ENERDAY
15th Conference on Energy Economics and Technology
"Creative Destruction?
Disruptive innovation in times of Covid and an accelerated energy system transformation"

Book of Abstracts

9th April 2021
Dresden

Contact
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50Hertz operates the electricity transmission system in the north and east of Germany, which it expands as needed for the energy transition. Our extra high voltage grid has an electrical circuit length of about 10,490 kilometres, or the distance between Berlin and Rio de Janeiro. The 50Hertz control area covers the Länder of Brandenburg, Mecklenburg-Western Pomerania, Saxony, Saxony-Anhalt, and Thuringia, as well as the city states of Berlin and Hamburg. Within these regions, 50Hertz and its 1,300 employees ensure that 18 million people are supplied with electricity around the clock. 50Hertz is a forerunner in the field of secure integration of renewable energy: in our grid area, more than 60 percent of the consumed electricity is already generated from renewable sources; by 2032, it is our goal to securely integrate 100 percent. The shareholders of 50Hertz are the Belgian holding Elia Group (80 percent), which is listed on the stock exchange, and the KfW bank group with 20 percent. As a European TSO, 50Hertz is a member of the European Network of Transmission System Operators for Electricity (ENTSO-E).

Foreword

Dear participants of the 15th ENERDAY Conference on Energy Economics and Technology,

this year, we decided to organize the 15th ENERDAY as digital conference due to the current Covid situation. On behalf of the Chair of Energy Economics (EE2) at the Technische Universität Dresden and the Workgroup for Economic and Infrastructure Policy (WIP) at Berlin Institute of Technology (TU Berlin), it is our pleasure to welcome you to this digital edition of the ENERDAY, the 15th Conference on Energy Economics and Technology, with this year's focus on "Creative Destruction? - Disruptive innovation in times of Covid and an accelerated energy system transformation".

The energy system transformation in Germany, Europe, and worldwide is undergoing unprecedented macro- and microeconomic and technical challenges, in times of Covid-19 and increasingly ambitious decarbonization targets. Covid-19 has exacted a significant human and economic cost while energy markets and the system as a whole have experienced the impact of policy measures adopted to combat the outbreak. While dips in electricity consumption and carbon emissions seem to be short-term in nature, the consequences of the public health crisis could well have an impact on the long-term trajectory of the energy system, especially in the context of decarbonisation efforts. In the context of economic stimulus packages, significant potential exists for the targeted deployment of investments toward the acceleration of the transformation of the economy towards carbon neutrality.
Against this backdrop, it is important to renew and deepen discussions on overarching issues and challenges associated with deep decarbonisation pathways, e.g., security of supply in the face of nuclear and coal power phase-outs and the role of disruptive technologies such as hydrogen as a means of scaling decarbonisation in the heating and transportation sectors. Last but not least, new climate policy measures merit particular attention and their sufficiency in reaching carbon targets in Germany, Europe, and globally.

- What are the key challenges? Which steps are necessary? What scenarios should be expected?
- What energy policy measures and strategies need to be taken to put Europe on track to reach the policy goals set for 2030 and beyond?
- How can decarbonisation policies in non-ETS sectors, e.g. heating, transport, be effectively implemented?

The 15th Conference on Energy Economics and Technology ("ENERDAY") provides this year a digital platform for discussing the pressing issues surrounding energy systems, markets and policies, with a special focus on the next steps beyond Covid and towards an accelerated energy system transformation. Empirical analysis, fundamental modelling approaches, best practice examples and evaluations of policy and market design are of particular interest. A special emphasis is placed on intensifying dialogue on techno-economic issues and perspectives. It is our wish that this year's ENERDAY will provide a platform for strengthening the dialogue between those involved in economic and technical fields as well as serving to bridge the gap between practice and theory.

Scientific cooperation partners include the GEE, the German Chapter of the International Association of Energy Economics (IAEE). It is our pleasure to express our sincere gratitude to our premium supporters of this conference: 50Hertz Transmission GmbH, one of the four German transmission grid operators and SachsenEnergie AG, the regional performance leader in the energy industry in Saxony.
As the organizers of the conference, we have been delighted by the high level of interest shown by the research community, which is reflected in the internationality of the participants and the number of submitted abstracts. We hope you enjoy the program and high quality of the research presented. We would like to thank all speakers for their contributions and the participants of the workshop for their attendance.

We wish you an interesting and enriching digital conference and fruitful discussions in this online format,

Dominik Möst and Christian von Hirschhausen
& EE2 organizing committee

Instructions for joining and participating in the online conference

Main Conference Room in Zoom

This year's conference is organized as a digital conference.

The conference is being held via the video conference software Zoom. It is recommended to download the software / app. For a seamless experience, it is recommended that you use the latest desktop version of Zoom (https://zoom.us/download).

You can enter the conference and keynote speeches as well as parallel session by clicking this link https://tu-dresden.zoom.us/j/86212114942 and entering the password!

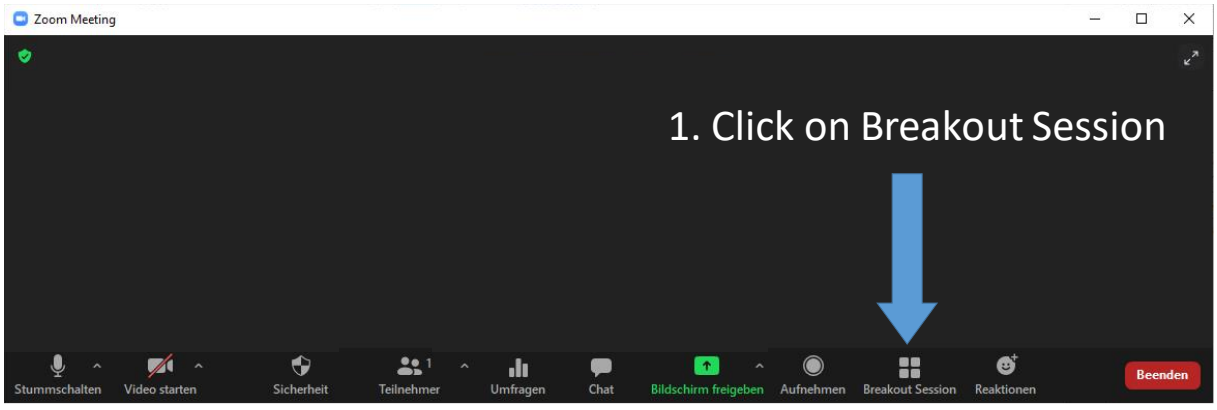
A **password** is required to enter the conference system! You must register to the conference to receive the password!

The password will be sent to registered participants at the latest on 8th April 2021.

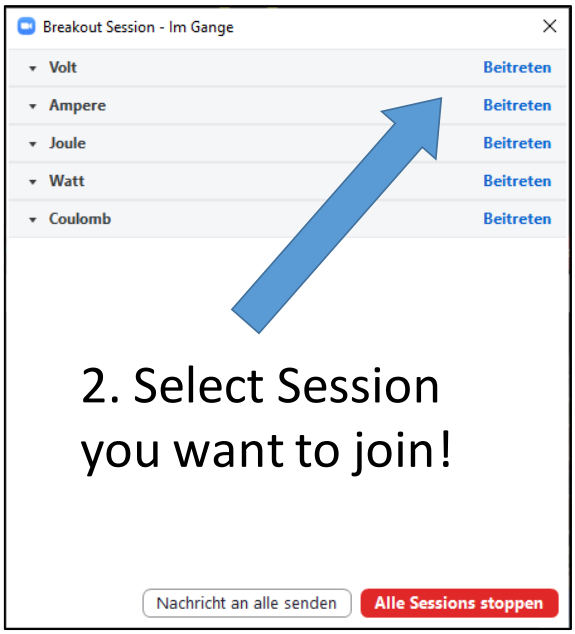
Parallel sessions will be organized as breakout rooms, accessible via the above-mentioned link.

