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# MIT CEEPR Newsletter

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MASSACHUSETTS INSTITUTE OF TECHNOLOGY



# Editorial

In November, voters in the United States exercised their right to influence the trajectory of federal policymaking by determining who will occupy the White House for the next four years. Energy and environmental policy have been on the ballot in previous elections, but rarely have two presidential candidates offered as contrasting a set of choices. With President-elect Biden now set to be inaugurated in January 2021, the country once again faces a major pivot in the policy parameters of U.S. energy production, distribution and use.

Addressing climate change, in particular, stands to become a defining priority of U.S. domestic and foreign policy. On the campaign trail, candidate Biden already outlined several cornerstones of his proposed approach over the next four years. Initially, at least, much of this agenda will be focused on reversing policy decisions of the current administration and resuming the broad array of executive actions that defined climate policy during the second term of the Obama administration.

Still, pressure from progressive elements in the Democratic party and the need to stimulate an economic recovery from the coronavirus pandemic will leave a distinct mark on the next administration's policy decisions. Investment in low-carbon technologies and infrastructure will feature more prominently, as will the impacts of the energy transition on vulnerable communities. Yet even if Democrats are able to secure a majority in both houses of Congress, political and judicial challenges will abound.

The resulting uncertainty marks familiar territory for CEEPR. Its research will inform the policy process with the same empirical approach it has brought to bear on earlier periods of federal energy and environmental policy making. Balanced, data-driven guidance is arguably most important when political momentum precipitates ambitious policy decisions. We look forward to working closely with our Associates as we navigate these developments and help chart a trajectory into the future.

—Michael Mehling

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# The Short-run and Long-run Effects of COVID-19 on Energy and the Environment

by: MIT Sloan Office of Media Relations

While the COVID-19 pandemic has reduced air pollution in the U.S., the longer-term impact on the environment is unclear. In a recent study, MIT Sloan School of Management Prof. Christopher Knittel and Prof. Jing Li analyzed the short- and long-term effects, finding that the actual impact will depend on the policy response to the pandemic. Their study suggests that pushing back investments in renewable electricity generation by one year could outweigh the emission reductions and deaths avoided from March through June 2020.

“The pandemic raises two important questions related to the environment. First, what is the short-run impact on fossil fuel consumption and greenhouse gas emissions? Second -- and more important but harder to answer -- what are the longer-term implications from the pandemic on those same variables? The health impacts from the pandemic could stretch out for decades if not centuries depending on the policy response,” says Knittel.

Li notes, “Climate change is one of the leading health issues of our time and it’s critical to understand the impact of delaying decarbonization efforts because of the pandemic. If the pandemic leads to a persistent global recession, there is a real threat to the adoption of clean technology, which could outweigh any ‘silver lining’ in environmental benefits.”

In their study, the researchers analyzed the short-term impact of the pandemic on CO<sub>2</sub> emissions in the U.S. from late March to June 7, 2020. They found a 50% reduction in the use of jet fuel and a 30% reduction in the use of gasoline. The use of natural gas in residential and commercial buildings declined by almost 20% and overall electricity demand declined by less than 10%.

“Overall, these reductions reflect a 15%

total reduction in daily CO<sub>2</sub> emissions, which is the largest annual percentage decline for the U.S. in recorded history,” says Knittel. “We estimate that the shutdowns saved about 200 lives per month, primarily driven by the lower emissions from transportation.”

However, the professors point out that the shutdown also halted most investment in the transition to low-carbon energy. Their paper notes that global electric vehicle sales are projected to decline by 43% in 2020 due to fewer auto sales overall combined with low gasoline prices. New residential rooftop solar and storage installations also declined along with energy efficiency audits. And clean energy jobs decreased by almost 600,000 by the end of April.

“The short-term impact of the pandemic is clear, but the long-term impact is highly uncertain,” says Li. “It will depend on how long it takes to bring the pandemic under control and how long any economic recession lasts.”

The best-case scenario, according to the researchers, is a swift and low-cost strategy to control the virus, allowing the economy to reopen by the end of 2020. In this scenario, investment trends prior to the pandemic will continue. “Unfortunately, we view a second scenario as more likely,” notes Knittel. “In this scenario, the consequences of the pandemic will be greater, with many more deaths and deeper disruptions to supply chains, and a persistent global recession. The need to backpedal on the reopening of the economy due to flare-ups could destroy rather than defer the demand for goods and services.”

In this scenario, the long-run impact on CO<sub>2</sub> and local air pollutant emissions could outweigh the short-run reductions. The delays in investments in renewables and vehicle fuel economy could lead to an additional 2,500 MMT of

CO<sub>2</sub> from 2020-2035, which could cause 40 deaths per month on average or 7,500 deaths during that time.

“Our findings suggest that even just pushing back all renewable electricity generation investments by one year would outweigh the emissions reductions and avoided deaths from March to June of 2020. However, the energy policy response to COVID-19 is the wild card that can change everything,” they wrote in an article for *Joule*.

Li explains that budgets will be strained to pay for the costs of the virus, making it challenging to invest in clean energy. And if a recession persists, there may be pressure to lessen climate change mitigation goals. However, stimulus packages could focus on clean energy, increasing clean air, clean jobs, and national security.

“Just stabilizing the economy can go a long way to putting clean energy trends back on track. We need to solve the pandemic and continue to address climate change. Otherwise, it will lead to even more tragedy,” adds Knittel.

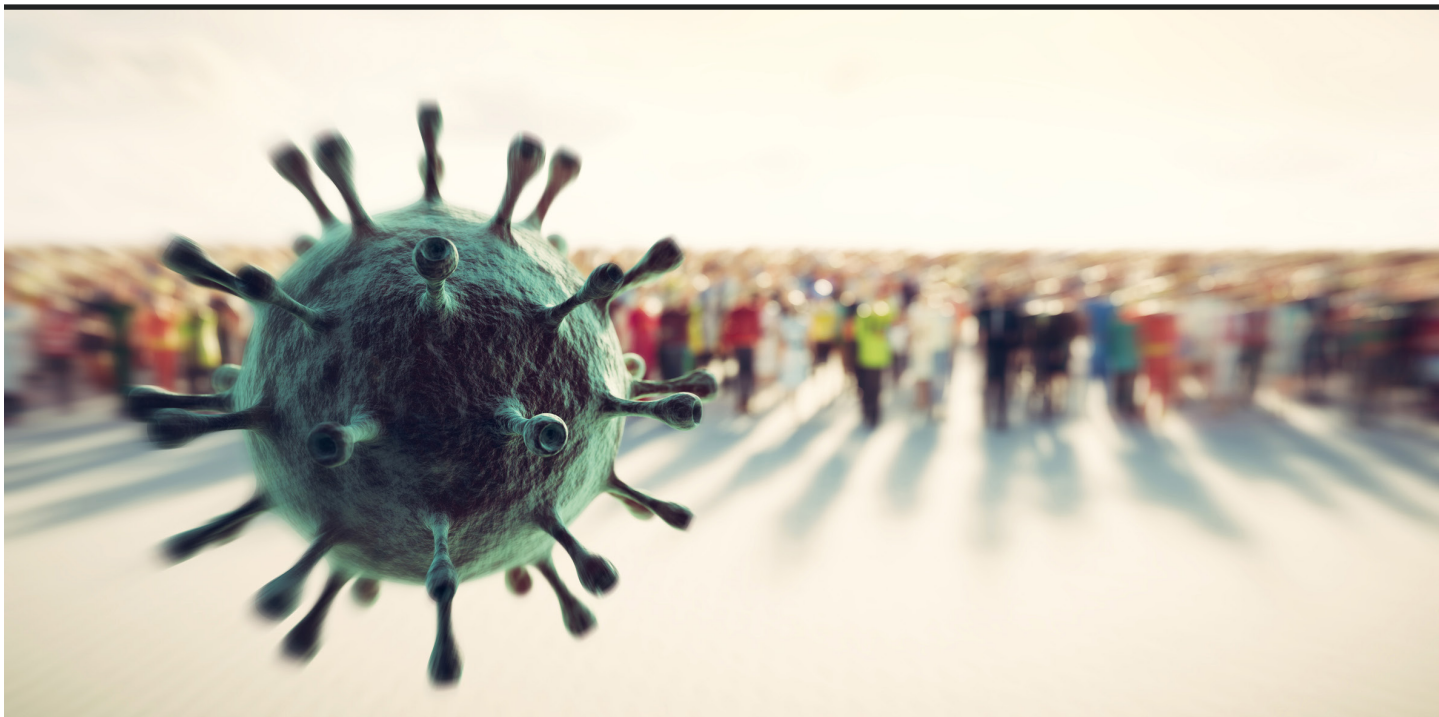
Li and Knittel are coauthors of “The Short-run and Long-run Effects of COVID-19 on Energy and the Environment” with Kenneth Gillingham and Marten Ovaere of Yale University and Mar Reguant of Northwestern University<sup>1</sup>. Their paper was published in a June issue of *Joule*.

<sup>1</sup> Kenneth T. Gillingham, Christopher R. Knittel, Jing Li, Marten Ovaere, and Mar Reguant (2020), “The Short-run and Long-run Effects of COVID-19 on Energy and the Environment”, *CEEPR WP-2020-011*, MIT, July 2020.

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# What Does and Does Not Correlate with COVID-19 Death Rates

by: MIT Sloan Office of Media Relations



Professor Christopher Knittel and CEEPR graduate student Bora Ozaltun explore the correlations of coronavirus death rates with a variety of factors, including patients' race, age, socioeconomic status, and local climate. Their findings have implications for determining how policymakers respond to the pandemic.

Cambridge, Mass.—Why does the coronavirus kill some Americans, while leaving others relatively unscathed?

A new study by researchers at the MIT Sloan School of Management sheds light on that question. The study, by Christopher R. Knittel, the George P. Shultz Professor of Applied Economics at MIT Sloan and Bora Ozaltun, a Graduate Research Assistant in the Center for Energy and Environmental Policy Research (CEEPR) lab, correlates Covid-19 death rates in the U.S. states with a variety of factors, including patients' race, age, health and socioeconomic status, as well as their local climate, exposure to air pollution, and commuting patterns.

