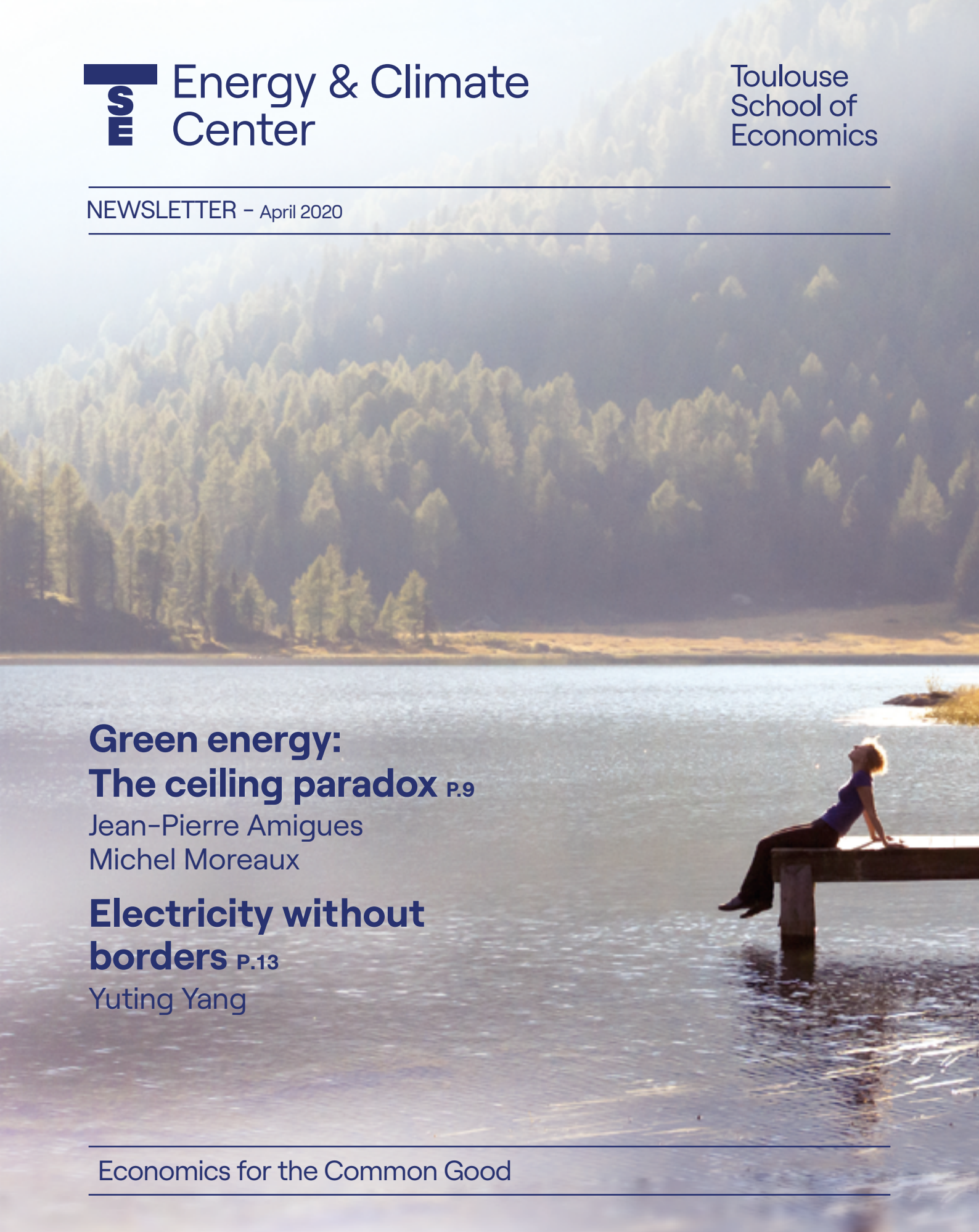
Energy & Climate Center

Toulouse School of Economics

NEWSLETTER – April 2020



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Director's message

Our doors close, but a window opens

Through the suffering, fear and uncertainty wrought by this pandemic, some green shoots of hope are visible. Covid-19 has succeeded where scientists and climate activists had failed: forcing governments to take radical actions in the face of a life-threatening problem. Will this crisis be the wake-up call that we can and must tackle climate change?

At TSE, like people across world, we are adapting to life under new restrictions. We closed our new building, after opening its doors earlier this year. We cancelled the Energy and Climate forum due to be held at the International Energy Agency in Paris on March 23. But our researchers are still hard at work, interacting remotely, developing their analyses to help policymakers manage the green energy transition, and studying the host of new research questions thrown up by the unprecedented developments of recent weeks.

In this newsletter, we feature a portrait of one of TSE's latest crop of promising energy economists, Yuting Yang, who has just secured a position at the University of New Mexico. We are also delighted to showcase her research on the costs and benefits of electricity interconnection in Europe. Meanwhile, established TSE researchers Jean-Pierre Amigues and Michel Moreaux outline the optimal dynamics of energy efficiency, the energy mix and land use in the presence of a cap on atmospheric levels of carbon dioxide.

