the highest-return assets within their portfolios – a process known as "high-grading" – has resulted in stable production despite declining capital expenditures. Likewise, drilled-but-uncompleted wells will allow for much shorter response times once prices firm. Kleinberg shed further light on the recovery technologies available for tight oil extraction, linking high annual decline and low recovery rates to the unavailability of secondary and tertiary recovery methods commonly used in conventional oil wells. Continued improvements in production efficiency could be dwarfed by a breakthrough in production enhancement technologies,

A discussion session during the Oil & Gas Symposium on April 22, 2015.

which would free up massive amounts of light and medium crude oil. Kleinberg went on to describe the implications of rapid growth in ethane production, and explained how the resulting price declines are fundamentally altering production costs in the petrochemical industry. Gordon Kaufmann and Christopher Knittel, both of MIT, followed with a number of observations that stimulated lively discussion.

In the third and final session on "The New Geopolitics of Oil & Gas", MIT's Sergey Paltsev traced a number of recent developments around the globe driven by energy geopolitics, such as European efforts to reduce gas imports from Russia in the wake of the conflict in Crimea, or Russia's "Eurasian Strategy" and pivot to new markets such as China. Together with aspirations to reduce global carbon emissions, Paltsev argued, these political uncertainties will continue to shape global oil and gas markets. Meghan O'Sullivan of Harvard University then highlighted how changing geographies of oil and gas production have fundamentally altered the geopolitical balance in the world. U.S. shale gas and tight oil extraction, for instance, has provided the "single strongest antidote to narratives of American decline", while an oil price below the fiscal breakeven point of many Middle Eastern producers may completely redefine the current social contract in these countries. Gilbert Metcalf of Tufts University and Robert Ritz of Cambridge University responded with comments and questions before opening for a discussion with the audience.

A recurrent theme throughout the symposium's three sessions was the pervasive role of uncertainty – uncertainty about future hydrocarbon production and consumption patterns, uncertainty about evolving markets and trade flows, but also domestic and foreign policy uncertainty. How best to navigate such uncertainty in an increasingly complex market environment will remain one of many attendant challenges for future research at CEEPR.

"U.S. shale gas and tight oil production have provided the single strongest antidote to narratives of American decline."

2014 Fall Research Workshop

A balanced mix of current themes in the energy and environmental policy debate featured at CEEPR's 2014 Fall Research Workshop, held in Cambridge, Massachusetts, on November 20 and 21, 2014. Recent developments in the Crimea prompted lively discussion during the first session on the "New Geopolitics of Oil and Gas" with Gilbert Metcalf of Tufts University and MIT's Sergey Paltsev.

An equally dynamic session followed, with Karen Palmer of Resources for the Future and CEEPR Director Christopher Knittel assessing the U.S. Environmental Protection Agency's proposed rule to limit greenhouse gas emissions from existing power plants ("Understanding the U.S. Clean Power Plan"). A lunch presentation by Susan Solomon, recently designated the Director of the MIT Environmental Solutions Initiative, rounded out the early segment of the workshop.

In the afternoon of the first day, a session on "Renewable Energy and the Grid" gave MIT's Richard Schmalensee an opportunity to discuss preliminary results of the MIT "The Future of Solar Energy" study chaired by him (see also p. 8 in this newsletter). Henry Yoshimura of ISO New England complemented Schmalensee's presentation with a perspective on renewable energy integration from an Independent System Operator.

Solomon Hsiang of the University of California, Berkeley and MIT's Adam Schlosser ended the first day with a timely reminder of the many interdependencies between energy and water supply ("Revisiting the Water and Energy Nexus"). During the ensuing dinner, James Stock of Harvard University shared insights from his recent service in the President's Council of Economic Advisers.