The findings have important implications for determining who is most at risk of dying from the virus and for how policymakers respond to the pandemic.

Using linear regression and negative binomial mixed models, the researchers analyzed daily county-level COVID-19 death rates from April 4 to May 27 of this year. Similar to prior studies, they found that African Americans and elderly people are more likely to die from the infection relative to Caucasians and people under the age of 65. Importantly, they did not find any correlation between obesity rates, ICU beds per capita, or poverty rates.

"Identifying these relationships is key to helping leaders understand both what's causing the correlation and also how to formulate policies that address it," says Prof. Knittel.

"Why, for instance, are African Americans more likely to die from the virus than other races? Our study controls for patients' income, weight, diabetic status, and whether or not they're smokers. So, whatever is causing this correlation, it's

none of those things. We must examine other possibilities, such as systemic racism that impacts African Americans' quality of insurance, hospitals, and healthcare, or other underlying health conditions that are not in the model, and then urge policymakers to look at other ways to solve the problem."

The study, which has been released as a Center for Energy and Environmental Policy working paper<sup>1</sup> and is in the process of being released as a working paper on medRxiv, a preprint server for health sciences, contains additional insights about what does, and does not, correlate with COVID-19 death rates. For instance, the researchers did not find a correlation between exposure to air pollution. This finding contradicts earlier studies that indicated that coronavirus patients living in areas with high levels of air pollution before the pandemic were more likely to die from the infection than patients in cleaner parts



of the country.

According to Prof. Knittel, the “statistical significance of air pollution and mortality from COVID-19 is likely spurious.”

The researchers did, however, find that patients who commute via public transportation are more likely to die from the disease relative to those who telecommute. They also find that a higher share of people not working at all, and thus not commuting, have higher death rates.

“The sheer magnitude of the correlation between public transit and mortality is huge, and at this point, we can only speculate on the reasons it increases vulnerability to experiencing the most severe COVID-19 outcomes,” says Prof. Knittel. “But at a time when many U.S. states are reopening and employees are heading back to work, thereby increasing ridership on public transportation, it is critical that public health officials zero in on the reason.”

The proportion of Americans who have died from COVID-19 varies dramatically from state to state. The statistical models that Knittel and Ozaltun created yield

estimates of the relative death rates across states, after controlling for all of the factors in their model. Death rates in the Northeast are substantially higher compared to other states. Death rates are also significantly higher in Michigan, Louisiana, Iowa, Indiana, and Colorado. California’s death rate is the lowest across all states.

Curiously, the study found that patients who live in U.S. counties with higher home values, higher summer temperatures, and lower winter temperatures are more likely to die from the illness than patients in counties with lower home values, cooler summer weather, and warmer winter weather. This implies that social distancing policies will continue to be necessary in places with hotter summers and colder winters, according to the researchers.

“Some of these correlations are baffling and deserve further study, but regardless, our findings can help guide policymakers through this challenging time,” says Ozaltun. “It’s clear that there are important and statistically significant difference in death rates across states. We need to investigate what’s driving those differences and see if we can understand how we might do things

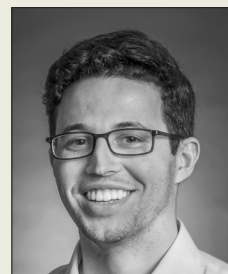
differently. ■

<sup>1</sup> Christopher R. Knittel and Bora Ozaltun (2020), “What Does and Does Not Correlate with COVID-19 Death Rates”, *CEEPR WP-2020-009*, MIT, June 2020.

This article originally appeared: <https://mitsloan.mit.edu/press/research-mit-sloan-explores-correlations-coronavirus-death-rates-a-variety-factors-including-patients-race-age-socioeconomic-status-and-local-climate/>



Christopher R. Knittel



Bora Ozaltun

## The Value of Pumped Hydro Storage for Deep Decarbonization of the Spanish Grid

by: **Anthony Fratto Oyler and John E. Parsons**

This paper<sup>1</sup> addresses the role of pumped hydro storage (PHS) to decarbonization of the electricity sector. Strategies for decarbonization generally look to expanded penetration of renewable generation, especially wind and solar PV. The variability in the renewable resource is a major challenge that must be managed. Electricity storage of some form or another is one important management tool. Pumped

hydro is a mature storage technology, and—aside from reservoir hydro—accounts for the vast majority of storage installed on power systems across the world.

To conduct our analysis, we use Spain’s power system as a case study. Spain has an ambitious decarbonization target: a 100% renewable electricity grid by 2050. Spain also has a large installed base of

pumped hydro storage—the highest capacity in Europe, and the fourth highest in the world, following the U.S., China and Japan. Our analysis will show how this existing capacity improves the utilization of all low-carbon generation sources, including solar PV, wind, and also nuclear, while decreasing the dispatch of natural gas-fired generation and therefore reducing greenhouse gas (GHG) emissions. We then evaluate the

impact of additional investment in pumped hydro and how this impact varies as low-carbon sources become an even larger share of the system.

Our results demonstrate that even in the Spanish case, with a high installed base of pumped hydro storage, additional investments become warranted as low-carbon generation expands. We conduct our analysis looking out to 2030 projections for load and alternative portfolios to serve that load. As a reference point, we take the Distributed Generation scenario detailed in the Ten-Year Network Development Plans 2018 developed by the European Network of Transmission System Operators for Electricity (ENTSO-E) in collaboration with their sister organization responsible for natural gas transmission systems. This scenario was used as one base case scenario in the report by Spain's Commission of Experts tasked in 2017 with informing Spain's

Inter-ministerial Working Group's development of a future Law on Climate Change and the Energy Transition. This is our Base Case scenario. We then analyze three deeper decarbonization scenarios—each one utilizing expanded investments in one low-carbon technology, including nuclear (preserving Spain's existing nuclear plants), wind, and solar PV. In each of these deeper decarbonization portfolios, incremental investment in pumped hydro capacity is a cheaper source of carbon abatement than further investments in either wind or solar PV capacity.

The focus in this paper is on pumped hydro storage's use as a balancing resource to complement the hourly dispatch of other generation, whether as a peaking resource to complement baseload and load-following generation or as a flexible resource to firm up wind or solar generation. Pumped hydro can

provide a variety of other services as well, including frequency regulation and operating reserves, but they are not included in our valuation. If they were, they would strengthen the case for further investments. ■

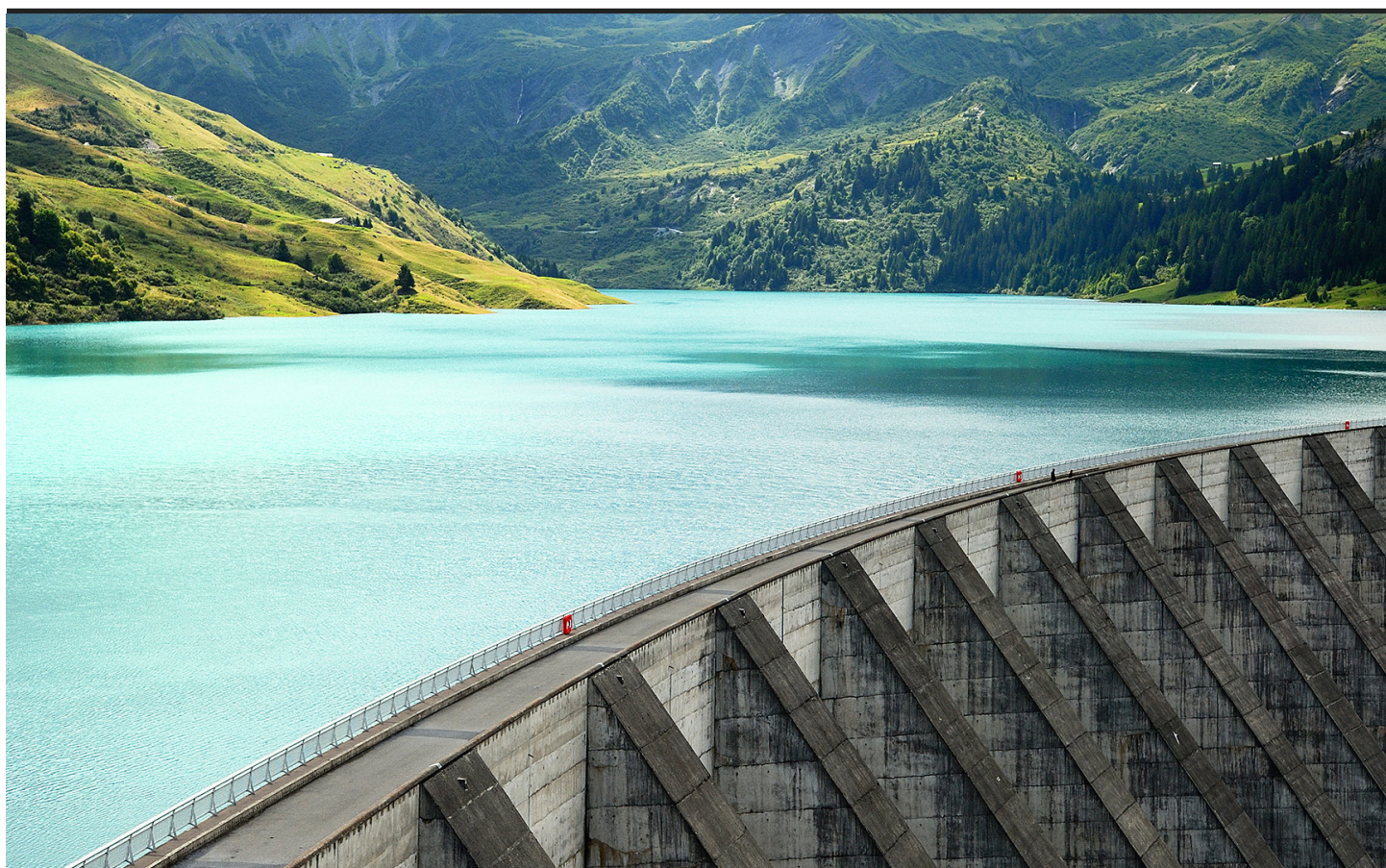
<sup>1</sup> Anthony Fratto Oyler and John E. Parsons (2020), "The Value of Pumped Hydro Storage for Deep Decarbonization of the Spanish Grid", CEEPR WP-2020-007, MIT, May 2020.