To participate in the sessions, please enter one of the five breakout rooms:

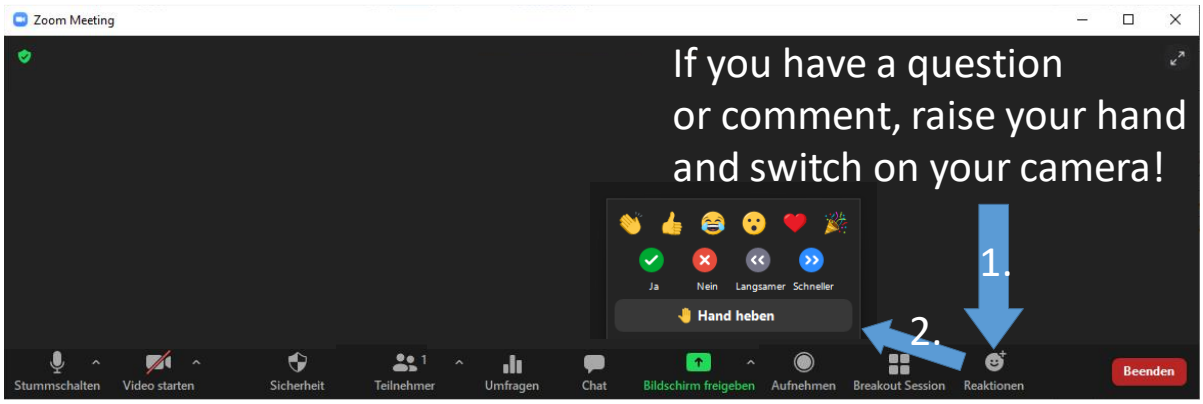
- Volt
- Ampere
- Joule
- Watt
- Coulomb



Select the session you would like to join. You can switch from one session to another, but we recommend remaining in one session for its duration.



To ask a question or offer a comment, please raise your hand and wait to be prompted by the chair before switching on your camera. If you prefer to submit a question to be read aloud, you can use the chat function. The session chair will moderate the sequence between the discussant and Q&A.



If a session closes and you would like to carry on the discussion, please use the spatial chat (see below) to engage with speakers and other conference participants.

Virtual coffee breaks and individual exchange in Spatial chat

In order to enable discussion and dialogue between conference participants, as is the custom during coffee breaks at conferences, the platform spatial chat is being made available during the conference. Especially, the break in the afternoon after the keynote speech, but also the time before the conference begins can be used to engage with conference participants via the platform. Furthermore, spatial chat can be used if a session closes and you would like to carry on the discussion.

In spatial chat space, each person is represented by a circle with your face via webcam. You can move your circle/avatar toward others visible in the space. Depending on the distance on the screen to other persons, the conversations will become audible. You can only speak to persons your circle/avatar is close to.

Use the following link to enter the spatial chat conference space:

https://spatial.chat/s/enerday

Conference program on Friday, 9th April 2021

Conference **Friday, 9 April 2021, 8:00 am**

8:00	Virtual Get Together // Spatial Chat: **https://spatial.chat/s/enerday**
8:30	**Opening Address** (https://tu-dresden.zoom.us/j/86212114942) Prof. Dr. Dominik Möst, TU Dresden Prof. Dr. Christian von Hirschhausen, TU Berlin
8:40	**Keynote Speech** **Windnode as a blueprint for a transition towards 100% renewables** Markus Graebig (50Hertz Transmission GmbH)

9:25 **Mini Break / Joining the Virtual Conference Breakout Rooms**

9:30 - 10:45	**Power-To-Gas /Hydrogen** Virtual Room: Volt Chair: Hendrik Scharf	**Market Design & Congestion Management** Virtual Room: Ampere Chair: Christina Wolff	**P2P Energy** Virtual Room: Joule Chair: Richard Weinhold	**Decarbonization Pathways** Virtual Room: Watt Chair: Steffi Schreiber	**Power Systems Modelling** Virtual Room: Coulomb Chair: Manuel Eising
9:30	**Stocks, Flows and Hydrogen: An Open-Economy Baseline Model** Thomas Baldauf, DLR	**Potential of Demand Side Management and Biogas Plants in regional market-based congestion management** Tanja Mast, TH Ingolstadt	**Would You Like to Trade Your Energy? A Comparative Survey Experiment on Energy Trading Platforms** Shandelle Steadman, Loughborough Univeristy	**The energy transition in India: quantifying effects of the low-carbon transition on the Indian energy system** Alexandra Krumm, TU Berin	**An integrated modelling approach to evaluate power system operation stability in decarbonization pathways** Maciej Raczyński, AGH University
9:55	**Role of cogeneration and heating networks in renewable energy systems** Leonard Göke, TU Berlin	**Zonal pricing in Germany – A preferable tradeoff between nodal and uniform pricing?** Alfredo Zamora, TU Berlin	**Optimal expansion and configuration of peer-to-peer electricity trading in local communities** Theresia Perger, TU Wien	**European decarbonization pathways: comparison, robust findings and the European Green Deal** Karlo Hainsch, TU Berlin	**Renewable Energy Targets and the Storage Cycling Trap: Unintended Effects and Implications for Power Sector Modeling** Martin Kittel, TU Berlin
10:20	**Impact of green gas imports on infrastructure investments**	**Market outcomes in Flow-based Market Coupling: a model-based impact analysis of the**	**Prosumer Empowerment through Community-Power-Purchase-Agreements: A**	**Production cost uncertainties of Small Modular Reactor concepts - A model-based**	**Discount factors and hurdle rates: the dark horses of capacity expansion planning**

	Philipp Hauser, VNG	**fundamental parameters** Lisa Lorenz, TU Dresden	**Market Design for Peer-to-Peer Swarm Grids** Jens Weibezahn, TU Berlin	**Monte Carlo analysis** Björn Steigerwald, TU Berlin	Smaranda Sgarciu, BTU Cottbus

10:45 **Break / Joining the Virtual Conference Breakout Rooms**

11:00 - 12:15	**Impacts of Carbon Pricing** Virtaul Room: Volt Chair: Matthew Schmidt	**Locational Incentives** Virtual Room: Ampere Chair: Hannes Hobbie	**Flow-based Market Coupling** Virtual Room: Joule Chair: Martin Lieberwirth	**Flexibility/Decen-tralized energy systems** Virtual Room: Watt Chair: Christoph Zöphel	**E-Mobility** Virtual Room: Coulomb Chair: Julia Guitierrez
11:00	**The Joint Impacts of Carbon Pricing and Renewable Generation on Fossil Generation Profits in Germany** Christian Gambardella, PIK	**Where to place new power generation? A methodology to design cost-reflective locational instruments** Anselm Eicke, Hertie School	**Update on Flow Based Market Coupling Parameters - From minRAM to Generation Shift Key** Constantin Dierstein, TU Dresden	**Assessing the value of demand response in a decarbonized energy system - a large-scale model application** Steffi Misconel, TU Dresden	**Battery-electric vehicles: open-source modeling of time series data and their application in power system models** Carlos Gaete, TU Berlin
11:25	**Food Industry case study on the influence of CO2 certificate and internal CO2 pricing on the decarbonization and investment strategies into energy supply technologies** Nicolas Fuchs, Fraunhofer ISE	**Policy Implications of Spatially Differentiated Renewable Energy Promotion: Multi-Level Scenario-Based Analysis of Regional Onshore Wind Auctioning in Germany** Siamak Sheykhha, RWTH Aachen	**Flow-based market coupling in multi-level electricity market models** Lucas Lang, FAU Erlangen-Nürnberg	**Modelling Electricity Storage Needs in Europe: A Separation of Drivers** Alexander Roth, TU Berlin	**Evaluating policy instruments for the balancing of renewable energies using electric vehicles: On the interplay between distribution and transmission grids** Anya Heider, Reiner Lemoine Institute
11:50	**Market integration of Power-to-Gas during the energy transition – Assessing the role of carbon pricing** Michael Bucksteeg, Univ. Duisburg-Essen	**Local Incentives and Sector Coupling: Friends or foes?** Susann Freitag, TenneT	**Flow Based Market Coupling in Fundamental Electricity Market Models: Methods and Parametrization for Renewable-Dominant Power Systems** Richard Weinhold, TU Berlin	**Exploring the trade-off between cost and security of supply for decentralized autonomous energy systems** Febin Kachirayil, University of Aberdeen	**Cost-benefit Analysis of Residential On-Site E-Car-Sharing** Carlo Corinaldesi, TU Wien