On the second workshop day, the roughly 80 attendees were invited to explore current trends in Chinese energy and transport policy with MIT's Valerie Karplus and Shanjun Li of Cornell University. Kevin Green of the U.S. Department of Transportation's Volpe Center and Christopher Nevers of the Alliance of Automobile Manufacturers concluded the workshop with a candid review of vehicle fuel economy and emissions standards in the United States ("CAFE and Tailpipe Emissions Standards: State of Play"). As always, the invitation-only event provided a valuable opportunity to discuss ongoing energy and environmental policy research at MIT with a select audience from industry, government, and academia, helping shape the research agenda and ensuring its continued relevance going forward.

UPCOMING WORKSHOPS
July 9-10, 2015, London, UK
November 19-20, 2015, Cambridge, MA

Pricing Carbon to Address Climate Change: Insights from British Columbia

by: Michael Mehling

"Sound climate policy makes for good politics." In a nutshell, that was the message conveyed by a high-ranking delegation of government, civil society and business representatives from British Columbia, who discussed experiences with their province's carbon tax at an Earth Day Colloquium organized on April 13, 2015 by CEEPR and the MIT Energy Initiative (MITEI). More than 200 participants convened in the Walker Memorial's spacious Morss Hall to hear first-hand how British Columbia was able to introduce a carbon price, and what effects it has had on the local economy and the environment.

Ross Beaty of Alterra Power Corp. relates his company's experiences with a carbon tax.

MIT Chancellor Cynthia Barnhart opened the event with a brief welcome address, handing over to Parliamentary Secretary for Energy Literacy and the Environment of British Columbia, Mike Bernier. In his keynote address, Bernier described the history, design and early impacts of his province's carbon tax, which he praised for shifting costs from desirable to undesirable activities, namely from employment and investment to pollution. Because the tax is revenue-neutral, he explained, it has helped limit carbon emissions and fuel use while reducing individual and corporate income taxes, effectively boosting the British Columbian economy. "What we've been doing in British Columbia has not gone unnoticed", Bernier noted, pointing to growing interest in his province's experience with carbon pricing from the United States and elsewhere.

Susanna Laaksonen-Craig, Head of the Climate Action Secretariat in the British Columbia Ministry of Environment, provided further detail on the technical design and implementation of the carbon tax. In her remarks, she reminded the audience that the tax had been lauded as a "textbook example of a carbon tax" by former MIT professor and statesman George P. Shultz.

Speaking on behalf of the private sector, Ross Beaty, Founder and Chairman of the Pan American Silver Corporation and Executive Chairman of Alterra Power Corporation, conceded that companies usually oppose new taxes. Still, so Beaty, corporate leaders increasingly acknowledge the need for climate action, and British Columbia's local economy, in particular, has seen far-reaching impacts from climate change. Enlightened companies were thus ready to embrace political leadership when the carbon tax was introduced, quickly seeking ways to innovate and reduce compliance costs under the stable policy framework it offered.

Christopher Knittel, the William Barton Rogers Professor of Energy Economics at the MIT Sloan School of Management and CEEPR's Director, commented on the carbon tax from an economist's point of view. Despite almost universal agreement among economists on the merits of carbon pricing, he noted that few jurisdictions have decided to implement this policy option. On the contrary, the United States has recently seen a resurgence of rigid performance standards, which not only tend to impose higher cost than the externalities they avoid, but also have unintended consequence such as rebound effects. By contrast, he argued, a carbon price has positive spillover effects, such as revenue generation to reduce other taxes.

Drawing the discussion to a more local context, Massachusetts State Senator Michael Barrett of the 3rd Middlesex District answered questions on his own bill aimed at introducing a fee on carbon-based fuels in Massachusetts. All the revenue, he explained, would return to taxpayers by way of rebates, distributed in such a way that low-income households pay less for pollution than high-income households. Because of its revenue neutrality, moreover, the fee – so Barrett – does not fit the legal definition of a tax, allowing state officials who have pledged to oppose new taxes to support his bill.

An engaged discussion with the audience ensued, reflecting interest in carbon taxation as a policy option for Massachusetts and the U.S., and leading to detailed questions about policy design, impacts and ways to avoid hardship for different segments of society. Secretary Bernier's parting advice to Senator Barrett and the largely Massachusetts-based audience was to "take the politics out of carbon pricing." But once introduced, he added, the tax can limit pollution without harming the economy.