Anthony Fratto Oyler



John E. Parsons



Pumped hydro storage (PHS) is an old solution to a new problem—the variability of renewable generation. Our case study of Spain demonstrates how PHS significantly increases the dispatch of low-carbon technologies and lowers emissions. We show that additional PHS investments are warranted as the penetration of low-carbon technologies increases.



# Abatement Strategies and the Cost of Environmental Regulation: Emission Standards on the European Car Market

by: *Mathias Reynaert*

The EU has adopted an emissions standard aimed at reducing CO<sub>2</sub> emissions from passenger cars by 18%. The emission standard is very demanding: each firm has to reduce its average emission across yearly sales to 130 g CO<sub>2</sub>/km. For comparison, the US CAFE standard required only 152 g CO<sub>2</sub>/km in 2016. The EU standard is an attribute-based regulation; the policy target not only depends on CO<sub>2</sub> emission but also vehicle weight. The attribute basing makes the policy target less stringent for firms producing heavier vehicles. The EU announced the standard in 2007, and it became binding in 2015.

Evaluating the impact of emission standards is not an easy task. Firms can choose between different strategies to reduce emissions. The first strategy is to change pricing to shift the sales mix to vehicles with CO<sub>2</sub> emissions below the target. The second strategy is downsizing. Firms can sell smaller and less powerful vehicles that are more fuel-efficient. The third strategy is technology adoption. Firms can improve the fuel-efficiency of their vehicle fleet by adopting technologies that improve the combustion process. A fourth strategy is gaming. To establish emission ratings, the regulator requires that vehicles go through a test procedure. Firms reduce emissions during the test procedure but not necessarily on the road. Enforcement of the emission standard plays a role in limiting gaming.

In a first step, an MIT CEEPR Working Paper explains the trend in sales-weighted official CO<sub>2</sub> emissions between 1998 and 2011 in the EU market.<sup>1</sup> I find that official emissions, as measured during the test, reduce by 14% after the policy announcement. Price changes or the introduction of smaller vehicles do



Emission standards are one of the primary policy tools used to reduce CO<sub>2</sub> emissions in the passenger vehicle market. Emission standards set mandatory limits on average emission rates (or fuel economy) across the fleet. The US implemented the Corporate Average Fuel Economy Standard (CAFE) in 1975, and today emission standards are in place from China to Mexico.

not explain the decrease in emissions. Instead, the results reveal that technological progress is twice as fast after the regulatory announcement. Firms respond to emission standards by increasing the speed of technology adoption, at least when we look at the official emission ratings. When we study the performance of vehicles on the road, the picture changes drastically. I find that only 30% of the increased technology adoption is measurable on the road so that 70% is attributable to gaming.

Next, the paper sets up an economic model of demand and supply to study the impact of the regulation on consumers, firms, and the environment. Firms' costs increase because of technology adoption. The increase in costs reduces profits and lowers consumer surplus. Because of the gaming, the reductions in actual CO<sub>2</sub>

emissions are a mere 5% instead of the 18% target. The sum of the value of emission savings and consumer and profit losses is negative so that the regulation reduces welfare. However, when I consider two additional non-targeted welfare effects, I find the emission standard to have a small positive impact. The emission standard also reduces other externalities, such as local pollution, congestion, and accident risk. And, there is a correction of consumer undervaluation of fuel economy.

The economic model also allows studying how the market outcomes differ if the EU designed the regulation differently. I focus on two aspects: the attribute base of the standard and the lack of enforcement.

First, I study the attribute basing, which makes the emission target dependent

on vehicle weight. Firms selling more lightweight vehicles face a more stringent attribute-based target. I find that attribute basing makes it much costlier to lower emission by changing prices. Firms have to distort prices more to reach the target because there are fewer vehicles to which firms can shift sales. If the regulation has a flat target without attribute basing, firms opt for changing prices together with some technology adoption. The flat target reaches actual CO<sub>2</sub> emission reductions of 11%, much closer to the 18% target. Why, then, was the attribute basing introduced? The attribute basing redistributes the incidence of the regulation between French, Italian, and German producers. The simulations show that the positions of the national governments are in line with the interests of their domestic firms. The French and Italian governments were in

favor of regulation without attribute basing, while Germany lobbied for a steep attribute design.

Gaming is also a product of the political environment. A recent evaluation by the European Parliament has placed responsibility for enforcement failures with the car producing member states. The economic model in this paper allows computing the effects of better enforcement. A better test procedure would mean that official and actual emissions are more similar. With more enforcement, the reductions in consumer surplus and profits are higher. Firms have to adopt costlier technology, and this increases prices further. But enforcement would have led to much higher CO<sub>2</sub> and other externality savings, and the policy would have been welfare improving. Overall, this shows that the political and practical implementation of

emission standards is crucial to understand the welfare consequences of these types of policies. ■ ■ ■

<sup>1</sup> Mathias Reynaert (2020), "Abatement Strategies and the Cost of Environmental Regulation: Emission Standards on the European Car Market", CEEPR WP-2020-014, MIT, July 2020.



Mathias Reynaert

## State Ownership and Technology Adoption: The Case of Electric Utilities and Renewable Energy

*by: Bjarne Steffen, Valerie J. Karplus, Tobias S. Schmidt*

Technological change in industries that are characterized by large technical systems often occurs incrementally along given technological trajectories. Given the urgency to mitigate climate change, a key concern for researchers and policymakers alike is to identify strategies for inducing and accelerating the adoption of radically new technologies in such otherwise slow-moving sectors.

The electricity industry is a prime example: While electricity is indispensable for modern societies, its generation is the single largest contributor to anthropogenic CO<sub>2</sub> emissions (IPCC, 2014). At the same time, electricity is a commodity that can be produced using an array of different technologies, including established and

very carbon-intensive technologies (e.g., coal) as well as largely carbon-free technologies (e.g., renewables like solar PV and wind turbines). Incumbent utilities play an important role in many countries, and the adoption of renewables by these players is a key requirement for a low-carbon transition of the industry.

While the effectiveness and efficiency of various policy instruments to support investments in renewables has been studied, little is known on the role of utility ownership. Particularly in the European Union (EU), the liberalization of electricity markets led to a co-existence of state-owned and private utilities. Past research studied pros and cons of these options in terms of productivity and market power,

amongst other factors, but the role of ownership in the adoption of low-carbon technologies remains elusive. To fill this gap, we bring together innovation literature and the economics literature on ownership to derive hypotheses how ownership could affect renewable energy adoption by utilities, including through drivers such as incentives to innovate, exploiting state ownership to advance climate policy, general climate policy stringency, and the impact of incomplete contracting.<sup>1</sup>

Empirically, we study the case of incumbent utilities in the European Union (EU) during 2005–2016 (a period in which the EU was bound by the Kyoto protocol, and all EU countries had binding targets to increase the share of renewable energy in their energy mix). A





Many policymakers aim to redirect electric utilities' power plant investments toward renewables. In much of Europe, state-owned and private utilities co-exist in a liberalized market environment, but the impact of ownership on the adoption of renewables is unclear. By investigating the investments of incumbent utilities in the EU during 2005–2016, we study the mechanisms by which ownership made a difference.

large-n regression analysis of state-owned and private utilities' investment decisions allows us to test our hypotheses with observational data. In addition, we present a qualitative analysis of the investment motives for ten utilities with the most remarkable shifts toward renewables, complementing the regression analysis with further evidence of the mechanisms involved.

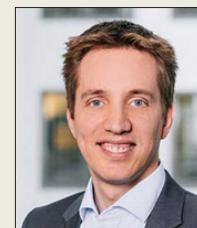
We find that in the EU, state-owned utilities had a higher tendency to invest in renewables, particularly from 2009 on. While theory suggests that private companies might be superior in terms of the adoption of new technologies that allow for long-term productivity growth, it appears that state ownership may be more effective in inducing investments that support pro-social objectives, such as climate policy targets. Given the general commercial viability of renewables, we find evidence that governments promote the adoption of renewables by direct fiat and by the choice of managers. However, state ownership does not exert its influence in a vacuum: it interacts with the existence of pro-adoption policies, and state enforcement capabilities.

Regulatory capture is a global phenomenon in which companies seek to advance their interests by exerting influence through the political process. Thus, the effect of state ownership can hinge on the ability of the state to enforce its agenda at the company level. In the EU, we find that state ownership complements regulatory enforcement. Hence, it plays a different role compared to weak enforcement environments such as China in the mid-2000s, where empirical evidence suggests that state control was rather a substitute for systematic enforcement (Karplus et al., 2017, 2020).

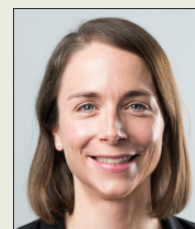
While in the case of the EU, there was a significantly higher tendency to invest in renewables at state-owned as compared to private utilities, it is important to note that the question of how ownership structures affect socially-desirable technology adoption is separate from the question of how ownership affects commercial performance. Thus, potential advantages of state ownership from a technology adoption point of view will need to be weighed against any disadvantages from a productivity point of view. In this sense, our results should not be considered an argument

for nationalization. However, we suggest that, in the cases where state ownership already exists—such as among electric utilities in Europe—policymakers can strategically exploit this ownership structure to support achievement of climate policy targets. ■

<sup>1</sup>Bjarne Steffen, Valerie J. Karplus, Tobias S. Schmidt (2020), "State Ownership and Technology Adoption: The Case of Electric Utilities and Renewable Energy", CEEPR WP-2020-016, MIT, August 2020.