12:15	**Lunch Break and spatial chat: https://spatial.chat/s/enerday**				
13:15 - 14:30	**Environmental Policy Instruments** Virtual Room: Volt Chair: Michael Bucksteeg	**Load, efficiency and solar forecasting** Virtual Room: Ampere Chair: Wolf-Peter Schill	**TSOs & Grid Operation** Virtual Room: Joule Chair: Constantin Dierstein	**Energy behaviour** Virtual Room: Watt Chair: Jens Weibezahn	**Gas Infrastructure** Virtual Room: Coulomb Chair: Hendrik Scharf
13:15	**EU Emissions Trading at a Crossroads** Andreas Schröder, ICIS	**Development of subsector electricity load profiles** Stephan Seim, TU Berlin	**What a Transmission system operator (TSO) can do and needs for Green Europe in 2050** Christian Dobelke, TenneT	**The potential of sufficiency measures to achieve a fully renewable energy system – a case study of Germany** Citlali Rodriguez del Angel, TU Berlin	**Modelling the impact of the energy transition on gas distribution networks in Germany** Johannes Giehl, TU Berlin
13:40	**The European Market for Guarantees of Origin for Green Electricity: A Model-Based Evaluation of Future Price Scenarios** Reinhard Madlener, RWTH Aachen	**Analysis of energy-efficiency measures in multi-cylinder paper drying** Hélene Godin, Universität Stuttgart	**Efficient concertation of reactive power resources** Erika Kämpf, Universität Kassel	**The Effect of Descriptive Information Provision on Electricity Consumption: Experimental Evidence from Lithuania** Fissha Marye, University of Vilnius	**Assessing the Impact of Uncertainties on Infrastructure in the European Natural Gas Market: A robust optimization approach** Matthew Schmidt, TU Dresden
14:05	**The impact of carbon prices on power sector emissions: insights from a model-comparison experiment** Oliver Ruhnau, Hertie School	**Methodology to Improve the Predictability of Solar Energy Generation with Confirmatory Evidence from Germany** Kevin Forbes, UC Dublin	**Contrasting countertrading mechanisms: market effects between Germany and Denmark West** Manuel Eising, EIFER	**Reducing energy consumption and carbon emissions of residential buildings through behavioral change** Tarun Khanna, MCC Berlin	**Trial of Basic Control Strategies of Gas Supply and Distribution Networks to Allow Integration of Renewable Gases from Distributed Production** Johannes Ruf, DVGW
14:30	**Break**				
14:45	**Keynote Speech** **Keynote Speech: Covid-19 - Merely an interruption or the death blow for the international coal market?** Prof. Dr. Pao-Yu Oei (Prof. Economics of Sustainable Energy Transition at Europa-Universität Flensburg) Paola Parra (Research Associate at the Workgroup for Economic and Infrastructure Policy (WIP), TU Berlin)				
15:30	**Spatial Chat: https://spatial.chat/s/enerday**				
15:50	**Award ceremony / Closing remarks: https://spatial.chat/s/enerday**				

Content

Keynote 8:40 – 9:25

Virtual Room: https://tu-dresden.zoom.us/j/86212114942

Windnode as a blueprint for a transition towards 100% renewables

Markus Graebig [1]

[1] *50Hertz Transmission GmbH*

Session 9:30 – 10:45
Power-to-Gas/Hydrogen

Virtual Room: Volt
Chair: Hendrik Scharf

Stocks, Flows and Hydrogen: An Open-Economy Baseline Model

Thomas Baldauf**,** DLR

Role of cogeneration and heating networks in renewable energy systems

Leonard Göke, TU Berlin

Impact of Green Gas Imports on Infrastructure Investments

Philipp Hauser, VNG

Stocks, Flows and Hydrogen: An Open-Economy Baseline Model

Thomas Baldauf[1]

[1] *German Aerospace Center (DLR), Institute of Networked Energy Systems,*
thomas.baldauf@dlr.de

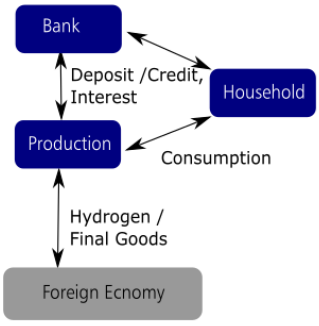
Keywords: Stock-Flow Consistent Modeling, Open-Economy Model, Agents, Import Dependency

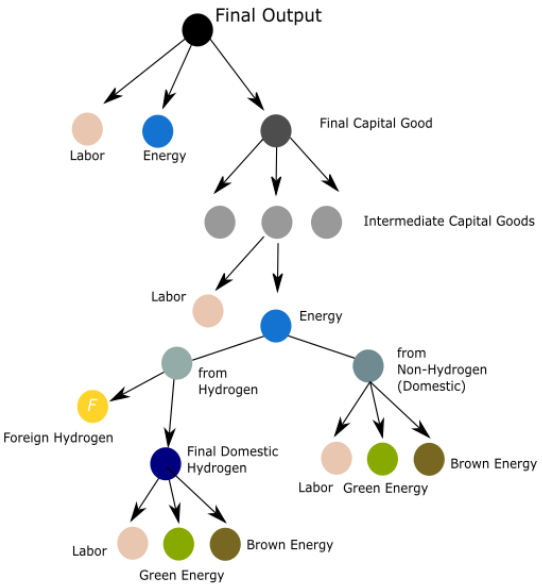
Motivation

The motivation of this paper is to construct a baseline open-economy model for a European country with domestic hydrogen production and hydrogen imports from foreign countries. The idea is to study the effect of different configurations of the production structure on indicators like price level, import intensity and financial leverage.

Hydrogen might play an important role in the future energy system of Germany and other European countries. Most likely, large fractions of the hydrogen supply will come from foreign economies where electrolysis is expected to be cheaper, due to a high supply potential of renewable energy sources. The model is able to describe basic qualitative macro-economic developments for different import scenarios.

Methods: The Model





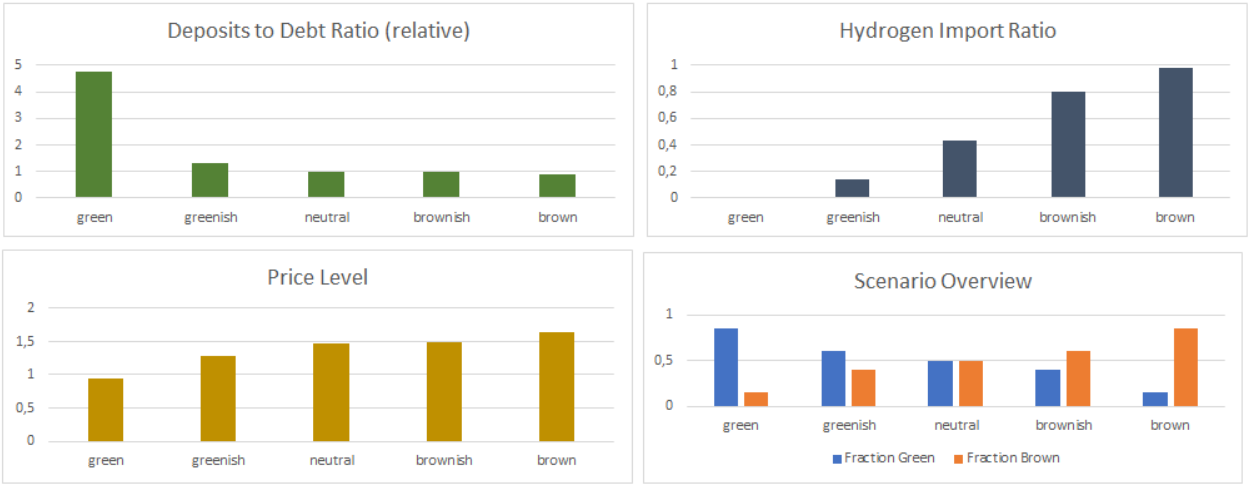
To conduct a policy laboratory experiment, I use a lightweight stock-flow consistent model, built with a novel in-house agent-based Python tool.[1] The model consists of a household (demander),

a bank (which acts as the central accounting unit), the foreign economy and a supply agent. Agents have their own accounting systems each, which allow for separate balancing of equity and liabilities. The most detailed agent is the supply block, which is disaggregated into different production elements as sub-agents.

Households adjust their consumption according to an adaptive rule. The production structure of the economy consists of nested Constant Elasticity of Substitution (CES) and Cobb-Douglas production agents with individual balance sheets and individual mark-up-learning adaptive rules. These nested supply agents produce a final good (of which a fixed fraction is exported), using intermediate goods, labor and energy from hydrogen and non-hydrogen sources. The bank provides the financial intermediary to organize dividends, deposits and credits among the agents. Different scenarios are analyzed: A “green” scenario, where renewables dominate the energy system, a “brown” scenario, where dirty energy dominates, and three intermediate scenarios with a mix in between. The dirty technologies in the domestic sector are assumed to be about twice as expensive as the green technologies, leading to cost shifts between domestic and imported hydrogen.

Results

The results of the study show how the country under consideration can depend on hydrogen imports in different scenarios. The effect of the import intensity on the macroeconomic indicators depends strongly on the elasticity between domestic hydrogen and foreign hydrogen, as well as the production elasticities of green vs. brown energy production. Changing the production elasticity parameters (“Fraction Green” / “Fraction Brown”), one can see that the leverage ratio of the bank is strongly affected. This is due to the relative costs of domestic green and brown energy production, as well as due to the relative cost of domestic and foreign production.