We must hope that Covid-19 shakes the world out of its complacent approach to other long-ignored health and financial risks. We must hope that fighting the pandemic and its economic fallout will bolster rather than distract from the fight against climate change.

Wishing you good health in these difficult times.

Stefan Ambec
Director, TSE Energy & Climate Center

News

TSE Director Christian Gollier wins the Turgot Prize for the best book on Financial Economics

> ***An original and insightful thinker, Christian expresses his hope as well as his doubts about our ability to meet the climate challenge and proposes concrete economic solutions to preserve the future of all. To avoid catastrophe, we need to start making sacrifices now.***

On March 12, TSE Director Christian Gollier was awarded the 33rd Turgot prize for his latest book ***"Le climat après la fin du mois".*** The prestigious prize giving ceremony took place in Bercy, at the Ministry of Economy and Finance, under the patronage of Bruno Le Maire, Minister of Economy and Finance.

More about the Prize:

Created by the Alumni Association of the Institut de Haute Finance, the Prix Turgot is an annual event that rewards essential contributions to the necessary financial education strategy to raise awareness among fellow citizens of the economic and financial issues and challenges of the modern world. Over the years, the awards ceremony has become the major meeting place for finance professionals: around 500 personalities from the economy, universities, companies, banks and finance take part in it.

An original and insightful thinker, Christian expresses his hope as well as his doubts about our ability to meet the climate challenge and proposes concrete economic solutions to preserve the future of all. To avoid catastrophe, we need to start making sacrifices now.

Ridesharing at Harvard

A PhD student at TSE, Rossi Abi-Rafeh's research focuses on empirical industrial organization. The GEMCLIME project (Global Excellence in Modelling of Climate and Energy) funded his recent research visit at Harvard's economics department.

The research I was conducting at Harvard aims to better understanding the pricing and participation of drivers on the largest global ridesharing platform. Digitally enabled ridesharing has the potential to reduce CO^2 emissions from long-distance car transport by reducing the numbers of cars in circulation. Understanding how passengers and drivers make their choices on the platform is important to guide platform design. The presence of a global dominant platform in this sector is also inviting scrutiny from regulators: inferring drivers' preferences and switching costs is important for regulation and policy.

I am grateful for GEMCLIME's funding. I had the opportunity to present the project at the Department of Economics and the Kennedy School. I could discuss my research with world-class academics – like Ariel Pakes, Edward Glaeser and Jason Furman, whose research agendas influence global policy – and hear their thoughts and advice. My research stay has resulted in a policy paper providing an overview of the economics of long-distance ridesharing; and, in the near future, an academic work-in-progress paper.

GEMCLIME
Global Exchange in Modelling of Climate and Energy

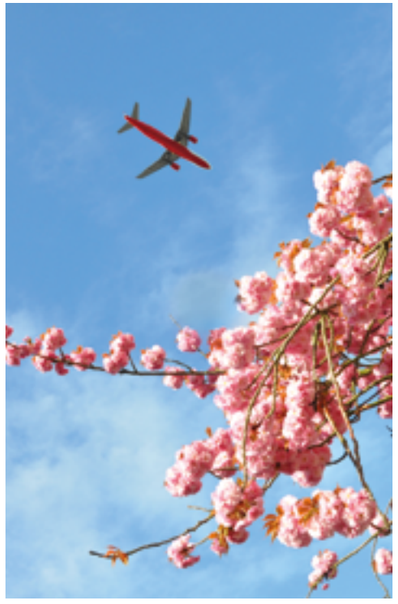
https://www.competitionpolicyinternational.com/ridesharing-platforms-and-the-long-tail-of-mobility/

TSE students to set up free carbon footprint calculator

Last fall, TSE launched its first call for projects aimed at encouraging TSE students and alumni to develop innovative initiatives for the common good. The winning project has been awarded €4,500 to help develop a free online carbon footprint calculator.

Team members (current and former students, William L'Heudé, Anaïs Escanes, Jaime Avila Farrar, Vincent Larrieu, and Tiphaine Gouraud), believe that raising carbon footprint awareness is essential in reducing greenhouse gas emissions. They are convinced their calculator will encourage individuals, businesses and communities to modify their consumption patterns as existing tools are often costly, fragmented, and lacking in methodological transparency. They say the calculator is a first step in a larger project to organize a mechanism for voluntary carbon offsetting by those who wish to fund eco-friendly projects in France.

plateforme.carbone@gmail.com



Portrait

From the classroom to the job market to the real world.

Recently graduated from TSE, one of our alumni speaks to us about her new roles and her experience as TSE student.

Yuting Yang

Energy economist at University of New Mexico speaks to us about her stay at TSE and how it prepared her for a career in academia.

She followed the environmental and energy economics track at TSE and today concentrates on the impact of electricity interconnection on the transition towards a low-carbon energy sector.

What can you tell us about your recent research?

I look at whether expanding cross-country or regional electricity transmission can help foster renewable investment and reduce carbon emissions.

What are the policy tools that governments can use to ensure lower emissions?

Depending on the level of the carbon tax, I find that expanding electricity interconnection may lead to lowered renewable investment and increased emissions because trade may dampen the competitiveness of renewable power. To avoid the adverse impact on the environment, when and where to put the interconnection becomes crucial.