Bjarne Steffen



Valerie J. Karplus



Tobias S. Schmidt

# Electrifying Transportation: Issues and Opportunities

by: *Bentley C. Clinton, Christopher R. Knittel, and Konstantinos Metaxoglou*

The stock of electric vehicles (EVs) worldwide increased by 65 percent between 2017 and 2018 to approximately 5 million total vehicles (IEA, 2019b). An expanding EV fleet represents a potentially large transition in energy demand from the established liquid transportation fuel supply network to the electricity system. The International Energy Agency estimates this transition could reduce oil demand by 2.5 to 4.3 million barrels per day and increase electricity demand by 640 to 1,110 terawatt-hours (IEA, 2019a). Such a transition requires a significant deviation from the status quo for automobile consumers and producers alike. In this paper<sup>1</sup> we take stock of the global LDV ecosystem and highlight issues and challenges likely to arise as electricity expands its role as a

transportation fuel.

Our assessment pays particular attention to trends in vehicle stock, fuel markets, and refueling infrastructure before turning to a study of market dynamics and an analysis of catalysts and consequences of broad transportation sector electrification. Three such inquiries are: (i) a comparison of vehicle cost factors and investigation of the break-even cost relationship between oil and battery prices; (ii) an approximation of the energy demand effects for a range of LDV electrification scenarios; and, (iii) an estimate of the foregone fuel tax revenue attributable to the current EV fleet. Additionally, we discuss the benefits of EVs in the context of avoided ICEV emissions and conclude with some thoughts on electrification in other

transportation sector contexts, namely, medium- and heavy-duty freight transport, and the role EVs may have in ride sharing and autonomous vehicle networks.

## Break-even costs

We build on the analysis of Covert, Greenstone and Knittel (2016) to calculate the break-even price of oil for a range of battery costs. Using historical data, we map monthly crude oil prices to gasoline prices in the US and apply the resulting parameters to a model of operating costs for ICEVs and EVs. The result of this calculation is included in the accompanying Figure. Points below the solid line represent oil price and battery price pairs where ICEVs are less expensive to operate than EVs. The opposite relationship holds for points above the line. To a first order, the relationship is close to a 1:1 mapping between oil prices and battery costs; this does not bode well for EVs. At current battery prices (approximately \$160/kWh), oil prices would need to exceed \$135/bbl for EVs to be cost competitive. We repeat this calculation for a number of scenarios ranging from imposition of a carbon tax to incorporation of avoided maintenance costs realized by EV owners. While these do lead to more favorable break-even cost levels, the comparison remains unfavorable to EVs at current battery and oil prices. We next modify our analysis to include assumptions unique to PHEVs (dashed line in Figure) and find a more favorable break-even scenario for these vehicles, though we caution this result is sensitive to baseline PHEV assumptions.<sup>2</sup>

## Energy demand effects

We apply existing simulations of intra-day EV charging patterns from the National Renewable Energy Laboratory's EVI-Pro tool to publicly available data on

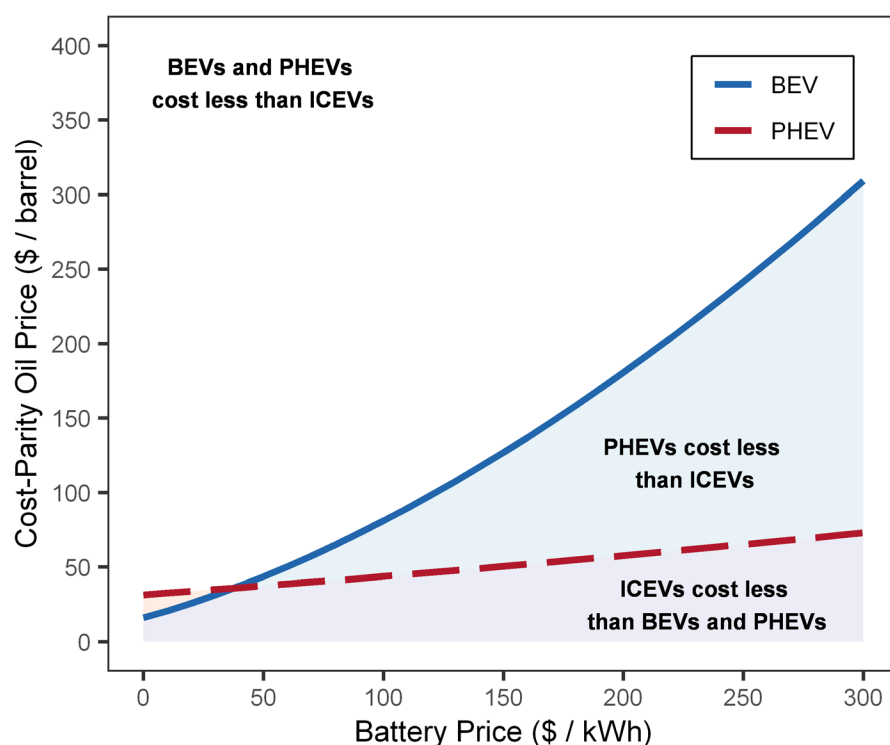


Figure: BEV and PHEV Cost Parity Frontier

Curves represent cost-parity oil price and battery price pairs. Points along the curve are computed by setting ICEV and BEV (or PHEV) operation costs equal and incorporating battery price considerations for EV models. The oil-to-gasoline price relationship is estimated by linear regression in log form.





In this chapter of the forthcoming Handbook on the Economics of Electricity, we examine the global implications of electrifying the transportation fleet. Our analysis covers an array of topics including vehicle cost considerations, infrastructure concerns, emissions consequences, and the potential effect of electrification on gasoline tax revenues. We also discuss aspects of the electrification frontier, paying particular attention to the role of electricity in the medium- and heavy-duty sector and for ride sharing and autonomous vehicles.

EV ownership and electricity generation infrastructure to illustrate the potential effect of LDV electrification on a select group of power systems (Wood et al., 2017). Our assessment of energy and power requirements of these fleets indicates current adoption levels of EVs pose limited challenges on a grid-level scale, but the projected increases in EV adoption—and any long-term push for high-level or full electrification—will require long-range planning actions by key electricity market participants. These actions are likely to include a mixture of capacity additions, infrastructure expansion, and the introduction of load-shifting options (e.g., smart charging) and compatible incentives (e.g., time of use rates) for EV owners.

### Foregone fuel tax revenues

A decline in reliance on liquid transportation fuels necessarily decreases tax revenues derived from fuel sales, all else equal. In scenarios with high levels of EV ownership, revenue shortfalls must be recouped from other sources. We explore these issues in a number of national markets and quantify the required scale of alternative

revenue-generating mechanisms. Expanding on the methods of Davis and Sallee (2019) and accounting for cross-sectional variation in fuel excise tax levels, EV fleet sizes, annual miles traveled, and ICEV fleet efficiency, we determine foregone tax revenues. Our calculations indicate electricity excise taxes or annual fees for EV owners would significantly increase current cost burdens on EV owners. While such a move has the potential to depress EV adoption rates, more information is needed to evaluate these tradeoffs; we are actively pursuing such an assessment with ongoing work.

The push toward a fully electrified vehicle fleet is one of opportunity, but also faces many challenges. This chapter examines a number of these in the global context. Results of our work demonstrate that electricity's place in the future portfolio of transportation fuel options depends crucially on EV cost competitiveness, model availability, and forward-looking actions by the electricity supply network. In preparing for next steps toward an electrified LDV sector, stakeholders and policymakers alike will need to consider these aspects of the market along with implications for

emissions and tax revenues for transportation infrastructure investment. ■

<sup>1</sup> Bentley C. Clinton, Christopher R. Knittel, and Konstantinos Metaxoglou (2020), "Electrifying Transportation: Issues and Opportunities", *CEEPR WP-2020-010*, MIT, June 2020.

<sup>2</sup> As part of our analysis, we developed an online tool for users to modify these assumptions. The tool can be accessed here: <http://ceep.mit.edu/research/projects/WP-2020-010-tool>



Bentley C. Clinton



Christopher R.  
Knittel



Konstantinos  
Metaxoglou

# The Roosevelt Project: A Progress Update and Next Steps

by: *Nina Peluso and Sade Nabahe*

The Roosevelt Project, introduced in our August 2019 Newsletter, takes a multidisciplinary approach to examine the transitional challenges associated with progress toward a deeply decarbonized U.S. economy. The project aims to chart a path forward through the transition that minimizes worker and community dislocations and enables at-risk communities to share in the economic upside of the transition itself. The first phase of the project involved a set of cross-cutting white papers on topics related to the transition, listed below.

Following the release of the white papers<sup>1</sup>, the Roosevelt Project hosted a launch webinar, during which Professor

and former US Secretary of Energy Ernest Moniz was joined by a group of high-level experts from academia, public policy, and civil society to discuss initial findings. This first phase of the project highlighted the importance of a comprehensive, regional approach to transition planning. Recognizing that regional benefits and attendant dislocations stemming from the transition will be geographically concentrated is a fundamental precursor to effective policy intervention.