Conclusion and Outlook

The model represents a proof-of-concept baseline model with the possibility of further expansion. The model exhibits some basic qualitative response to structural parameters. It is thus an ideal starting point for the development of an optimal financing strategy of hydrogen technologies and international trade expansion.

In order to make the model quantitatively more meaningful, further work will be done. Most importantly, to study labor effects and leverage ratios, a more detailed labor and financial market will be employed. Because the model has an agent-based structure, more agent-based features can be easily included. The agent-based fashion will allow for the introduction of different behavioral strategies. The labor market can be implemented in an agent-based searching-and-matching fashion.[2] This will allow for realistic forecasts of the (un)employment effects of hydrogen imports. Also, the financial system could be expanded by cross-border trading of green bonds in order to temporarily alleviate the cost of dirty energy. Expansions with international trade modules are also possible. Also, the dynamics of the financial alignment with post-COVID-19 measures could be analyzed, in order to better understand the post-crisis green transformation financing mechanism.

Footnotes

1. For comparable modeling approaches, see for example

   Caiani, Alessandro, et al. "Agent based-stock flow consistent macroeconomics: Towards a benchmark model." *Journal of Economic Dynamics and Control* 69 (2016): 375-408.

   Reissl, Severin. "Heterogeneous expectations, forecasting behaviour and policy experiments in a hybrid agent-based stock-flow-consistent model." *Journal of Evolutionary Economics* 31.1 (2021): 251-299.

   Pedrosa, Ítalo, and Dany Lang. "Heterogeneity, distribution and financial fragility of non-financial firms: an agent-based stock-flow consistent (AB-SFC) model." (2018).

2. An example for an agent-based labor market model approach can be found in

   Mitkova, Mariya. "Labour Market Model with On-the-job Search, an Agent-based Approach." (2017).

Role of cogeneration and heating networks in renewable energy systems

Leonard Göke[1]

[1] *Workgroup for Economic and Infrastructure Policy, TU Berlin, Germany, lgo@wip.tu-berlin.de*

Keywords: macro energy systems, sector integration, decarbonization, renewable heating

Motivation

The design of future energy systems based on renewable energy is subject to many open and widely discussed questions: What place will synthetic fuels like hydrogen have in such a system? How can heat supply be decarbonized? What kind of thermal backup capacities do high shares of solar and wind require?

The future role of cogeneration and heating networks intersects all these questions. Apart from electricity, hydrogen is the only energy carrier available to provide renewable heat. At the same time, hydrogen power plants are one of the few options to backup intermittent generation from renewables. However, high costs suggest restricting the use of hydrogen to highly efficient plants and to times when all other options are exhausted. Cogeneration combined with other technologies in local heating or district heating networks matches both these requirements.

Methods

The question is analyzed based on a detailed capacity expansion model that covers the transformation of the European energy system in the next 30 years and is based on the open modelling framework AnyMOD. To cover the wide range of influencing factors, the model introduces several methodological advancements. On the one hand, these enable greater spatio-temporal detail to capture fluctuations in generation and demand for electricity and heat. On the other, they improve the technical representation, in particular in the heating sector, by accounting for the thermal inertia of buildings and the trade-off between residential or network heating.

Results

Only preliminary results so far.

Impact of Green Gas Imports on Infrastructure Investments

Philipp Hauser[1,2]

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[2] *VNG AG, Germany, philipp.hauser@vng.de*

Keywords: Green Gas, Hydrogen, Infrastructure, Energy System Analysis

Motivation

In the context of the energy transition and the Green Deal, two efforts drive the natural gas sector. Firstly, the reduction of greenhouse gas emissions during the production, transport and usage of natural gas and, secondly, being part of the energy transition by integrating renewable based gases, also called Green Gases (GG) or Green Hydrogen, into the energy system. The Green Deal provides a strategy to react on gas source dependence in two ways. First, it diversifies suppliers as the introduction of GG production facilities enables new supply countries to enter the gas market. Second, it substitutes fossil natural gas by a new defossilized fuel, namely hydrogen. Against this backdrop, the question arises of what is the impact of GG on making investment decisions and for providing SoS in the gas markets.

Methods

The analysis considers the expansion option in GAMAMOD-EU.sto by allowing additional investments in so-called “Green Gas Facilities” that can provide a substitute to natural gas. The production of GG causes investments and production costs, but does not produce greenhouse gas emissions. To make GG competitive, the model assumes a model-wide CO_2 price that customers pay for natural gas consumption. Using a stochastic-optimization approach, the analysis focuses on investment in pipelines, LNG import terminals, storages and Green Gas facilities. Furthermore, a sensitivity shows the impact of the CO_2 price level on the results.

Results

The results illustrate that the consideration of GG might be a game changer for the future gas market in terms of supply structure and infrastructure projects. With regard to the assumed RES potentials within the EU-28 it is questionable whether the entire RES potentials are really available for GG production or whether they will be integrated in the electricity sector. However, larger North African potentials are favorable starting at an emission price of 100 EUR/t CO2 and have the potential to provide major supplies for the EU-28.

Session 9:30 – 10:45
Market Design & Congestion Management

Virtual Room: Ampere
Chair: Christina Wolff

Potential of Demand Side Management and Biogas Plants in regional market-based congestion management
Tanja Mast, TH Ingolstadt

Zonal pricing in Germany – A preferable tradeoff between nodal and uniform pricing?
Alfredo Zamora, TU Berlin

Market outcomes in Flow-based Market Coupling: a model-based impact analysis of the fundamental parameters
Lisa Lorenz, TU Dresden

Potential of Demand Side Management and Biogas Plants in regional market-based Congestion Management

Tanja Mast[1]*, Benedikt Hümmer[1], Uwe Holzhammer[1]

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Keywords: Smart Market, grid congestion, biogas plants, demand side management

Motivation

Under the current congestion management regime and under the upcoming, reformed 'Redispatch 2.0', resolving congestions by redispatch and feed-in management is compensated according to the cost-recovery principle. Since no additional revenue can be generated, flexibility options have no incentives to engage voluntarily in congestion management. The 'Smart Market' approach supplements the cost-based regime with a market-based element. Market participants offer their flexibility to resolve congestions in a market that is temporarily and spatially limited and can thereby generate additional revenues according to the 'pay-as-cleared' principle. Competition among market participants coupled with a bid cap results in cost reductions compared to the current system. Since loads and smaller capacities (< 100 kW) can also submit bids on the Smart Market, this approach integrates previously unused flexibility potential into congestion management. This paper analyses the potential of load shifting and flexible biogas plants in market-based congestion management and demonstrates how these flexibility options can reduce the curtailment of renewables at distribution grid level in Bavaria by participating in Smart Markets.

Methods

Time series for vertical grid congestions are modelled using a simplifying methodology based on the expected feedback to the transmission grid of NUTS3-regions in Bavaria for the year 2025. Schedules of flexible loads and biogas plants are determined by an open-source tool (flexible loads) and an optimization model (biogas plants). These are used to identify the availability of the flexibility options for congestion management and the resulting bids in the Smart Market.

Results

Ca. 82% of all biogas plant bids on Smart Markets are below 5 €/MWh and can therefor undercut bids of loads (5 - 200 €/MWh). But due to low availability and stagnating biogas expansion, their

potential for relieving congestions is limited. High availabilities and rapid growth of some flexible loads (eMobility, P2H applications) lead to high potential of load shifting in market-based congestion management.

Zonal pricing in Germany – A preferable tradeoff between nodal and uniform pricing?

Alfredo Zamora Blaumann[1]
Christoph Weyhing[2]

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[2] *German Economic Research Institute (DIW Berlin),*

Keywords: price zones, market zones, energy system modeling, market splitting, power flow

Motivation

The outcome and efficiency of electricity markets is heavily influenced by their geographical configuration. Market zones often align with national borders, whilst generation and load patterns differ on smaller geographical scales. Zonal configurations with historically grown centralized energy infrastructures are outdated by fast growing decentralized renewable generation, which leads to network congestions and inefficiencies. This problem can be resolved by either adapting the infrastructure or changing the zonal configuration. Academic publications that investigate optimal zonal configuration often use electricity system data prior to 2015 with renewable shares under 30%, while in 2019 number increased to over 45%. Hence, the effects of growing renewables on zonal configurations are rarely investigated. This research aims to give an update for 2020 on the discussion on market splitting by the example of Germany.

Methods

Based on a model of the German transmission grid including demand and supply, market clearing is simulated for a defined multi-zonal configuration with subsequent redispatch. The zones are arranged according to transmission bottlenecks and in line with existing research. The results focus on the implications on system costs, market prices, congestion management and regional generation. We pay special attention to the exchange between zones to estimate the impact of different inter-zonal trading capacities. The zonal configuration is benchmarked against a nodal pricing and a uniform pricing approach.