Reducing carbon emissions has been center stage in efforts to mitigate climate change. The main goal is to decarbonize the energy sector. With the continuous reduction in the cost of wind turbines and solar panels, it seems that we could achieve a future of zero-carbon emissions. I am interested to understand what are the necessary steps the world needs to take to achieve this goal, and what are the challenges and obstacles we need to watch out for along the way.

What attracted you to your new role?

I will be starting a tenure-track position at the Economics Department of the University of New Mexico next fall. I have been hired as an Energy economist, in collaboration with the EPSCoR New Mexico SMART grid project. Therefore, apart from the regular duties as an economics professor to teach classes and do research, I will be involved directly with the state-wide project to design and implement distributed micro-grids in the neighborhoods where they would reduce carbon emissions from energy use and increase climate resiliency. This is why I was attracted to this position. I will be collaborating with a group of engineers, physicists, computer scientists, and economists to carry out this project. It will be a great learning opportunity for me and, hopefully, I will be able to contribute what I know to the community.

I hope I will be able to transfer the knowledge that I have accumulated over the years to my students. Meanwhile, I will continue to collaborate with other researchers and produce quality output that can, hopefully, guide policymaking in fighting climate change.

How has your time at TSE prepared you for your new role?

My time at TSE has prepared me for a career in academia in many aspects. First and foremost, I have learned to do rigorous research both independently and in collaboration with other researchers. Secondly, TSE has trained me to communicate my research confidently. The many opportunities for PhD students to present our work (workshops, seminars, and conferences) and interact with researchers have gradually shaped us to be better presenters over time. Thirdly, TSE has always supported the academic exchange beyond its walls, which helped me build a research network. For example, I was financed by the GEMCLIME mobility grant to visit the University of California, Santa Barbara in spring 2019.

The three-month visit gave me the opportunity to experience research life in the US first-hand. I was able to interact closely with the local researchers, present my work and receive valuable feedback from them. Having this close interaction also benefited me on the academic job market.

Do you have any reflections on the role of economists in these challenging times?

There is a disheartening expression on the internet these days saying that "COVID-19 is the earth's vaccine against the virus of humans". We have seen staggering evidence that across the globe, due to the lockdown measures of many countries and the huge reduction in economic activities, pollution has been declining, water has become clear, and wildlife has come wandering into places where it had never been seen before. This devastating time has painted a picture of what the Earth would be like without us and provided causal evidence on how human activities have damaged the natural environment.

Moreover, this pandemic has made us realize vividly how connected the world is and how every individual is an organic part of society. Although the disease started in one city in China, it quickly spread and escalated to all parts of the world within two months. We have seen from the Asian countries that in order to effectively contain the spread, we need quick responses from the government, citizens should be responsible and practice strict social distancing, and we need countries to help each other in terms of medical supplies and experience. This is not a time to be politically divided between governments or for individuals to rely on the action of the states and not hold themselves responsible.

This pandemic should be considered as an early warning for climate change. Governments need to know that they cannot free-ride on other countries' commitments to cut emissions. All individuals should bear in mind the externality of their actions on the environment. We cannot afford to delay action until it's too late.

Do you have any career advice for future TSE students?

We always knew that the job market is tough, more so for some than others. Be confident and apply for jobs that you are passionate about. Not only will this keep you motivated through the ups and downs of the market, more importantly, your passion can really influence how others perceive you and your work.

TSE offers great training and support for its students. Former PhD students can also offer valuable support. I was lucky enough to receive a grant funded by a group of Chinese alumni for my final year as a PhD student. You should always make use of the opportunities and never hesitate to ask for help.

Research highlights

Green energy: The ceiling paradox

Jean-Pierre Amigues and Michel Moreaux

The fight against climate change will require strategic decisions about renewables and fossil fuels, adjusting the balance of investment and improving output. In a recent paper, TSE researchers Jean-Pierre Amigues and Michel Moreaux outline the optimal dynamics of energy efficiency, the energy mix and land use in the presence of a cap on atmospheric levels of carbon dioxide.

The green transition requires significant improvements in conversion rates of primary energy into ready-to-use energy and progressive substitution of fossil fuels by carbon-free energy. In most cases, land is needed to capture solar radiation, which implies competition for land use: developing green energy may require allocating more sunshine to energy production and less to food production. Furthermore, given that atmospheric pollution must be limited, the urgency of the need for substitution and/or conversion-rate improvements evolves through time.

Dynamics of conversion rates

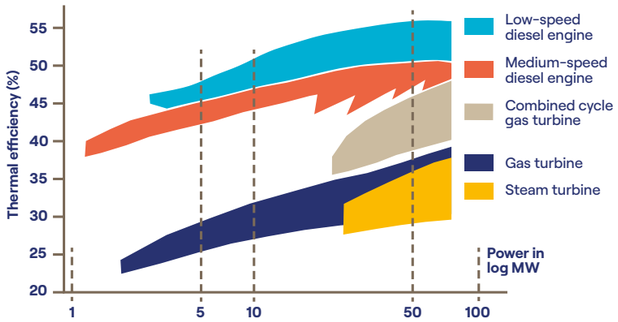
Any conversion of energy into another form implies a loss, as expressed in the Second Law of Thermodynamics. Conversion rates of primary energy into useful energy – that is, the thermal efficiency of energy converters – have increased spectacularly since the beginning of the 18th century. Similar increases are recorded for the conversion of solar radiation into useful energy, from solar-cell efficiency to the productivity of land in generating biofuels.