To that end, the Roosevelt Project has advanced to the second phase, developing action plans for four regional case studies: Appalachian Pennsylvania, Industrial Heartland, Gulf Coast and New

Mexico. The cases were chosen to capture variance across the unit of analysis (county, state, region), key drivers of the transition, local social, economic and demographic realities, and importantly, deep collaborations with local partners. The case studies are as follows:

Appalachian Pennsylvania faces ongoing disruption from the decline of coal and disruption from the potential decline of natural gas. The region will also face a moderate risk of heat stress and high risk of extreme rainfall in the years to come, driven by climate change. Across Appalachia, driven by a lack of economic competitiveness and emissions regulation, coal production has declined



- **Assessing the Role of Public Policy in Industrial Transitions: How Distinct Regional Contexts Inform Comprehensive Planning** (Peluso, Kearney, and Lester, 2020)
- **Social Impacts of Energy Transition** (Beckfield, Evrard, Sampson, and Waters, 2020)
- **Distributed Effects of Climate Policy: A Machine Learning Approach** (Green and Knittel, 2020)
- **Building the Energy Infrastructure Necessary for Deep Decarbonization throughout the United States** (Hsu and Ulama, 2020)
- **Public Attitudes on Energy and the Climate** (Ansolabehere, Thom, and Tingley, 2020)
- **Just Institutions for Deep Decarbonization? Essential Lessons from 20th Century Regional Economic and Industrial Transitions in the United States** (Gallagher and Glasmeier, 2020)
- **Energy Workforce Development in the 21st Century** (Foster, Nabahe, and Ng, 2020)
- **Energy and Manufacturing in the United States** (Foster, Nabahe, and Ng, 2020)
- **Fostering Innovative Growth in Regions Exposed to Low Carbon Transition** (Karplus, Kearney, and Pawar, 2020)

The Roosevelt Project held a launch webinar on September 10, 2020 to coincide with the release of a series of white papers. A recording of the webinar can be viewed at: <https://www.youtube.com/watch?v=6F-px5bJQFA>



by over 45% since 2005 and is expected to drop further in the coming years. The region has lost over 33,500 coal jobs since 2011 — 82% of total U.S. coal job losses. The bulk of those losses are concentrated in just 16 Appalachian counties, including Greene County. Pennsylvania as a whole is home to 9% of the nation's coal jobs. The economic impacts of the ongoing decline of coal in Appalachian Pennsylvania have been buffered in part by a boom in natural gas. Pennsylvania has gone from having negligible gas production, as recently as 2008, to producing 19% of the nation's natural gas today. This boom shows little sign of slowing: Greene County experienced a 33% year-over-year growth in natural gas production in 2019. Without intervention, Appalachian Pennsylvania faces continued, accelerating job losses due to the decline of coal, and the impending decline and uncertain role of natural gas in the future.

The Industrial Heartland case study focuses on Michigan, Ohio, and Indiana and the contained Midwestern motor vehicles manufacturing region. Ohio and Indiana are highly susceptible to future climate damages, particularly with respect to high heat, extreme rainfall, and water stress. Michigan's environmental future is relatively less fraught, but the state could eventually shoulder the burdens of its southern neighbors as they face increasing climate damages. The region's economic future is integrally tied to its motor vehicles manufacturing industry – any future planning should confront rapid changes in that sector accompanied by the electrification of transportation. All three states are densely populated, stand to retire substantial fossil infrastructure, and must consider a transition away from traditional energy sources across all sectors (electricity, transportation, & buildings).

The Gulf Coast case study includes counties surrounding the Texas and Louisiana border, a region that contributes substantially to American oil and gas production in the US and its related petrochemical and chemicals'



One of the Roosevelt Project's Phase II Case Studies looks at the oil and gas industry in the US Gulf Coast, with particular focus on the area surrounding the Texas and Louisiana border.

industries. Texas alone is home to 37% of total US crude oil production, 24% total natural gas production, in addition to the most installed wind energy. This region will experience adverse effects due to climate change and potentially experience an economic downturn if decarbonization plans are not designed with economic resilience in mind. Climate change will pose high water stress that will affect agriculture and impact oil and gas production. Rising global temperatures will also increase hurricane and tornado risks. Economic and climate impacts will vary depending on location, but the region's distributed, unique strengths are accessible to solve such challenges.

The New Mexico case study focuses on the fossil fuel industry and economic welfare challenges that underrepresented minorities face. As a minority-majority state, 48.5% of the state population identify as Hispanic or Latino and 8.6% as Native American. The state has roughly 21% of individuals living below the poverty line which is 5.8% more than the national average and is unevenly distributed across regions. In the coming years, New Mexico will primarily experience water stress that could potentially impact mining activities as well as the general population. However, the state is home to leading energy research institutions that could further develop technologies

that will aid in the future decarbonization efforts, and has recently adopted a new set of forward leaning climate and social goals that may be in tension with its legacy fossil fuel industry. New Mexico also has considerable solar generation resources but faces transmission isolation from major population centers. ■

<sup>1</sup> Learn more about the Roosevelt Project here: <http://ceepr.mit.edu/roosevelt-project>

The full white papers can be accessed here: <http://ceepr.mit.edu/roosevelt-project/publications>



Nina Peluso



Sade Nabahe

# Distributed Effects of Climate Policy: A Machine Learning Approach

by: *Tomas W. Green*



How do policy makers address climate change aggressively enough to meet stated climate goals (keeping global temperatures below 1.5° C) without harming communities and households reliant on fossil fuels?

Using different machine learning algorithms, I created a statistical model of the household carbon footprint (HCF) for an average household in each US Census tract and used each carbon footprint to estimate the costs and benefits of policy options. Carbon pricing, when accompanied with a dividend, is progressive for urban, rural, and suburban households. There are transfers from the Midwest and Plains to the Coasts when the dividend is evenly divided, but this can be mitigated by adjusting the dividend slightly (<8% increase or decrease). Adjusting the carbon dividend for both geography and urbanity increases the average benefit to low-income households and reduces the heterogeneity of impacts within income groups. The effects of regulatory policy tend to be regressive and are, on average, a net cost to households who are low income – especially those in rural areas. Combining a carbon price and dividend with regulatory standards can remove the regressive trend of

regulations, but regional and urban-rural transfers are harder to mitigate.

The results from my work underscore the high variability in household carbon footprints across a number of dimensions. This research was part of my Master's thesis, and the results are contained in a subsequent Working Paper co-authored with my supervisor, Professor Christopher R. Knittel.<sup>1</sup>

Two dimensions warrant focus. First, my results suggest that based on consumption of goods and services, low income consumers are likely to spend more on carbon taxes, as a share of their income. I am not the first to find this result. The regressivity of carbon taxes, ignoring the use of the revenues, is a well-known argument against their use. While recent work suggests that after accounting for the impact of carbon taxes on firms and employment (known as source-side effects), carbon taxes are no longer regressive, the regressivity of

carbon taxes on the consumption dimension (use-side effects) is likely to be a major political obstacle.

My work highlights a second dimension that is likely to pose a political obstacle that is just as large, if not larger, than the regressivity of carbon taxes: the wide range in carbon footprints across rural and urban communities. Indeed, the geographic correlation of carbon footprints is nearly as significant as the variability across income levels. For example, the difference in average household emissions between the top and bottom quintile is smaller than the difference between the average household in California and Missouri.

These results accentuate the importance of how revenues from a carbon tax are recycled into the economy. From an economic efficiency perspective, the best use of the revenue is to reduce existing taxes that are a drain on economic activity and efficiency, such as income or sales taxes. As inefficient (e.g., income) taxes are replaced with efficiency-enhancing taxes, such as carbon taxes, we not only help reduce climate change, but we also improve the overall efficiency of the macro economy. The drawback of such a carbon tax policy is that it requires jointly adopting a carbon tax together with larger tax reforms, as well as the commitment of policy makers to not increase the income or sales taxes in the future. As tax reform packages are seen once per generation and are often political hot potatoes, I suspect that the political hurdles of such a system are insurmountable.

A more simple policy design refunds the revenues collected by the carbon tax in the form of household dividends, so-called "tax-and-dividend" plans (such as the Baker-Schultz plan). No tax-and-dividend plan to date differentiates



across region, although some adjust for other factors such as the size of household. While such a policy has the advantage of being straightforward, it ignores the large geographic differences in carbon footprints that I document, particularly across rural and urban settings.

Correcting for heterogeneity can also improve the progressive outcome of policy. When I adjusted the dividend to increase the amount for low-income households and reduced the amount for high-income households, I found that the benefits for rural households increased on average but that the impacts within each income group were more heterogeneous. When I adjusted the dividend for both geography and urbanity, there was an increase in the average benefit to low-income households and a reduction in the heterogeneity of impacts within income groups.

I recommend a tax-and-dividend policy design that accounts for the rural-urban divide in carbon footprints. There are

many ways to achieve this outcome. The basic structure is to condition the level of the dividend on some information about the type of the household. It is of upmost importance that households have limited ability to alter their type themselves. If a household can take strategic actions to affect their dividend level, then they will have less of an incentive to reduce their carbon footprints. In addition, the dividends cannot be state-specific. Having them be based on the average carbon content of a given state will reduce the incentives of state policy makers to adopt carbon-reducing policies. I leave the details of such a plan for future policy discussions.

My results underscore an important lesson: climate policies that generate revenue within the policy itself afford policy makers the flexibility to protect disadvantaged groups. There is need for transparency in the impact to the public of each policy option – “do nothing” is the worst option, but all policy has a cost on some portion of the public. Vulnerable groups should be supported by public policy rather than burdened

by it. Spurring the change necessary to steeply cut carbon emissions will pose significant costs and if these costs are distributed through regressive policy, the transition to a sustainable future will not be equitable. ■

<sup>1</sup>Tomas W. Green and Christopher R. Knittel (2020), “Distributed Effects of Climate Policy: A Machine Learning Approach”, CEEPR WP-2020-R3, MIT, September 2020.