Results

Preliminary results show a reduction of redispatch and curtailment to almost negligible values by shortening the available trading capacity between zones significantly. Hence, market outcome aligns better with the physical infrastructure and generation is properly allocated in the market. While redispatch costs drop with more restricted trade, generation costs rise. Also, limited

trading capacities lead to price spreads between northern and southern zones, which increase with decreasing trading limits. Market prices in the southern zone deviate from the others averaging 40 €/MWh over the other zones illustrating its dependency on low-cost renewable generation from other zones.

Market outcomes in Flow-based Market Coupling: a model-based impact analysis of the fundamental parameters

Lisa Lorenz[1]

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Lisa Lorenz is a student at the chair of energy economics and has been awarded with the **enerward award 2021** (https://www.enerconnect.net/awards/) for her diploma thesis with the title "*Market outcomes in Flow-based Market Coupling: a model-based impact analysis of the fundamental parameters*".
The enerward award distinguishs outstanding theses in the field of energy economics at the Technische Universität Dresden and is awarded by the enerConnect Association (https://www.enerconnect.net/).

Abstract
Market coupling and the calculation of cross-border transmission capacities is the prerequisite for an internal European electricity market. Since 2015, flow-based market coupling has been used for cross-border capacity calculation on the day-ahead market of Central Western Europe. An expansion of the algorithm to the Core region, a combination of Central Western Europe and Central Eastern Europe, is foreseen. The cross-border capacity calculation using flow-based market coupling is performed simultaneously with the market coupling and is therefore based on the actual power flows within the transmission network and its physical restrictions. Model parameters such as generation shift keys (GSKs), critical network elements (CNEs), CNE selection thresholds and security margins significantly affect the market outcomes. In this work, the influence of the flow-based market coupling model parameters on the market outcomes is investigated using four different generation shift key strategies, each applying three CNE selection thresholds.

Session 9:30 – 10:45

P2P Energy

Virtual Room: Joule
Chair: Richard Weinhold

Would You Like to Trade Your Energy? A Comparative Survey Experiment on Energy Trading Platforms

Shandelle Steadman, Loughborough Univeristy

Optimal expansion and configuration of peer-to-peer electricity trading in local communities

Theresia Perger, TU Wien

Prosumer Empowerment through Community-Power-Purchase-Agreements: A Market Design for Peer-to-Peer Swarm Grids

Jens Weibezahn, TU Berlin

Would You Like to Trade Your Energy? A Comparative Survey Experiment on Energy Trading Platforms

Anna Rita Bennato, Monica Giulietti and Shandelle Steadman[1]

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Keywords: Energy Trading, Prosumers, Consumer Behaviour, Vignette, Survey Experiment

Motivation

As energy markets are transitioning and are becoming more decentralized, energy trading platforms are emerging as a potentially beneficial tool that can facilitate the coordination and integration of energy generated from renewable sources. However, since these platforms are still a novel innovation, there is plenty of scope to investigate consumer decision making in these new markets. The analysis developed in this work contributes to the experimental and behavioural economics literature, as it relies on microeconomic and behavioural economic theories and techniques to study consumer behaviour in this emerging market. Given consumers and prosumers increasing importance in the transition to a net-zero energy system, it investigates their willingness to participate in energy trading platforms, and seeks to determine the preferences and socio-economic factors which motivate their use, while also studying the behavioural components that drive individual decisions.

Methods

In order to test investigate consumer behaviour, we use a survey-experiment which involves a theoretical vignette. This method is adopted to investigate individual decisions on whether to join (or not) such energy platforms. We also collect information on participants' socio-demographic characteristics, attitudes and behavioural biases, testing the influence of these factors on the decision. We examine both sides of the two-sided trading platform as we investigates both consumers and prosumers, and the survey is carried out in Italy, Spain and the United Kingdom, allowing us to analyse and compare individual behaviour across different countries.

Results

Our results found that 48% of consumers and 70% of prosumers provided a positive response to the vignette, suggesting that there is positive interest and openness towards participating in the platform. Although some individuals stated that they would be interested in joining the platform in order to gain savings and earnings and trade energy with members of their community, the

results suggested that these conditions did not have a significant effect on individuals' decisions to join. However we did find some preferences that affected different groups' decisions, such as their desire to be early adopters, their desire to be independent from their energy supplier, their pro-environmental attitudes, and their involvement in energy communities. Some groups were also influenced by their behavioural biases such as their risk preferences and present bias.

Optimal expansion and configuration of peer-to-peer electricity trading in local communities

Theresia Perger[1]

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Keywords: Peer-to-peer trading, Energy communities, Open source modeling, Bilevel programming, KKT conditions

Motivation

In European electricity markets, energy communities become more and more prevalent, and new concepts for active end-user involvement emerge, such as peer-to-peer trading and other local energy markets. Energy communities are independent of local microgrids and they are not necessarily site-dependent, which allows prosumers to actively participate on a voluntary basis. The objective of this work is to find an optimal configuration extending an existing energy community, where participants exchange electricity using a peer-to-peer trading mechanism, by including new members in the community.

Methods

The proposed method is based on the existing open source model[1] FRESH:COM (Fair energy sharing in local communities) developed by the authors, which is a linear program that allocates electricity in local energy communities via peer-to-peer trading. The objective function considers the minimization of grid purchases by the community and the willingness-to-pay of the individual prosumers and thus the maximization of the community's social welfare over a whole year. The contribution of this work is the transformation of the model into a bilevel optimization problem, where the original linear program (with the objective of maximizing the social welfare) becomes the lower level problem (follower) to the upper level problem (leader), which aims at finding an optimal configuration to extend the community by respecting the preferences of the community's members (multi-objective optimization). Formulating the KKT (Karush–Kuhn–Tucker) conditions of the lower level problem, the bilevel problem is transformed to a linear problem with complementarity conditions.

Results

The results of the optimization problem show the optimal dimensioning of PV system size and electricity demand of the expansion of an energy community, starting from an original

community set-up. Different scenarios and sensitivity analyses of the prosumers' willingness-to-pay are conducted.

Prosumer Empowerment through Community-Power-Purchase-Agreements: A Market Design for Peer-to-Peer Swarm Grids

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Keywords: rural electrification; P2P swarm grids; tariffication; market design

Motivation

Bangladesh is the largest solar home systems (SHS) market in the world, with more than 4.13 million SHS installed (IDCOL 2021) between 2003 and 2019, through a soft financing program run by the Government's Infrastructure Development Company Limited (IDCOL). The deep rural penetration of SHS and the average 30% of surplus electricity per SHS (Magnasco et al. 2016) are just two of the factors that have enabled the installation of the world's first rural area Peer-to-Peer (P2P) microgrids or P2P swarm grids (Dumitrescu et al. 2020). However, the trading of electricity between peers (rural households and small businesses interconnected in the P2P swarm grid) heavily relies on motivational drivers (Kirchhoff and Strunz 2019), as the design of the features and rules on how to buy or sell electricity locally are both un-regulated and in their early stages (Lüth et al. 2018). One feature of the P2P swarm grid is the interconnection with the national grid infrastructure, through which not only electricity can be shared, but also benefits in terms of reducing peak demand, reserve requirements, operating costs, and improving reliability (Tushar et al. 2021). There are several market design approaches proposed for P2P grids, however their foci are on established electricity markets in the Global North.

Methods

In this paper we establish a market design methodology for P2P swarm grids in the Global South, in which the peers are rural households and small businesses, with installed capacities of up to 250 Wp. Through the market design, we propose a pricing mechanism for prosumers and consumers; furthermore, we introduce the community power purchase agreement (CPPA) - the tariff received by the P2P swarm grid for servicing the grid, once it is interconnected with the

national grid. We conduct the market design modelling for a P2P swarm grid in Dhobaura, Mymensingh, Bangladesh.

Results

Preliminary results show that, in order to incentivize the trading of electricity, electricity prices need to be differentiated by the type of peer (prosumer/consumer) and by the moment of the trading (day/night/surplus electricity in the P2P swarm grid). Moreover, preliminary results show how the CPPA improves the payback time of a peer's battery installation (component of the SHS) through the net compensation received for servicing the national grid. Finally, we provide policy recommendations for the public sector to adopt CPPA versus net-metering coupled with viability gap financing (VGF).