In agriculture, the relevant metric is how solar radiation can be converted into useful biomass and how biomass can be converted into food and energy sources. Because the average solar radiation received per unit of land surface can be taken as roughly constant, an index of the thermal efficiency of the transformation is the output per surface unit.

Technical progress is generally seen as the driving force of these improvements in thermal-efficiency rates, but Jean-Pierre and Michel note that efficiency rates are also an economic choice resulting from substitution decisions about inputs. More thermally efficient energy converters are also generally more costly. The researchers'

Energy efficiency

The thermal efficiency of energy converters has increased spectacularly since the beginning of the 18th century.
Source: Smil V. (2010)



The power ratings and conversion efficiencies of steam engines, Otto-cycles gasoline engines, steam turbines, combined cycle gas turbines and medium and low speed diesel engines (Based on a figure in Aabo 2007)

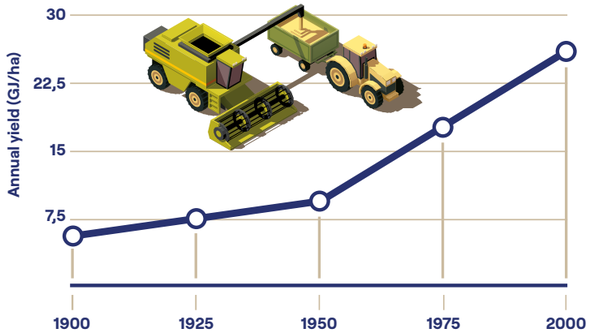
aim is to determine the dynamics of thermal-efficiency rates resulting from substitutions, absent any technical progress.

Land use and fossil-fuel competition

Choices about energy conversion rates cannot be separated from those about the energy mix. If fossil fuels become more expensive, firms have an incentive to improve the conversion rate for fossil fuels and to increase the share of renewables, which requires a shift in land use. Thus, the long road to a green economy is also a path of land reallocation between food production and useful energy production, together with a reallocation of useful energy production between non-renewable and renewable primary sources.

Food productivity

Trends of agricultural yields (world scale). *Source: Smil V. (2008), compiled from UN FAO statistical yearbooks*



Empirical and theoretical analyses suggest that the expansion of bio-fuels production has a positive effect on food prices. Food and energy production also have direct impacts on deforestation and the value of forest lands, and the induced wood production contributes temporarily to the renewable energy supply.

CO2 pollution

To reduce carbon dioxide pollution, adoption of more efficient techniques for using fossil fuels competes with substitution by clean, renewable resources. Jean-Pierre and Michel consider the empirically relevant situation in which fossil fuels are so abundant that the economy will be eventually constrained by a cap on atmospheric carbon levels. In contrast with climate models in the 'carbon budget' style, the researchers explicitly introduce the natural transfer of carbon from the atmosphere into the oceans and soils as a self-regenerating capacity of the environment determining the dynamics of the pollution stock together with emission flow. They assess not only the qualitative evolutions of the model's economic variables, but also the optimal timing of energy transition and the optimal period for the carbon cap.

To simplify the model, Jean-Pierre and Michel aggregate energy-conversion activities by households and industries into one energy transformation sector using renewable and non-renewable sources. For each primary source, the transformation sector optimizes its conversion techniques to adapt to the dynamics of environmental regulation and the economic conditions for producing primary resources. The fossil-fuel price and the social cost of carbon are determined endogenously together with the optimal dynamics of thermal efficiencies. The researchers postulate stock-dependent extraction costs of the fossil fuel and show how the part of the fossil-fuel endowment left forever underground – "the unburned fossil-fuel stock" – is also endogenously determined.

> ***Technical progress is generally seen as the driving force of the spectacular improvements in thermal-efficiency rates, but efficiency rates are also an economic choice resulting from substitution decisions about inputs.***

Main results

The energy transition is a sequence of three time phases. During a first phase, the economy accumulates carbon until it faces the cap constraint. Then the cap binds, implying a constant rate of fossil-fuel extraction. As fossil fuels are exhaustible, there must exist some time when, even without a carbon constraint, the economy would choose to extract fossil fuels at a lower rate than the cap. Thus, the economy escapes from the cap and enters an unconstrained phase until the end of fossil-fuel exploitation – that is, the ultimate green economy in which all energy and food is from renewable sources. Before the constrained period, the shadow cost of carbon rises; it then decreases during the constrained phase, falling to zero at the end of the phase and forever after.