Tomas W. Green

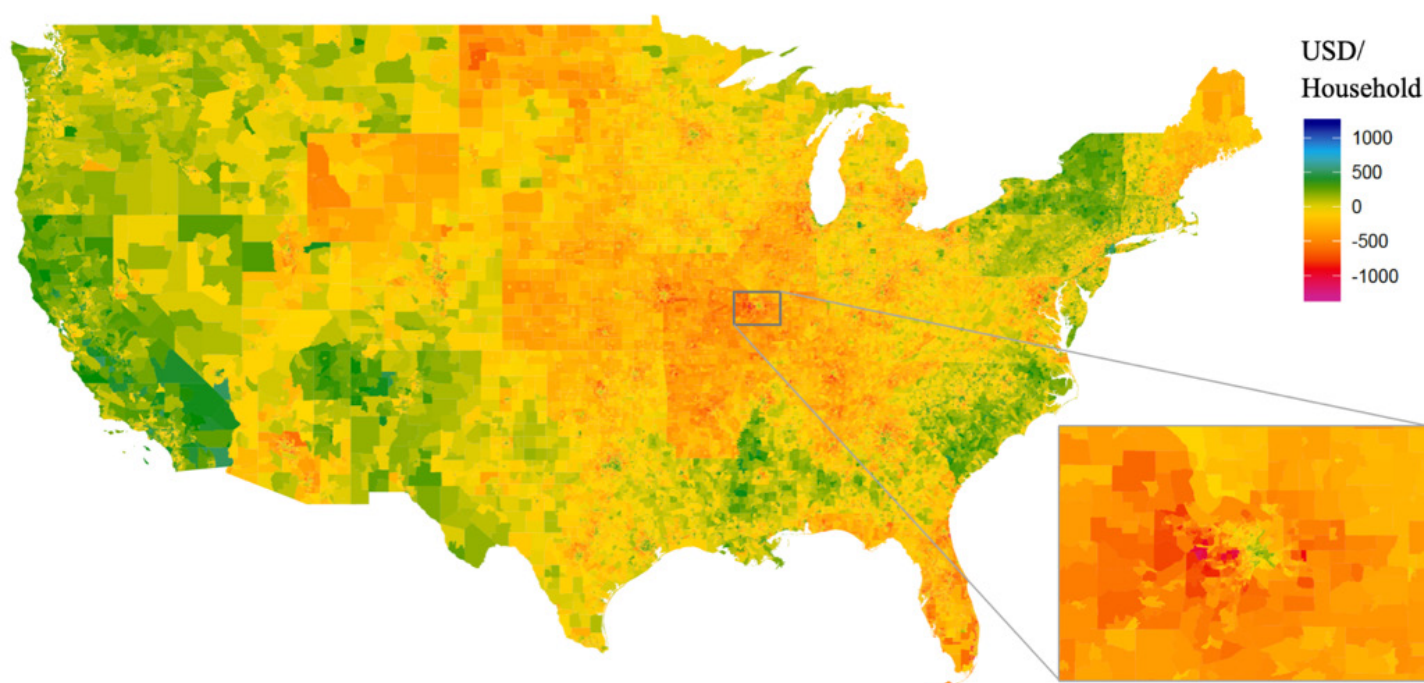


Figure: Geographic distribution of net benefits and costs of a \$50 carbon price with all revenue returned in terms of an equal dividend to each US household (expanded view of Saint Louis, Missouri).

# Distributional Effects of Net Metering Policies and Residential Solar Plus Behind-the-meter Storage Adoption

*by: Andrés Inzunza and Christopher R. Knittel*

In the face of a widespread penetration of distributed energy resources (DER) in electric grids, such as residential solar PV, batteries, electric heat pumps, etc., an inadequate tariff design may have uneven consequences across different socioeconomic groups. In the U.S., owners of residential solar systems are wealthier than non-owners, given that more than 80% of solar owners belong to the top 3 income quintiles (Barbose et al., 2018). If, for instance, an important portion of utilities costs is collected through the volumetric charge of tariffs, solar adopters, whose electricity consumption from the grid is lower, would contribute less to paying for the electric infrastructure (e.g., networks), and thus, uncollected revenues would have to be obtained from other customer groups (S. Burger et al., 2019). Moreover, other types of DERs, such as behind-the-meter (BTM) batteries, could provide an even greater opportunity to reduce electricity bills paid by adopter clients (Hledik & Greenstein, 2016). These resources allow the consumer to

manage the amounts of electricity they consume from the system flexibly and could be used to further optimize their consumption.

Adding further complexity to the context, net metering (NEM) schemes are widely adopted in the U.S. and around the world in order to incentivize investment on residential solar PV systems and more recently, on behind-the-meter storage (California Public Utilities Commission, 2019; The Commonwealth of Massachusetts Department of Public Utilities, 2019). Under the simplest definition, these schemes consist of valuing net imports (i.e., consumption) and net exports of power from customers premises to the grid at the full retail tariff. In many jurisdictions in the U.S. and other countries, an important fraction of network costs is recovered through volumetric charges (Brown & Faruqi, 2014). Hence, given that NEM policies help DER adopters avoid some of these costs, we argue that these policies may

increase undesirable distributional impacts of DER adoption, under some tariff designs. In this context, the present work aims at answering the following research questions:

1. How do different tariff designs combined with NEM schemes interact with different levels of solar PV and BTM storage adoption, in terms of the economic impact on adopters and non-adopters of DER?
2. How would the benefits and costs of solar and storage adoption be distributed across different income quintiles?
3. How do different tariff designs combined with NEM schemes and solar plus storage adoption interact with other aspects relevant to policy making, such as the economic value that adopters draw from the adoption of BTM storage and potential costs/benefits due to increased/decreased needs regarding network assets?



By using a dataset containing close to 100,000 customers' half-hourly load data and income quintiles from Chicago, IL, we simulate the operation of residential solar and behind-the-meter battery systems under various adoption levels and calculate both resulting bills for every client, as well as cost shifts arising from the combination of NEM and the allocation of network and policy costs through volumetric charges (i.e., in \$/kWh).



To address these questions, we use half-hourly data for the year 2016 for ~100,000 customers in Chicago, IL, to which we randomly assign solar or solar plus storage assets, with increasing penetration levels.<sup>1</sup> We calculate the operation of these assets by means of several instances of an optimization model capable of calculating DER operation that would minimize each client's yearly bills. We test three different NEM regimes (On, Off and the NEM regime currently applicable to BTM storage in California) and several different tariffs designs and calculate cost-shifting effects of DER adoption from adopters and non-adopters due to residual cost avoidance by the former. Additionally, using socioeconomic data from customers we assess how bill impacts differ across different income groups.

Overall, results show that the combination of NEM schemes and recovery of residual costs through volumetric charges may cause important cost shifting effects from adopter onto non-adopter customers, raising equity and fairness concerns. Firstly, under NEM schemes, we calculate that adopter customers may, on average, obtain bill reductions of 71% when installing solar

plus storage, whereas non-adopters can see their bills increase around 18% in high DER penetration scenarios (i.e., 45% penetration). Moreover, under the same NEM schemes, 45% adoption and considering solar plus storage adoption alone, we calculate that customers from the two lowest income quintiles may suffer bill increases in the 16-19% range on average, while removing NEM schemes reduces these increases to the 11-12% range.

We also set out to investigate potential effects on power management for grid operators. Although we did not model grid operation, we calculated the aggregated change on load patterns after DER operation and used the pre-DER adoption condition as a proxy for the design condition of the grid. Overall, we see that in 3 out of 4 tariff designs considered, NEM schemes provide incentives to use the grid more intensively, which could be a cause for concern by grid operators, due to potential higher network investment costs.

While the analysis performed here used data from Chicago, Illinois in the U.S., fundamental causes for the cost-shifting effects of DER adoption and inadequate

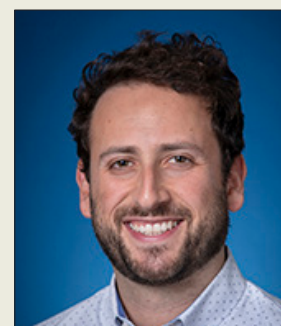
tariff designs can be tested using our methods in any other jurisdictions where similar tariff and billing practices are present (e.g., other states in the U.S., Chile, Australia, U.K., etc.).

Finally, it is important to note that in this study we have focused our efforts on identifying and quantifying specific potential effects of NEM schemes without intending to perform a comprehensive analysis of the benefits and costs of these policies. Many aspects not considered in this study matter when performing such an assessment, such as benefits on reduced environmental footprint of the energy supply, job creation and potential incentives for grid-defection. Consequently, results here should be considered in combination with an assessment of these other effects in order to provide quality recommendations on the societal desirability of NEM schemes. ■■■

<sup>1</sup> Andrés Inzunza and Christopher R. Knittel (2020), "Distributional Effects of Net Metering Policies and Residential Solar Plus Behind-the-meter Storage Adoption", CEEPR WP-2020-018, MIT, October 2020.



Figure: Bill impacts of DER adoption on non-adopters by income quintile and NEM regime, calculated under time-of-use tariff and 45% of solar plus storage adoption.



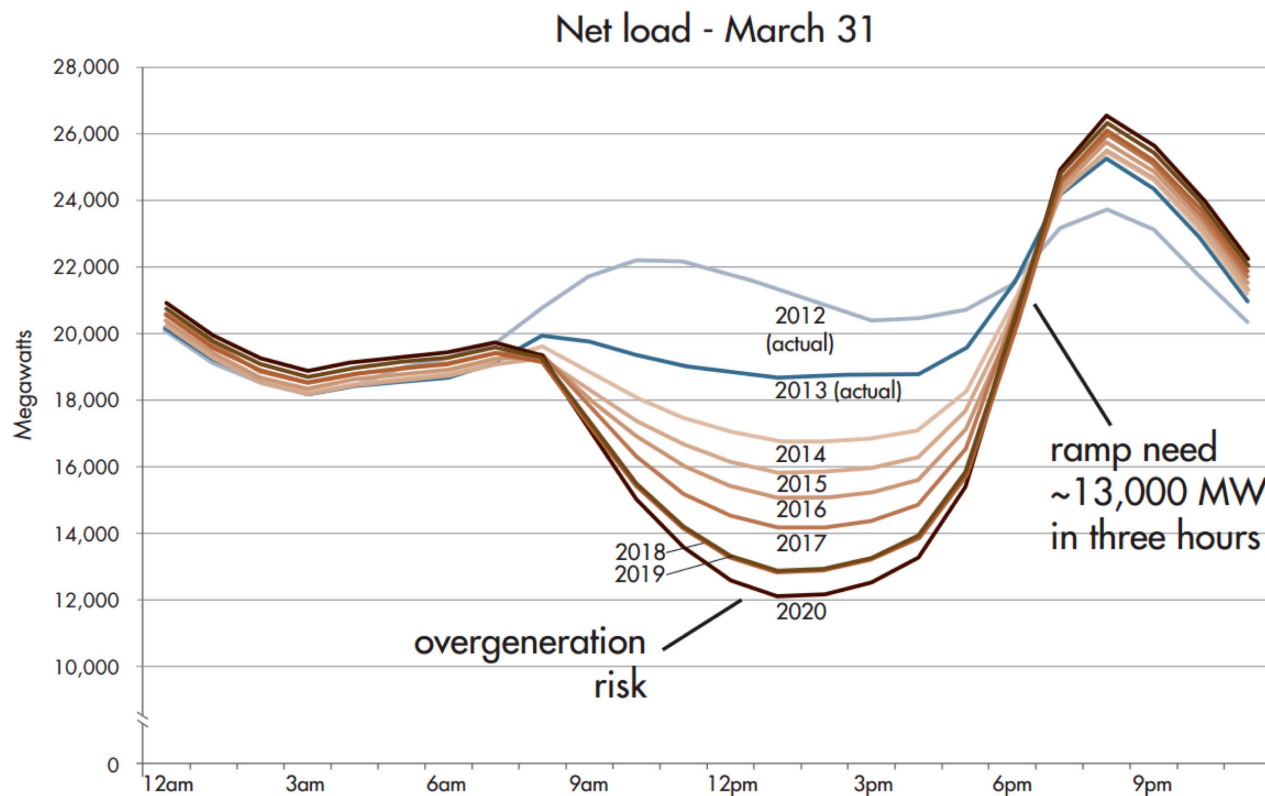
Andrés Inzunza



Christopher R. Knittel

# Competitive Energy Storage and the Duck Curve

by: Richard Schmalensee



The original CAISO 'duck chart' showing steep ramping needs and overgeneration risk on a typical spring day. Source: CAISO, 2013