Session 9:30 – 10:45
Decarbonization Pathways

Virtual Room: Volt
Chair: Steffi Misconel

The energy transition in India: quantifying effects of the low-carbon transition on the Indian energy system

Alexandra Krumm, TU Berlin

European decarbonization pathways: comparison, robust findings and the European Green Deal

Karlo Hainsch, TU Berlin

Production costs uncertainties of Small Modular Reactor concepts - A model-based Monte Carlo analysis

Björn Steigerwald, TU Berlin

The energy transition in India: quantifying effects of the low-carbon transition on the Indian energy system

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Keywords: India, renewable energy, energy system modelling

India experienced immense changes in the energy sector in the last decades and continues to do so. Energy access and security are key objectives of the Indian government, linked to economic growth. Therefore, the Indian government is facing a challenging balancing act between upholding climate targets, and at the same time reduce energy poverty, enhance energy security, and meeting demand growth. Therefore, this paper looks at a sector-coupled energy system including the sectors power, heating, transportation, and industry at a state level for India, using the open-source energy system model GENeSYS-MOD. The model is a linear optimization problem, where the total system costs of a given energy system are optimized for a set time horizon. The pathways are computed with the model determining the cost-optimal capacity additions, supply mix, storage usage, and energy flows.

Two scenarios are analysed to assess developments of the Indian energy system under varying CO2 constraints. 2 Degree a scenario compatible with limiting global warming to 2°C, and a Delayed Action scenario that serves as a baseline. Results show that achieving the goal to limit global warming to 2°C requires immense and fast expansion of renewable energy sources (RES), increase of energy efficiency, and strengthening of the grid to integrate RES, all complemented by ambitious climate policies. This paper contributes to existing literature by both presenting detailed regional future energy pathways for India and their policy-relevant implications, as well as providing an open dataset and model to the public.

European decarbonization pathways: comparison, robust findings and the EGD

Karlo Hainsch[1*], Konstantin Löffler[1,2], Thorsten Burandt[1,2,3], Hans Auer[4], Pedro Crespo del Granado[3], Paolo Pisciella[3], Sebastian Zwickl-Bernhard[4]

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Keywords: Energy Transition Strategies, Energy Policy, Scenarios and Storyline Definition, Energy System Modelling, Pathway Comparison

Motivation

The pledge for greenhouse gas neutrality formulated in the European Green Deal (EGD) comes at a time where the amount of decarbonization pathway studies rises. Since results of said studies are highly influenced by input assumptions and underlying structures, focusing on the adequate communication on the results is imperative to allow policy and decision makers to take informed decisions. Reviews and comparisons of pathways are therefore a suitable tool while at the same time playing to the strengths of models which lies in the insights being gained from different model runs and scenarios rather than absolute and raw numbers.

Methods

We introduce a novel scenario generation and evaluation process, expanding the classical two-dimensional approach into a 3D-methodology. Additionally, we compare four decarbonization scenarios computed in the H2020 openENTRANCE project with scenarios from two other studies, highlighting common findings and differences across the scenarios. The three-dimensional approach not only enables an assessment of the scope of the scenarios but also an evaluation of common findings which in a second step are mirrored against the action plans of the EGD to identify areas where more action is required.

Results

Results show that, while the interpretation of scenario results is always subject to the input assumptions, a coherent set of findings can be achieved through extensive analysis of the studies. Openness both in terms of methodology and data is key. No-regret options can be identified as well as areas where results might point into different direction across studies (e.g. role of hydrogen or CCS). The EGD, while covering a lot of important fields, lacks concrete ambitions when it comes to sufficiency aspects and how to promote them.

Production costs uncertainties of SMR-concepts - A model-based Monte Carlo analysis

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Keywords: Costs, nuclear, SMR, Scale - effects, uncertainty

Motivation

In this paper we analyze the competitiveness of SMR concepts ("small and modular reactors" (Chu 2010)). We combine investment and production theory with Monte Carlo simulations of uncertain parameters. SMR concepts are nuclear power plants with relatively low power ratings (e.g., up to 300 MW_{el}, see Pistner and Englert (2017), Pistner et.al. (2021), Mignacca and Locatelli(2020), Boarin et.al. (2021)). They are currently re-emerging in the debate about large scale decarbonization of the energy sector because of the failure of nuclear power plants with higher power output (e.g., 1,000 – 1,600 MW_{el}) to become competitive (Lloyd, Lyons, and Roulstone 2020; Wealer et al. 2021). The value proposition of SMR developers and national energy and defense administrations is that SMR concepts could overcome their disadvantage of size through increased productivity by – among others – mass production, learning, co-siting, (Rothwell 2016; Boarin et al. 2021).

Methods

We analyze the costs of SMR concepts employing publicly available cost and recent cost theory, to evaluate an investment decision with the help of Monte Carlo simulation of economic indicators (Wealer et al. 2021). We collected a unique economic dataset for SMR concepts from different manufacturers (Pistner et al. 2021) and following Lloyd et.al. (2020) and Rothwell (2016), recalculate costs to identify cost-intervals in dependence to scaling factors. To evaluate this interval, we determine the net present value with randomizing relevant parameters through a Monte Carlo simulation.

Results

Our results suggests that the lack of competitiveness attributed to large nuclear reactors also applies to current SMR concepts with a low capacity. Moreover, predictions suggest no commercial success in the long term. Our results further indicate that current cost theory only has limited applicability for SMRs and requires further research to understand known sources of uncertainty to be able to more accurately evaluate current concept pricing for SMRs.

Session 9:30 – 10:45
Power Systems Modelling

Virtual Room: Coulomb
Chair: Manuel Eising

An integrated modelling approach to evaluate power system operation stability in decarbonization pathways
Maciej Raczyński, AGH University

Targets and the Storage Cycling Trap: Unintended Effects and Implications for Power Sector Modeling
Martin Kittel, TU Berlin

Discount factors and hurdle rates: the dark horses of capacity expansion planning
Smaranda Sgarciu, BTU Cottbus

An integrated modelling approach to evaluate power system operation stability in decarbonization pathways

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Keywords: energy modelling, decarbonization, unit commitment, capacity expansion

Motivation

The ambitious climate goals of the European Green Deal aim at reaching carbon neutrality by 2050. For a coal-based system, such as Poland's, this means faster and deeper transformation than already planned. Such a transformation raises questions about the future electricity mix and system stability issues.

Widely used in policy development, long-term Capacity Expansion optimization models (CE) often fail to capture system dynamics in detail due to computational limitations. As a consequence, their results may underestimate the need for dispatchable sources in the system with a high share of intermittent renewables. Unit Commitment and Economic Dispatch (UCED) models are capable to evaluate the system stability. They, however, are commonly run for short periods of time. Coupling the two models provides an opportunity to improve the long-term planning by evaluation of the technical feasibility of the long-term scenarios.

Methods

CE and UCED models working in a feedback loop. The UCED model, run with a rolling time horizon, evaluates the technical feasibility of a long-term scenario. If a future capacity mix proves to be infeasible from the point of system operation stability, the CE model is used again to update this mix with adjusted parameters forcing an increase in the number of dispatchable sources. The loop is repeated until stability is achieved, as measured by the number of hours of lost-load.

Results

Depending on the scenario, in 2050 in Poland out of the forecasted 80-100 GW of installed capacity, about 15-20 GW should be installed in dispatchable sources. The UCED model showed infeasibility for the first version of the electricity mix elaborated with the use of the CE model. Therefore, additional ca. 10 GW of dispatchable electrical capacity had to be added to achieve system stability.

Renewable Energy Targets and the Storage Cycling Trap: Unintended Effects and Implications for Power Sector Modeling

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Keywords: Open Source Modeling, Minimal Renewable Share, Renewable Energy Policy Targets, Power Sector Modeling

Motivation

To decarbonize the economy, many governments have imposed a minimum share of renewable energy in total electricity supply. Yet, implementing such renewable energy targets in power sector models is a surprisingly delicate issue. They may cause excessive storage use, a modeling artefact, visible through contemporaneous chargingand discharging of the same electrical storage facility ('unintended storage cycling'). This analysis is carried out in the context of the research project Modezeen, supported by BMWi.

Methods

We use a parsimonious power sector model to i) analytically examine the impact of different renewable target constraint formulationson equilibrium conditions of storage operators, and ii) quantify how unintended storage cycling distorts model results.

Results

Unintended storage cycling distorts storage investment decisions, reducing the arbitrage and capacity value of storage. This also affectsthe optimal configuration of othercomponentsof the power system. Unintended storage cycling may decrease renewable energy integration potential and increase emission intensity, which counteracts the intuition of implementing renewable energy policy targets in power sector models. We identify unintended storage cycling as a result of certain implementation strategies of minimum renewable targets. We determine solution strategies to eradicate unintended storage cycling.