During the unconstrained phases, the useful energy price rises together with the fossil-fuel conversion rate into useful energy. When renewable energy is produced jointly with non-renewable energy, its conversion rate also rises

> ***The long road to a green economy is also a path of land reallocation between food production and useful energy production, together with a reallocation of useful energy production between non-renewable and renewable primary sources.***

and it takes an increasing share of the energy mix. Land use devoted to renewable energy expands at the expense of land use for food production, and land rent increases. The food sector reacts by increasing its productivity, although not enough to prevent the decline of the food-production rate and thus the rise of the food price. Such findings are in line with existing studies of land-use competition between food and biofuel production. Jean-Pierre and Michel strengthen these conclusions by showing that even if the food sector can improve its productivity, food supply should still decrease.

A novel feature of Jean-Pierre and Michel's model is that the optimal carbon price path fully internalizes the potentially adverse impacts of climate regulation on food-delivery conditions in a dynamic setting. However, full internalization does not qualitatively alter the conclusion of a positive effect of carbon regulation on food prices. A high degree of substitutability between biofuels and fossil fuels magnifies this impact; a point they emphasize by showing that, with imperfect substitution possibilities, the impact of carbon pricing on food production could be lower.

During the constrained phase, the exploitation rate of fossil fuels must stay constant. This induces a constant price of useful energy and constant energy-conversion rates. This constancy implies that land sharing between renewable energy production and food production also remains constant, together with the land rent. The food-production sector then maintains constant levels of productivity and food prices. Jean-Pierre and Michel call this phenomenon the 'ceiling efficiency paradox' because, in the period in which the cap is most pressing, the economy optimally refrains from further efforts to mitigate the effects of the cap through better fossil-fuel energy conversion or more renewable energy production.

This rather striking conclusion is a direct product of Jean-Pierre and Michel's distinctive approach to energy-efficiency gains. In their model, the energy-production sectors do not benefit from technical progress in the form of cost reductions per unit of useful energy, but they can improve their energy-conversion performance through costly efforts. The researchers show that when faced with a climate policy aimed at stabilizing carbon emissions, the energy industry determines its energy-conversion strategy by solving a time-independent static optimization problem, resulting in time-independent stationary energy-conversion rates. This time stationarity extends to the land sharing between food production and renewable energy production, in turn stabilizing food-delivery conditions.

Summing up

Jean-Pierre and Michel examine the optimal dynamics of energy efficiency, the balance of renewables and non-renewables, and land use when atmospheric carbon levels are capped. They demonstrate that the first-best solution can be reached through a carbon-pricing scheme that adds the shadow cost of carbon to the ready-to-use energy price. Their analysis shows that the carbon price should rise before the carbon cap is reached. However, during the ceiling period, the carbon price must decline to keep the net surplus from fossil-fuel exploitation constant, just balancing the rise of the full marginal cost of extracted fossil fuels, the sum of their extraction cost and mining rent.

Energy and food prices are positively correlated because of competition for land. Introducing a carbon price will raise the food price and reduce the food supply when both oil and solar energy are supplied. As the carbon price increases the competitiveness of solar energy with respect to fossil fuels, this also increases the comparative advantage of solar energy production over food production in terms of land valuation.

Further reading

See 'Competing land uses and fossil fuel, and optimal energy conversion rates during the transition toward a green economy under a pollution stock constraint' and other research by Jean-Pierre and Michel at ***www.tse-fr.eu.***

In a similar setting, their 2018 paper *'Converting primary resources into useful energy: the pollution ceiling efficiency paradox'* shows contrasting effects of technical progress when applied either to fossil or renewable energy generation.

Electricity without borders

Yuting Yang

International exchange of electricity can improve the efficiency of electricity production and accommodate the use of intermittent renewables, such as wind and solar power. But a new paper by TSE PhD student Yuting Yang warns that, without a higher social cost of carbon, efforts to expand electricity interconnection may be harmful to the environment.

Renewable energy plays an essential role in decarbonizing the power sector. The International Energy Agency (IEA) projects that global renewable capacity will grow by over 50% by 2023. Intermittent energy sources that depend on weather conditions account for more than 80% of this growth. Intermittency imposes risks on the power system, which must instantaneously balance supply and demand at all times. Electricity interconnection, or cross-border transmission, is recognized as one of the solutions to this issue.

Trading benefits

Interconnection has several established benefits. First, international trade in electricity production harnesses varying comparative advantages across countries, which can lower prices to consumers through improved production efficiency.

Second, trade can facilitate the penetration of renewables to regions with insufficient renewable resources or technology, enhancing the potential to lower carbon dioxide emissions. A third benefit that is unique to electricity trading, especially in the case of uncertainty associated with renewable production, is insurance against local supply shocks. In particular, interconnection can serve as a backup for renewables with the importation of controllable thermal energy sources (such as coal or gas), or it can utilize the imperfect correlation of renewable production across space.

Sector specific electricity retail prices

Unit	Sector	Annual average retail price			
		FR	ES	PL	DE
€/MWh	Household	169.8	223.5	134.2	297.3
	Non-household	111	129.1	99.8	196.6

These potential benefits have led governments to expand electricity interconnection. The European Commission is implementing a policy to increase electricity interconnection from the current level of less than 10% of the total installed capacity to 15% by 2030. China, Japan, South Korea, Russia, and Mongolia have also been working together to construct the Asia Super Grid (ASG), which would utilize the abundant renewable resources in Mongolia and drastically reduce carbon emissions. How will these projects affect the adoption of green technologies and investment in capacity? More importantly, can interconnection policies always deliver positive outcomes in response to climate change?