Notable Changes

Over the past six months, CEEPR has hosted several Visiting Scholars working on a wide variety of topics in the energy and environmental policy space.

Between December 2014 and February 2015, **Antto Vihma**, a Senior Fellow with the Finnish Institute for International Affairs, conducted research on the geoeconomic dynamic behind Gazprom's decision to abandon the South Stream pipeline last year (see p. 4), and finalized a CEEPR Working Paper together with Columbia University's Johannes Urpelainen analyzing the influence of domestic constituencies on negotiating positions in the context of international climate policy (see below, WP-2015-001).

In April, **Robert Ritz** joined CEEPR from the University of Cambridge, where he is a University Lecturer and Assistant Director of the Energy Policy Research Group (EPRG). During his visit, Dr. Ritz studied competition in international natural gas markets from a strategic perspective, assessing its geopolitical implications and attendant motives. He presented this work at the CEEPR & MITEI Symposium on the price effects and geopolitical implications of unconventional oil and gas on April 22 (see p. 12).

Between April and June, **R. Andreas Kraemer**, a Senior Fellow at the Institute of Advanced Sustainability Studies (IASS) in Potsdam, Germany, will be conducting research on the economic costs of an energy transition such as that currently underway in Germany, and its implications for energy security. He presented his research questions and hypotheses at a CEEPR event on March 31.

Thomas Greve, a Research Associate at the University of Cambridge, visited CEEPR in April to continue his work on allocation in tender auctions, notably a bidding mechanism for the sale of heterogeneous commodities such as electricity with involvement of stakeholders. Dr. Greve presented his proposal to the MIT Electricity Student Research Group (ESRG) on April 15.

Recent Working Papers

WP-2015-005
Cash for Corollas: When Stimulus Reduces Spending
Mark Hoekstra, Steven L. Puller, and Jeremy West, April 2015

WP-2015-004
Limit Pricing and the (In)Effectiveness of the Carbon Tax
Saraly Andrade de Sá and Julien Daubanes, April 2015

WP-2015-003
The Use and Misuse of Models for Climate Policy
Robert S. Pindyck, April 2015

WP-2015-002
Financial Arbitrage and Efficient Dispatch in Wholesale Electricity Markets
John E. Parsons, Cathleen Colbert, Jeremy Larrieu, Taylor Martin and Erin Mastrangelo, February 2015

WP-2015-001
Soft Cooperation in the Shadow of Distributional Conflict? A Model-Based Assessment of the Two-Level Game between International Climate Change Negotiations and Domestic Politics
Johannes Urpelainen and Antto Vihma, February 2015

WP-2014-009
Strategic Policy Choice in State-Level Regulation: The EPA's Clean Power Plan
James B. Bushnell, Stephen P. Holland, Jonathan E. Hughes, and Christopher R. Knittel, December 2014

E2e Working Papers

WP-018
Tagging and Targetting of Energy Efficiency Subsidies
Hunt Allcott, Christopher Knittel, and Dmity Taubinsky, May 2015

WP-017
The Persistence of Moral Suasion and Economic Incentives: Field Experimental Evidence from Energy Demand
Koichiro Ito, Takanori Ida, and Makoto Tanaka, February 2015

WP-016
Are the Non-Monetary Costs of Energy Efficiency Investments Large? Understanding Low Take-up of a Free Energy Efficiency Program
Meredith Fowlie, Michael Greenstone, and Catherine Wolfram, January 2015

WP-015
Does Better Information Lead to Better Choices? Evidence from Energy-Efficiency Labels
Lucas Davis and Gilbert Metcalf, revised March 2015

WP-014
Belt and Suspenders and More: The Incremental Impact of Energy Efficiency Subsidies in the Presence of Existing Policy Instruments
Sebastien Houde and Joseph Aldy, October 2014

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

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A panel discussion on the British Columbian carbon tax held on April 13, 2015 in Morss Hall at MIT.