In 2008, modelers at the National Renewable Energy Laboratory accurately predicted what was later christened the "duck curve": an hourly pattern of total and net generation caused by the increased penetration of residential photovoltaic generation in the area served by the California Independent System Operator (CAISO) that resembled the shape of a duck. Growing solar penetration has deepened the duck's back during mid-day, whereas increased output from other sources has been required in late afternoons – resembling a duck's neck – when solar generation drops off and residential load increases.

Traditionally, the solution to this problem would be to build and use more gas turbines or combined cycle plants that can increase output rapidly. However, building more fossil-fueled generators is inconsistent with the goal

in California and elsewhere of reducing carbon dioxide emissions. As the costs of storage, particularly lithium-ion battery storage, have declined, storage has instead emerged as a potentially attractive, carbon-free alternative way of offsetting diurnal declines in solar generation.

What is more, the California Public Utilities Commission requires load-serving entities to procure storage as part of statutory requirements adopted in 2010, in part to facilitate expanded integration of solar and other variable renewable generation. Storage targets have also recently been established in Massachusetts, Nevada, New Jersey, New York, and Oregon, and they are under consideration in other states.

This state-level reliance on mandates contrasts with an apparent preference at

the federal level to rely on competition to drive investment in storage facilities. As solar penetration has increased, intra-day price differences have also increased, suggesting that with sufficient solar penetration, competitive storage providers could find it profitable to buy at mid-day when prices are low and sell a few hours later as solar generation begins to drop off and prices become high, thus mitigating or perhaps solving the duck curve problem.

The U.S. Federal Regulatory Commission issued Order 841 in 2018, which is intended to open wholesale energy markets (and other wholesale markets) to merchant storage providers. Efforts are ongoing to reach agreement on exactly how to define markets and establish tariffs to ensure that storage providers have access to wholesale markets on appropriate terms. But the



FERC policy rests on the presumption that energy markets can provide at least approximately optimal incentives for competitive investment in storage as well as generation.

An MIT CEEPR Working Paper<sup>1</sup> by Richard L. Schmalensee explores the validity of that presumption in the context of the duck curve by investigating the properties of a Boiteux-Turvey-style model of an electric power system augmented with the addition of storage. Models in this tradition assume constant returns to scale, stochastic and (generally) inelastic demand, and multiple dispatchable generation technologies without significant startup costs or minimum generation levels. If shortages occur, the system is assumed not to collapse, and price is assumed to rise to the value of lost load.

To focus on a necessarily simplified version of the duck curve problem, the model considered in the Working Paper has alternating periods of two types, labeled daytimes and nighttime, corresponding roughly to the duck's back and its neck. Renewable generation has positive, stochastic output only in daytime periods. Gas generation, which, for simplicity, stands in for the whole suite of dispatchable generation technologies, is assumed to be available

in both daytime and nighttime periods. Short-term storage can be installed at a constant cost per unit of capacity, and storage involves a constant fractional round-trip loss of energy. Demand in both days and nights is stochastic, constant within periods, and perfectly inelastic.

If energy prices are not capped below the value of lost load, Boiteux-Turvey-style models indicate that revenue from competition in energy markets leads to the economically efficient supply of generation capacity. Similarly, the results of Schmalensee's analysis highlight the benefits of relying on the competitive supply of storage, at least in the context of the duck curve problem. These results thus provide support for the preference at the U.S. federal level for storage to be determined by market competition.

In most energy markets in the U.S. and elsewhere, however, prices are capped below reasonable estimates of the value of lost load, and those caps are occasionally binding. Boiteux-Turvey-style models then imply that revenues from sales in energy markets will provide inadequate incentives for investment in generation. Consequently, most electricity markets in the U.S. have seen the introduction of "capacity mechanisms" to supplement energy

market revenues. These mechanisms typically involve a determination by a regulator or system operator of the level of generation capacity necessary for an acceptable level of reliability along with a capacity market or other mechanism for compensating suppliers of that capacity.

Just as caps on wholesale energy prices reduce incentives for investment in generation, it follows from the Boiteux-Turvey-style analysis applied in the Working Paper that caps on wholesale energy prices will lead to inadequate incentives for investment in storage for energy arbitrage. While this theoretical finding may not have been the motive for some U.S. states to adopt quantitative storage targets, it is likely that some analog to "capacity mechanisms" has been considered necessary to supplement energy arbitrage revenues and increase the supply of storage. Still, "capacity mechanisms" use reliability to determine the appropriate level of generation capacity; it is not clear how the appropriate level of storage capacity of various sorts would be sensibly determined. ■

—Summary by Michael Mehling



Power systems with high penetrations of solar generation need to replace solar output when it falls rapidly in the late afternoon – the duck curve problem. Storage is a carbon-free solution to this problem.

<sup>1</sup> Richard Schmalensee (2020), "Competitive Energy Storage and the Duck Curve", CEEPR WP-2020-012, MIT, July 2020.

California ISO (2013). *What the Duck Curve Tells us about Managing a Green Grid*. Folsom, CA.



Richard Schmalensee

# Going Beyond Default Intensities in an EU Carbon Border Adjustment Mechanism

*by: Michael A. Mehling and Robert A. Ritz*

As part of its Green Deal, the European Union (EU) is preparing a Carbon Border Adjustment Mechanism (CBAM) to address concerns about carbon leakage—uneven climate policies causing production, investment, and emissions to relocate outside the EU. All CBAM design options that are currently under consideration apply a carbon price to products imported from outside the EU. The European Commission has estimated that a CBAM could raise annual fiscal revenue of €5-14 billion for the EU. However, implementing a CBAM raises complex technical and administrative challenges. One of the more difficult steps involves determining the carbon intensity of imports, where lack of data as well as procedural and methodological obstacles will likely prompt reliance on default values—for instance, the average carbon intensity of domestic producers in a sector.

In a recent CEEPR Working Paper<sup>1</sup>, we propose a CBAM design with a voluntary “individual adjustment mechanism” (IAM) that allows non-EU producers to demonstrate that their actual carbon intensity lies below the default value. A CBAM based solely on default intensities runs counter to the economic logic of carbon pricing by distorting the incentives for emissions abatement. We suggest that the use of an IAM offers a superior policy option compared with such a “one size fits all” policy design. Specifically, an IAM captures additional economic benefits of carbon pricing—notably by rewarding the decarbonization efforts of producers outside the EU—and improves the legal prospects of a CBAM. Past case law suggests that it can help a CBAM comply with the free trade rules of the World Trade Organization (WTO). Moreover, the voluntary nature of the IAM also sidesteps obstacles under general

international law that would arise from making the disclosure of individual carbon intensities mandatory within the CBAM. Finally, implementing an IAM as part of the CBAM is practically feasible, drawing on the existing procedures for monitoring, reporting and verification of emissions under the EU Emissions Trading System (EU ETS).

## Economic Considerations

A CBAM design based solely on a default intensity runs counter to the economic logic of carbon pricing, which is based on polluters being charged according to their actual carbon intensities. There are two economic drawbacks. First, relatively clean producers get overcharged compared with high-carbon rivals. Second, it provides no incentives for abatement; the only way for a foreign producer to reduce its carbon costs is to reduce its sales to the EU. This means



We outline a CBAM design with a voluntary individual adjustment mechanism (IAM) that allows producers to demonstrate that their actual carbon intensity lies below the default value, and discuss economic and legal advantages as well as practical considerations.



that key benefits of carbon pricing are lost, in a way that favors high-carbon companies. Use of an IAM as part of the CBAM design gives companies exporting to the EU the option to demonstrate that their actual carbon intensity lies below the default value. Relatively clean producers are then no longer disadvantaged, and efficient abatement incentives are at least partially restored. A CBAM design with an IAM can be adjusted to take into account possible continuing free allocation for EU producers as well as the increasing use of carbon pricing outside the EU. We suggest that concerns about contractual “resource shuffling” under an IAM for industrial sectors may be significantly less pronounced than for California’s border adjustment on electricity imports.