Two-country model: Clean and Dirty

To answer this question, Yuting constructs a two-country model of optimal electricity production with renewable intermittency and trade. Each country can be either a Clean type (that has both fully controllable thermal and intermittent renewable technology) or a Dirty type (that has only thermal technology). The countries coordinate by choosing their consumption levels, installed capacities, and state-dependent output levels and trade quantities so their joint social welfare is maximized. This model captures all of the interconnection benefits and allows Yuting to identify additional tradeoffs regarding renewable capacity and carbon emissions.

> ***How will electricity interconnection affect the adoption of green technologies and investment in capacity? More importantly, can interconnection policies always deliver positive outcomes in response to climate change?***

Yuting first considers the case in which a Dirty country has an absolute advantage in thermal production over a Clean country. In this scenario, expanding interconnection has ambiguous effects on carbon emissions, depending on the level of the social cost of carbon (SCC). If the SCC is low (high), interconnection exacerbates (reduces) carbon emissions. Transmission is a two-way street and facilitates not only renewable diffusion when the wind is blowing, or the sun is shining, but also the dispersion of cheaper thermal production when generation backup is needed. With a low SCC, interconnection gives the Clean country access to a lower-cost thermal technology, decreasing its adoption of renewables (reverse technique effect). In addition, consumption in the Clean country increases, because of the cheaper backup thermal energy (scale effect). Both the scale and the reverse technique effect push emissions upward. However, with a high SCC, interconnection expands the market of the Clean country's renewables, which are now less costly than thermal energy (technique effect). The technique effect and scale effect take opposite directions, and depending on which effect dominates, emissions can increase or decrease.

If both countries are the Clean type and differ only in the occurrence of the intermittent states, renewable curtailment (i.e., having idle renewable capacity or disposing of renewable-generated electricity) may be optimal in some states. Interconnection kicks in as insurance against intermittency when the wind in one country dies. For a country to export electricity, it must have a renewable capacity exceeding local demand. This excess supply becomes idle when the wind is blowing in both countries. The more positively correlated the occurrence of the two countries' windy states, the more likely some capacity stays idle and the higher the carbon emissions. Therefore, not allowing for curtailment reduces the capacity that can be installed, undermining any insurance motive of interconnection, and trade will not take place.

European simulations

To quantify the scale of the effect from the theoretical model, Yuting simulates the Germany-Poland (DE-PL) and France-Spain (FR-ES) interconnections to represent the Clean-Dirty and Clean-Clean case, respectively. For the FR-ES interconnection, she also simulates FR wind-ES wind and FR wind-ES solar separately, to explore the effect of intermittency correlation. The four countries represent four distinctive energy profiles: Germany has various types of coal and renewables; Poland is predominantly powered by coal; France has over 70% nuclear with gas and wind power; and Spain has a mix of nuclear, thermal, and renewables. The four countries are also geographically connected and have existing transmission lines in use. Therefore, understanding the impact of existing transmission capacity is important in the representative European Union (EU) context. Moreover, the simulation results can be generalized to any country or region with a similar energy profile.

Simulation results show that achieving the EU's 2030 interconnection target under an SCC of €45 per ton of CO^2 increases annual emissions by 1.69% in the DE-PL case, by 1.74% in the FR wind-ES wind case, and reduces emissions by 7.18% in the FR wind-ES solar case, all in comparison with the status quo. Compared to the binding target of cutting emissions by 43% in the EU power sector by 2030, interconnection can contribute a range from -5% to 23% of the target.

> ***Transmission is a two-way street and facilitates not only renewable diffusion when the wind is blowing, or the sun is shining, but also the dispersion of cheaper thermal production when generation backup is needed.***

Benefit-cost analysis

By conducting a benefit-cost analysis for expanding interconnection capacities, Yuting shows that although transmission lines require a high upfront investment, the lifetime benefit outweighs the cost. However, the net benefit is unevenly distributed across countries. For instance, in the DE-PL case, Germany obtains 100% of the net gain from a 5300 MW interconnection and Poland acquires none. The net importer (Germany) captures all the net benefit because of its increased consumer surplus and avoided investment cost of wind capacity.

This uneven distribution could shed light on how the interconnection investment cost should be shared. Currently in the EU, interconnection investments are shared between the interconnected countries and the European Commission. For example, the Biscay Gulf project between France and Spain receives €578 million from the EU, for an estimated cost of €1.7 billion.

Future research

The optimal capacities, production, and consumption characterized in Yuting's model can be decentralized as a competitive market equilibrium if there is a global Pigouvian carbon tax equal to the SCC. Although a direct carbon tax is most efficient, the public has been reluctant to accept a direct tax.

Therefore, most countries and regions including the EU and China are implementing revenue-neutral policies, such as the emissions trading scheme.

Her model framework can also be adapted to consider other carbon policy instruments, such as cap-and-trade, renewable portfolio standard, and feed-in-tariffs for renewables.