Discount factors and hurdle rates: the dark horses of capacity expansion planning

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Keywords: Electricity Market, Discounting, Capacity Planning, Uncertainty

Abstract:

Nowadays, bottom-up energy optimization models are widely used in energy economics research and policy consulting. These models rely on extensive datasets and various assumptions are needed to translate the complexity of the real world into systems of equations. Discount factors and hurdle rates are part of the input data in each state-of-the-art capacity expansion model. However, although several studies show sensitivity analysis, these input parameters do not receive attention adequate to the impact they have on model outputs. A few recent studies (García-Gusano et al., 2016; Hermelink and De Jager, 2015; Simões et al., 2013) highlight this issue and point out the need for further reseach.

In this paper, our contribution is two-fold. First, we analyze the impact of disregarding technology-specific hurdle rates in an optimization model of the European electricity market with investments in power generation capacities. For that, we benchmark key outputs (invested capacity mix, total system cost, electricity trade and CO_2 emissions) for model configuration with *standard* uniform and *technology-specific* hurdle rates. Second, we quantify the impacts caused by the choice of social discount factors and illustratively compare them with the impacts caused by the choice of other uncertain input parameters, such as fuel and CO_2 costs, electricity demand, and Renewable Energy Sources cost reduction rates. Our results show that a range of plausible assumptions on discount factors lead to a broad range of technology pathways (e.g. a system with a lower social discount rate favours the investment in renewable sources).

Taken together, our findings indicate that careful consideration of social discount factors and hurdle rates is of paramount importance for modelling exercises that aim for long-term policy planning. Our illustrative modelling example and conclusions are relevant for both energy modellers and policymakers with an empirical interest in European energy markets.

Session 11:00 – 12:15
Impacts of Cabon Pricing

Virtual Room: Volt
Chair: Matthew Schmidt

The Joint Impacts of Carbon Pricing and Renewable Generation on Fossil Generation Profits in Germany

Christian Gambardella, PIK

Food Industry case study on the influence of CO_2 certificate and internal CO_2 pricing on the decarbonization and investment strategies into energy supply technologies

Nicolas Fuchs, Fraunhofer ISE

Market integration of Power-to-Gas during the energy transition – Assessing the role of carbon pricing

Michael Bucksteeg, University of Duisburg-Essen

The Joint Impacts of Carbon Pricing and Renewable Generationon Fossil Generation Profits in Germany

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Keywords: Carbon pricing; EU ETS; Electricity Markets; Renewable Generation; Ex-post Analysis; Applied Econometrics;

Abstract:

This paper identifies and disentangles thespecific and combined effects of the surge in EU emission allowances prices (EUA) and growth in wind and solar generation on the operating profits of fossil generators in Germany. Based on market data from 2016 to 2019, we estimate the marginal day-ahead electricity market price and fossil generation response of renewable generation and emission prices, accounting explicitly for potential interaction effects. We use unit level generation data, which allows us to investigate whether changes in the EUA price caused systematic and heterogeneous changes in the impact of renewable generation on fossil dispatch rates. Importantly, we exploit across-year-variations in fossil input prices and renewable generation in order to detect the mid to long-effects of carbon pricing and renewable generation growth. Combining the estimated wholesale price and fossil generation impacts with unit specific generation cost data, we can estimate short-run operating profits at the unit level. Using counterfactual predictions, we decompose the observed changes in fossil dispatch rates and operating profits in order to disentangle the joint and individual effects of rising EUA prices and growth in renewable electricity. Our key findings are threefold. First, we find a statistically significant interaction effect between the EUA price and renewable generation on the German day-ahead market price for electricity. Increasing EUA prices can therefore reinforce the negative wholesale price effect of wind and solar generation during off-peak periods and attenuate (amplify) the negative wind (solar) price effects during peak and shoulder-peak periods. Second, we also find a statistically interaction effect on the hourly capacity factors of fossilgeneration units. The interaction effect is negative and most pronounced for lignite unitsimplying that lignite capacity factors respond on average twice as strong to renewable generationthan before EUA prices reached 2019 levels. Simultaneously, higher EUA prices are found to mitigate the negative marginal impacts of wind and solar generation on the average hourly capacity factors of gas

units. Third, the interaction effect of renewable generation and emission prices is relatively irrelevant for explaining observed changes in fossil dispatch rates and annual operating profits. However, our counterfactual predictions suggest that the combined change in EUA prices and renewablegeneration seems to majorly explain the observed decline in cumulative operating profits of lignite and coal units between 2016 and 2019. That is about 80 to 90 percent of the observed drop in the median of annual lignite and coal unit profits, which amount to about 74.4 percent 95.7 percent relative to 2016 profits, can be explained by the joint impact of increasing EUA prices and renewable generation growth. Accordingly, each factor taken separately only explains a relatively small fraction of these changes.

Food Industry case study on the influence of CO2 certificate and internal CO2 pricing on the decarbonization and investment strategies intoenergy supply technologies

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Keywords: Industry Decarbonization, Energy System Analysis, CO2Pricing, Technology Investment

Motivation

Facing uncertain energy prices and climate change risks the industry is looking for decarbonization strategies (Bataille et al. 2018). But especially in companieswith high sharesof heat and steam demand, change considerably dependson the availability of market ready renewable supply technologies. Furthermore, decarbonization strategies must also considerdependencieson the existing energy supply system and technologies. This paper aims to study potential decarbonization pathways under different CO_2 prices for a food industry case study.

Methods

The industry caseprocesses aremodelled withinthemixed-integer linear energy system optimization model DISTRICT to investigate investment decisions and operating control. The energy system consists of supply and demand technologies and covers theinterconnected electricity, heating, cooling, and steam demand and supply on multiple temperature levelsandtechnology expansion. External CO_2 prices are considered for current and future fuel prices. Within industry development scenarios for 2020,25,30 influence under CO_2 neutrality and cost optimality are measured.

Case Study Results

CO_2 price levels strongly influence the economic decisions into new energy generation technologies. CO_2 production neutrality within the current investment cost frame accounts to double the total cost of fossil fuel strategiesand in this case is only achievable with hydrogen based combined heat & power. Renewable energypotential at the industry site potential can neither cover the electricity, nor the heating or coolingdemand. Although internal CO_2 pricing or higher external CO_2 prices can incentivize a more renewable transition, production neutrality with high shares of high temperature heat and steam demand is very costly with currently available technologies

Market integration of Power-to-Gas during the energy transition – Assessing the role of carbon pricing

Michael Bucksteeg[1], Jennifer Mikurda[2], Christoph Weber[3]

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Keywords: Market modelling, Power-to-Gas, Carbon pricing

Motivation

To reduce CO_2 emissions, energy policy measures have focused on supporting renewable energy sources (RES) in Germany. While the massive expansion of wind and solar energy has primarily led to a decarbonization of the electricity sector, other sectors like heating or transport remain below the climate targets. Against this background, Power-to-Gas (PtG) is seen as a solution supporting the decarbonization of other sectors. Consequently, the coupling of sectors has gained importance in academic and political debates. This contribution studies the role of the regulatory framework for the integration of PtG facilities during the energy transition. With special attention to CO_2 pricing, we aim at answering the question if a consistent pricing of CO_2 emissions can support the integration of climate-friendly flexibilities.

Methods

We utilize an optimization model covering electricity and heating markets and extend the model by the PtG technology and competing flexibilities like storages and demand side management. To model the conversion of electricity to hydrogen or methane, we consider the conversion process as a storage process with the gas network as storage. We develop several scenarios with regards to levies, levels of CO_2 price, techno-economic parameters of flexibilities and shares of variable RES for the year 2025.

Results

The numeric assessment of the European power market is based on the Best Estimate scenario of Entso-E's Ten Year Network Development Plan 2018 with the year 2016 as reference year. The electrolyser capacity in Germany is assumed to be 2 GW for both PtH2 and PtM in 2025. We find that a consistent CO_2 pricing with crediting of CO_2 emissions avoided by green hydrogen or methane supports the market integration of PtG, whereas too low CO_2 prices might lead to adverse effects. Based on the modelling results, implications for energy policy are presented.

Session 11:00 – 12:15
Locational Incentives

Virtual Room: Ampere
Chair: Hannes Hobbie

Where to place new power generation? A methodology to design cost-reflective locational instruments

Anselm Eicke, Hertie School

Policy Implications of Spatially Differentiated Renewable Energy Promotion: Multi-Level Scenario-Based Analysis of Regional Onshore Wind Auctioning in Germany

Siamak Sheykhha, RWTH Aachen

Local Incentives and Sector Coupling: Friends or foes?