### Legal Considerations

An IAM improves the prospects that a CBAM will be found in alignment with WTO rules on non-discrimination. It helps ensure greater symmetry in the treatment of domestic and foreign goods by giving foreign producers the option to follow the same process of emissions monitoring, verification and reporting (MRV) that domestic producers follow under the EU ETS. Because it strengthens the environmental effectiveness of the CBAM by providing a stronger incentive for foreign producers to reduce their carbon intensity, the IAM also increases the likelihood that the measure can be justified through recourse to the general exceptions set out in the GATT. Past case law, including a GATT panel decision affirming the design of a border tax adjustment imposed by the United States, supports this assessment. In the United States – Superfund case, a GATT panel affirmed a border tax adjustment imposed by the United States under the Superfund Amendments and Reauthorization Act of 1986 (SARA) on certain imported substances produced from feedstock chemicals subject to a domestic excise tax. Importers were required to furnish the information necessary to determine the amount of feedstock chemicals, but if they failed to

do so, the United States was authorized to apply a default – or baseline – rate equal to the predominant method of production in the United States. According to the panel, this reliance on a default rate in combination with individual determination was sufficient to demonstrate equivalence between the domestic excise tax and the border measure applied to imports. In another case, the WTO Appellate Body determined that use of a statutory or default baseline for foreign gasoline importers was discriminatory as long as domestic refiners were assessed against individual baselines, a practice that should be extended to importers. Finally, by obviating the need for the EU to collect emissions data from foreign entities, the voluntary nature of the IAM lowers the risk of the CBAM being considered a violation of the sovereignty of affected trade partners under general international law.

### Practical Considerations

An IAM can be rendered operational by including a general provision in the legislative text establishing the CBAM, with technical details left to delegated acts adopted by the European Commission. Importers seeking to avail themselves of the IAM would have to furnish information documenting the actual emissions associated with production of the imported goods. Ideally, the modalities of this process will follow those applied to comparable domestic products and avoid imposing an excessive burden on foreign producers. Under the EU ETS, the relevant modalities form part of an

annual compliance cycle based on an approved monitoring plan, guidance documents setting out detailed emission measurement and calculation methodologies for different activities, and independent verification of reported emissions by an accredited third party. Importers choosing to exercise the IAM could thus be required to furnish a monitoring plan for each installation producing the imported goods, and include an emissions certificate with each product shipment that applies the same calculation methods as their EU counterparts. Likewise, importers could be required to obtain independent verification by an accredited verifier as a means of ensuring the integrity of reported data. To limit the burden on importers, verification could be allowed by entities accredited in the country from which imported products originate. The Text Box below exemplifies the calculation of an IAM. ■

<sup>1</sup>Michael A. Mehling and Robert A. Ritz (2020), “Going Beyond Default Intensities in an EU Carbon Border Adjustment Mechanism.” CEEPR WP-2020-019, October 2020.



Michael A. Mehling



Robert A. Ritz

### Payment obligation under a CBAM with an IAM =

$$q_{ijk} \times \Delta t_{ijk} \times \max\{0, \min\{z_{ijk}, Z_i\} - f_i \times y_i\}$$

For product  $i$  supplied by producer  $j$  in country  $k$  outside the EU with an actual carbon intensity of  $z_{ijk}$ , to which the EU (absent the IAM) applies a default carbon intensity of  $Z_i$ ; free allocation for product  $i$  in the EU is  $f_i \in (0, 1)$ , average carbon intensity in the EU is  $y_i$ , and  $\Delta t_{ijk}$  is the shortfall in country  $k$ ’s carbon price relative to the EU carbon price. Using illustrative parameter values, we estimate that an IAM could reduce by 10-50% the compliance obligation of a relatively efficient non-EU blast furnace steel producer, depending on the extent of continuing EU free allocation.

Text Box: Calculating the Payment Obligation

## CEEPR Welcomes New Members to the Group for the 2020-2021 Academic Year

As mentioned in last issue's Director's Letter, COVID-19 has had an unprecedented impact on activities at MIT and major adjustments were made to keep faculty, staff, and students safe, including a campus-wide closure. Nevertheless, the work at the Institute, and at CEEPR, continues on without pause. Director Christopher Knittel and other faculty supervisors oversaw final graduate student theses work and guided many of our research assistants through to the completion of their studies. CEEPR congratulates **Tomas Green, Andrés Inzunza, Benny Ng, Bora Ozaltun, and Sohumi Pawar** on their graduation and Master's degrees from the MIT Technology and Policy Program. In addition, **Omer Karaduman** successfully defended his dissertation and has been conferred a Ph.D. degree from the Department of Economics. We look forward to sharing their research work in the CEEPR Working Paper Series over the coming months. Finally, this year, CEEPR is pleased to welcome these new members to the group:



**Sanjam Chhabra**  
Research Associate

Sanjam Chhabra joins CEEPR after completing her Master's in International and Development Economics at Yale this year. She is passionate about using methods in applied microeconomics to answer policy-relevant questions and has undertaken empirical projects spanning the fields of development, health, and climate.

At CEEPR, Sanjam will be working with Director Christopher Knittel to study the economic impact of various climate policies on households in the United States. Her current project employs novel methods to estimate household carbon footprints and their distribution across geography, urbanity, and income groups. As a Research Associate, she will also assist in data analysis and oversee randomized controlled trials for energy and environmental economics projects across CEEPR.



**Jack Morris**  
Graduate Research Assistant

Before coming to MIT, Jack Morris studied applied mathematics and operations research at William & Mary in his home state of Virginia. Jack has applied his mathematics knowledge beyond the classroom by forecasting electricity demand with neural networks, designing scheduling algorithms for the US Air Force, and simulating self-driving ride-hailing fleets for his undergraduate thesis. At CEEPR as a Graduate Research Assistant, Jack will be working with Dharik Mallapragada and Christopher Knittel on exploring new ways to incorporate technological and regulatory uncertainty into MITEI's capacity expansion modeling framework. His current project analyzes natural gas stranded asset risk amid the carbon transition with a case study in the US Southeast.

When he is not researching and studying for his Technology & Policy Program classes, you will often find Jack running along the Charles River, strumming his guitar, or playing board games with his brothers.



**Vivienne Zhang**  
Graduate Research Assistant

Vivienne Zhang is a first year master's student studying Technology & Policy at MIT Institute for Data, Systems, and Society. She is interested in applying innovations in data science and software development to help transition to a more sustainable future. Prior to MIT, she worked in the renewable energy industry in San Francisco Bay Area in a variety of functions, including business development, project management, policy design, and financing. She graduated with a BA in environmental economics from Yale University.

As a CEEPR Graduate Research Assistant, Vivienne will be working with Director Christopher Knittel on En-ROADS, a policy simulation model that lets users explore decarbonization strategies, in collaboration with Climate Interactive and the Joint Program on the Science and Policy of Global Change. She would be modeling the economic impacts of accelerated decarbonization scenarios including carbon tax and increased afforestation.



## Recent Working Papers

### WP-2020-019

Going Beyond Default Intensities in an EU Carbon Border Adjustment Mechanism  
Michael A. Mehling and Robert A. Ritz, October 2020

### WP-2020-018

Distributional Effects of Net Metering Policies and Residential Solar Plus Behind-the-meter Storage Adoption  
Andrés Inzunza and Christopher R. Knittel, October 2020

### WP-2020-017

Quantifying the Distributional Impacts of Rooftop Solar PV Adoption Under Net Energy Metering  
Scott P. Burger, Christopher R. Knittel, and Ignacio J. Pérez-Arriaga, September 2020

### WP-2020-016

State Ownership and Technology Adoption: The Case of Electric Utilities and Renewable Energy  
Bjarne Steffen, Valerie J. Karplus, and Tobias S. Schmidt, August 2020

### WP-2020-015

A Multi-control Climate Policy Process for a Designated Decision Maker  
Henri F. Drake, Ronald L. Rivest, Alan Edelman, and John Deutch, July 2020

### WP-2020-014

Abatement Strategies and the Cost of Environmental Regulation: Emission Standards on the European Car Market  
Mathias Reynaert, July 2020

### WP-2020-013

Evolving Bidding Formats and Pricing Schemes in US and Europe Day-Ahead Electricity Markets  
Carlos Batlle, Ignacio Herrero, and Pablo Rodilla, July 2020

### WP-2020-012

Competitive Energy Storage and the Duck Curve  
Richard Schmalensee, July 2020

### WP-2020-011

The Short-run and Long-run Effects of COVID-19 on Energy and the Environment  
Kenneth T. Gillingham, Christopher R. Knittel, Jing Li, Marten Ovaere, and Mar Reguant, July 2020

### WP-2020-010

Electrifying Transportation: Issues and Opportunities  
Bentley C. Clinton, Christopher R. Knittel, Konstantinos Metaxoglou, June 2020

### WP-2020-009

What Does and Does Not Correlate with COVID-19 Death Rates  
Christopher R. Knittel and Bora Ozaltun, June 2020

### WP-2020-008

What We Know and Don't Know About Climate Change, and Implications for Policy  
Robert S. Pindyck, June 2020

### WP-2020-007

The Value of Pumped Hydro Storage for Deep Decarbonization of the Spanish Grid  
Anthony Fratto Oyler and John E. Parsons, May 2020

## The Roosevelt Project Papers

### The Roosevelt Project:

A New Deal for Employment, Energy, and Environment  
Ernest J. Moniz and Michael J. Kearney

Assessing the Role of Public Policy in Industrial Transitions: How Distinct Regional Contexts Inform Comprehensive Planning  
Nina Peluso, Michael J. Kearney, and Richard Lester

### Social Impacts of Energy Transition

Jason W. Beckfield, D. A. Evrad, Robert J. Sampson, and Mary C. Waters

### Distributed Effects of Climate Policy:

A Machine Learning Approach  
Tomas W. Green and Christopher R. Knittel

Building the Energy Infrastructure Necessary for Deep Decarbonization throughout the United States

David Hsu and Darryle Ulama

### Public Attitudes on Energy and the Climate

Stephen Ansolabehere, Elizabeth Thom, and Dustin Tingley

Just Institutions for Deep Decarbonization? Essential Lessons from 20th Century Regional Economic and Industrial Transitions in the United States

Daniel Gallagher and Amy Glasmeier

### Energy Workforce Development in the 21st Century

David Foster, Sade Nabahe, and Benny Siu Hon Ng

### Energy and Manufacturing in the United States

David Foster, Sade Nabahe, and Benny Siu Hon Ng

### Fostering Innovative Growth in

Regions Exposed to Low Carbon Transition

Valerie J. Karplus, Michael J. Kearney, and Sohum Pawar

All listed and referenced working papers in this newsletter are available on our website at [ceep.mit.edu/publications/working-papers](https://ceep.mit.edu/publications/working-papers)



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