In many cases, interconnected countries and regions may adopt different carbon policies. For example, California implements stringent cap-and-trade programs, whereas its neighboring states adopt few carbon policies. Since California is the largest electricity importer of all of the US states, the externality from the uncontrolled emissions of other states may decrease the social welfare of California. Future research is needed to investigate how interconnection with heterogeneous carbon policies affects total emissions.

Benefit-cost analysis of electricity interconnection

	5300MW	**DE** share	**PL** share
Benefit (B€)	57.78	100%	0%
Cost (B€)	0.966		
Benefit-cost ratio	59.77		

	FR wind - **ES** wind			**FR** wind - **ES** solar		
	10 700MW	**FR** share	**ES** share	10 700MW	**FR** share	**ES** share
Benefit (B€)	21.83	97.31%	2.72%	34.28	78.82%	21.24%
Cost (B€)	12.53			12.53		
Benefit-cost ratio	1.74			2.74		

The table shows the results of Yuting's benefit-cost analysis for achieving the EU target to raise interconnection from less than 10% of total capacity to 15% by 2030. The four countries in her simulation represent distinctive energy profiles: Germany has various types of coal and renewables; Poland is predominantly powered by coal; France has over 70% nuclear with gas and wind power; and Spain has a mix of nuclear, thermal, and renewables.

Summing up

Decarbonization requires alternatives to thermal power. Electricity interconnection can smooth the spatial intermittency of renewable production and make more efficient use of available technologies. However, Yuting's theoretical model shows that interconnection does not always lead to more renewables or lower emissions, unless the SCC is sufficiently high. Interconnection benefits whichever is the more efficient technology: renewables or thermal power. At low carbon prices, thermal power is more competitive than renewables; therefore, renewable capacity decreases.

Similarly, Yuting's simulations show that achieving the EU 2030 interconnection targets may increase carbon emissions. This is because countries have different energy taxes. Interconnection allows countries like Germany with very high domestic electricity taxes to buy cheaper electricity. Consequently, Germany may increase its consumption and reduce investments in renewable capacity, leading to more carbon emissions.

From a welfare perspective, Yuting's benefit-cost analysis suggests a positive net-benefit from interconnection. But the interconnected countries do not share the net-benefit equally. Her research sheds valuable light on where investment should be targeted and how the cost should be split between countries.

Further reading

Read *'Electricity Interconnection with Intermittent Renewables'* and other research by Yuting Yang at: *www.tse-fr.eu.*

Her paper builds on the existing theoretical literature on electricity production with intermittent renewables, developed in particular by fellow TSE researchers **Stefan Ambec** and **Claude Crampes**.

Outreach

Recent events

Energy workshop
Madrid, January 28, 2020

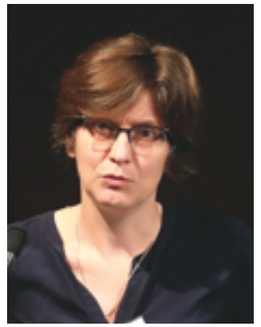
Organized by Natalia Fabra, the Madrid workshop gathered energy economists from TSE as well as associate faculties. Nine papers were presented covering various topics on energy and climate.

• **Estelle Cantillon** *(Université Libre de Bruxelles)* kicked off the day with the presentation of her paper entitled ***"What is Price Discovery Achieving in the New Zealand Electricity Market?"*** (joint work with Stefan Bergheimer and Mar Reguant). The goal of the paper is to assess the efficiency of the pre-dispatch period in the New Zealand power market. They find that the pre-dispatch market before the market price setting performs its information role. The main concern was the lack of commitment from the market participants. Second, they observe that the price goes up on average over the course of the pre-dispatch.

• **Stefan Lamp** *(TSE)* presented his work ***"(Mis)allocation of Renewable Energy Sources"*** (joint work with Mario Samano). The paper aims to measure the marginal benefits of renewable energy sources (RES) and compare them with Feed-in-Tariff (FIT). Is the allocation of solar production optimal? Using a rich dataset for Germany, they find a heterogeneity of the marginal valuation for solar PV and measure the cost of misallocation of RES due to FIT. They also elaborate on the role of transmission constraint in reallocating solar PV.

• **Natalia Fabra** *(University Carlos III of Madrid)* introduced her study ***"Technology Neutral versus Technology Specific Regulation"*** (joint work with Juan Pablo Montero). The paper aims to better understand the procurement of heterogeneous technologies: should they be procured through technology-specific or technology-neutral auction? What are the trade-offs involved? They also document a hybrid case (technology-banding). They find that a regulator with strong concerns about rent should use a technology-specific auction while a regulator concerned about cost efficiency should favor a technology-neutral auction. .

• **David Andres** *(European University Institute)* presented ***"Storing Power: Market Structure Matters"*** (joint work with Natalia Fabra). The goal of the paper is to analyze whether investment in storage is socially optimal and if it is dependent on market structure. It also aims to better understand decentralized storage operation and its impact on market outcomes. They find that the market does not provide adequate investment incentives in storage capacity: market power in generation leads to over-investment while market power in storage to underinvestment. They also highlight that vertical integration between storage and generation yields the most inefficient outcome. Storage also reduces the ability to exercise market power in generation, conditional on its being independently owned.



Estelle Cantillon (ULB)

Stefan Lamp (TSE)

Natalia Fabra (UC3M)

Davis Andres (EUI)

First Electrification Summit

Paris, October 16 - 17, 2019

Organized by EDF and the US Electric Power Research Institute (EPRI), the first Electrification Summit offered a unique opportunity to understand how electrification can transform the global energy landscape while contributing to international climate-change goals. The event gathered leaders in the field of electrification, experts in research and development, economists and decision-makers.

Senior TSE researcher Claude Crampes is an expert in network economics, industrial organization and the economics of intellectual property. In his keynote lecture, Claude highlighted that electrification has necessitated the building of continental-sized networks. He stresses, however, that a lot still needs to be done on the electricity-storage front.

> ***The very existence of the electric grid is the recognition of a technological failure: 150 years after the beginning of the electric era, we do not know yet how to store electric energy.***
>
> Claude Crampes - TSE

Analysis

Debates

TSE Debate is a portal that gathers the opinions and analysis of TSE researchers on topics of public interest such as electric cars, the European carbon market, and renewable energy. Members of the center regularly publish blog posts and newspaper op-eds that can be consulted in TSE Debate's "Energy" section. Here we feature some of the recent posts.

The cost of avoiding the carbon tax with standards

Stefan Ambec and Claude Crampes - March 31, 2020

The French's Convention Citoyenne pour le Climat reveals hostility to the carbon tax and a craze for technological standards. Carbon tax and technological standards are two levers of technical progress. Each has pros and cons that are worth recalling.

The costs of nuclear phase-out in Germany

Stefan Ambec and Claude Crampes - February 19, 2020

The decision to shut down eight nuclear reactors in the year following the Fukushima disaster contributed to higher electricity prices in Germany. It also led to the partial replacement of nuclear generation by electricity generated from coal, lignite and gas, and thus to an increase in CO^2 emissions and local pollution, the health effects of which have not been considered.

Will fertility be discussed at COP25?

Stefan Ambec and Claude Crampes - December 09, 2019

While our responsibility for global warming is no longer denied by anyone except for an (unfortunately powerful) minority of individuals, the means to mobilize in order to tackle it are far from unanimously accepted, particularly when it comes to reducing the birth rate.

Green electricity tinged with gray

Stefan Ambec and Claude Crampes - November 15, 2019

Do you want to reduce your carbon footprint and promote the transition to a low-carbon economy? Electricity suppliers have the product that meets your needs: green electricity.

Service priority in the electrical industry

Claude Crampes and Yassine Lefouili - October 03, 2019

Meeting demand is a requirement in every electricity system in developed countries. But it has a very high cost because the non-storability of electricity requires the installation of large production capacities, some of which are rarely used. Why not introduce supply cuts based on consumers' willingness to pay?

Interviews

- **Climat : les Européens prêts à des efforts, mais sans dépenser plus**
  Christian Gollier - La Croix, March 9, 2020
- **Grand angle : le rêve américain des économistes français**
  Christian Gollier - TV5 Monde, February 24, 2020
- **Les politiciens cachent à l'opinion publique les vrais coûts de la transition écologique**
  Christian Gollier - La Libre Belgique, February 23, 2020
- **Les compagnies aériennes face au défi de "la honte de voler"**
  Estelle Malavolti - La Croix, January 23, 2020
- **Grand témoin : L'économiste Christian Gollier favorable à un prix universel du carbone**
  Christian Gollier - Le Figaro, December 8, 2019
- **Transition énergétique : et le charbon alors ?**
  Christian Gollier - Autoactu, December 5, 2019
- **Un prix universel du carbone, la recette d'un économiste face au changement climatique**
  Christian Gollier - AFP, December 3, 2019
- **Un optimisme (très) prudent**
  Stefan Ambec - La Gazette du Midi, December 2, 2019
- **Le prix du carbone a une place centrale dans la transition environnementale**
  Christian Gollier - Le Monde, December 1, 2019

Articles

- **TSE : vers un Freespace climatique** | D'A.D'Architecture March 2020
- **France Closing Its Oldest Nuclear Plant Spurs Debate on Energy** | Bloomberg, February 22, 2020
- **Arrêt de centrales et perception du risque** | Le Monde, February 21, 2020
- **Les coûts de la sortie du nucléaire en Allemagne** | La Tribune, February 19, 2020
- **Faire payer les Chinois pollueurs : est-ce réaliste ?** | Capital, January 21, 2020

Energy & Climate Center

Toulouse School of Economics

The TSE centers showcase the research and other academic activities at TSE in a thematic area. The three existing centers are the Digital Center, the Sustainable Finance Center and the Energy & Climate Center.

These centers are created around wide, overarching topics with the scope to cover a range of industrial and policy issues affecting society at all levels.

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Publication director: Stefan Ambec
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Editorial contributions: James Nash
Graphic design and layout: Olivier Colombe
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Toulouse School of Economics
1, Esplanade de l'Université
31080 Toulouse Cedex 06
Tel: +33 (0)5 67 73 27 68
partnership@tse-fr.eu