Susann Freitag, TenneT

Session 11:00 – 12:15

Where to place new power generation?
A methodology to design cost-reflective locational instruments

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Keywords: Locational instruments, Locational pricing, Generation investment, Market regulation

Motivation

In most power systems, network costs are socialized and not imposed on generators. Consequently, the siting decisions of new generation investment rarely accounts for the resulting network cost. It is often argued that locational electricity markets internalize the cost of the transmission system to generators. I show that this believe only partly holds. Because the transmission system is usually over dimensioned in practice, locational electricity markets internalize short-run but not the long-run cost of transmission and result in non-optimal siting decisions of power generation. Less debated in the academic literature are locational instruments that provide financial
(dis-) incentives to invest in certain regions.

Methods

I present and discuss a methodology for cost-reflective locational instruments. Reflecting the long-run network cost, these instruments impose a penalty on generators that stress the transmission system and a premium on those that relieve it. I use a simplified power market model of Germany to analyze and compare the effect of locational instruments and market splitting.

Results

The simulation reveals that locational instruments provide adequate long-term signals but are unable to incentivize a cost-efficient dispatch of generation. As such, they are a complement rather than a substitute to locational electricity markets.

Policy Implications of Spatially Differentiated Renewable Energy Promotion: A Multi-Level Scenario-Based Analysis of Regional Onshore Wind Auctioning in Germany

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Keywords: Renewable energy, Onshore wind, Auction design, System dynamics, Policy support payments, Germany

Abstract

Auctions have been introduced in many countries as a useful alternative for renewable energy support. However, they often lead to a high concentration of renewable energy power plants at productive sites, at the expense of other, less favorable sites. This paper studies the impact of alternative renewable energy auction designs on the promotion of renewable energy in Germany, using a novel multi-level approach that enables to analyze auctioning on the national, north/south, and the federal states level. In contrast to previous studies, the analysis of the future market outcomes and the expected feed-in premia is performed by linkage with a large-scale hourly European dispatch and investment model. The proposed method and the results can help both renewable energy policymakers and investors in their decision-making. First, using a GIS tool, the onshore wind potential is studied at a high regional and temporal resolution. The geographic scope of the investigation is Germany, providing results for each of the federal states (NUTS-1 level). We use historic weather data as well as GIS analysis to determine bids for different wind classes and regions. The results of this analysis show a considerable untapped onshore wind potential in the southern federal states of Germany. Second, we analyze the impact of different auction designs on the expected auction results and on long-term investments in onshore wind peaks. To this end, we propose a novel system dynamics (SD) method to model and simulate renewable energy auctions. Finally, the policy support payments are compared for different auction designs using an electricity market simulation model. The findings suggest that more bidders from the southern federal states can win in the regional auctions. Detailed spatial analysis reveals a trade-offbetween balanced diversity of bidders and

the average auction price. We conclude that regional auctioning can indeed lead to significant support payment savings, and should thus be considered in renewable energy support policy design. Policymakers, on the one hand, can learn how different policy designs impact long-term investments, and find out in which regions investments are likely to take place. On the other hand, investors can learn about the expected profitability of investments for each region as well as the expected revenues under the current and the new market designs. Additional other scenarios can also give insights on the risks that the investor faces: Changes in the energy policy as well as uncertainty about the speed ofinvestment will lead to different market outcomes and will influence the expected long-term revenues.

Local Incentives and Sector Coupling: Friends or foes?

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Keywords: local incentives, market design, nodal pricing, power-to-gas, zonal pricing

Motivation

One major challenge of the future energy system is the *local* coordination of a variety of energy producers, consumers, prosumers, and storages to maintain a stable and efficient system operation. Another one is the cross-sectoral integration of energy vectors such as electricity, heat and hydrogen in an efficient and effective manner. This paper combines the two strands of discussion and analyzes the implications of local incentives in the form of nodal prices on the power-to-gas technology.

Methods

For the investigation, a SWOT analysis will be used since it can explore the characteristics of the local incentive that will improve or hinder the implementation and operation of power-to-gas technology on a larger scale in Germany. Additionally, external factors such as political or regulatory developments, which might influence this transformation of the energy system in a positive or negative manner, will be scrutinized. This research will be supported by quantitative analysis following the methodology of van Leeuwen and Mulder (2018). It will be investigated how zonal and nodal prices affect the dispatch decision of a power-to-gas plant using simulated zonal and nodal pricing data of the German system in 2025 as presented in vom Stein et al. (2020). The resulting dispatch will be analyzed regarding its contribution to relieving network congestion.

Results

The paper will present detailed results on how nodal will influence the development of an energy system by coordinating the location of energy supply and demand units as well as infrastructure investments across sectors and energy vectors. It is shown that local incentives can lead to a substantial increase in the number of operating hours of a power-to-gas plant and significantly raise the potential for grid-friendly operation of a P2G plant compared to zonal pricing. This research closes a gap in the literature regarding the implications of local incentives on sector coupling technologies and highlights the importance of the electricity market design for an efficient and effective expansion of sector coupling technologies.

Session 11:00 – 12:15
Flow-based Market Coupling

Virtual Room: Joule
Chair: Martin Lieberwirth

Update on Flow Based Market Coupling Parameters - From minRAM to Generation Shift Key

Constantin Dierstein, TU Dresden

Flow-based market coupling in multi-level electricity market models

Lucas Lang, FAU Erlagen-Nürnberg

Flow Based Market Coupling in Fundamental Electricity Market Models: Methods and Parametrization for Renewable-Dominant Power Systems

Richard Weinhold, TU Berlin

Update on Flow Based Market Coupling Parameters From minRAM to GSK

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Keywords: Flow Based Market Coupling, Optimization, Generation Shift Keys, minRAM

Abstract

Since the introduction of Flow Based Marked Coupling (FBMC) in 2015, science and practice have been concerned with the determination and optimization of the individual parameters within the market coupling process. In the process, the requirements have changed significantly since then. Especially due to the introduction of a guaranteed transmission capacity on lines which has to be available for trading (minRAM) and which will increase significantly in the next years as well as the extension of FBMC from the CWE region to the CORE region. In this context, parameters are to be standardized and unified. This applies in particular to the Genration Shift Keys (GSK). This raises the question which of the already established strategies for the determination of GSKs, which differ strongly from TSO to TSO, is suitable for a cross-zonal standardization. Furthermore, Schönheit, Dierstein & Möst (2020) were able to show that there is a direct correlation between the GSK strategy and the effects of minRAM. For this purpose, different minRAMs and different GSK strategies were examined and evaluated on the model side for their welfare effects. Starting from this basis, which is presented for discussion, this paper is extended by an optimization approach which aims to determine optimal GSK strategies. For this purpose, basedon real available data, it is examined which GSK parameters the power plants have actually applied. By means of an optimization model, the GSK are calculated in such a way that they reflect the actual power plant deployment based on the change of the net position of the respective bidding zone and depending on the available D2CF files at minimum deviations. The result of the investigation shall be an estimation which GSK strategy best reflects the real power plant dispatch changes and whether further strategies and concepts can be derived. In addition, the minRAM problem will be addressed, where an alternative strategy will be investigated for possible (welfare) effects. The Results are only preliminary results so far.

Flow-based market coupling in multi-level electricity market models

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Keywords: Flow-based market coupling, investment, generation capacity, transmission capacity, anticipation

Motivation

Flow-based market coupling was introduced in the CWE region in 2015 as the future way of allocating cross-border capacity. In contrast to the previously used NTCs, its calculation of the trade parameters is more transparent but follows a non-straightforward procedure. Grid characteristics are considered in the market in the form of a zonal PTDF-matrix, which is calculated based on Generation Shift Keys, an approximation of nodal weights within a price zone. This calculation makes the trade parameters dependent on medium-term market results: When considering investments in transmission and generation capacity, the market participants might anticipate their own influence on the trade parameters (for example changing the Generation Shift Keys), which leads to circular problems. Thus, the calculation of a market equilibrium including medium-term investment decisions needs a specifically designed solution algorithm.

Methods

In order to analyze flow-based market coupling including investment decisions, we use a multi-level electricity market model. On the first level, the grid planner creates an initial investment plan for new transmission capacity by anticipating a reference-day market result without investment in generation capacity and calculates the flow-based parameters on that. Firms acting on the spot market for electricity observe the trade parameters and determine the market result including investment decisions on the second level. On the third level, congestion management is calculated in order to make the market result feasible. After this, the network planner is assumed to be able to make an adjustment on the investment plan in transmission capacity in an additional loop, but generation investment is not adjusted anymore. In this way, the circular problems of investments in a flow-based market coupling environment are accounted for, but the model remains solvable.

Results

The solution algorithm is applied on a simple example network, which is designed to depict the CWE-region. Results for the flow-based application show differences regarding welfare distribution, capacity investment decisions and the overall market equilibrium, when comparing it to usual market designs like NTC-based price zones or nodal pricing.

Flow Based Market Coupling in Fundamental Electricity Market Models: MethodsandParametrization for Renewable-Dominant Power Systems

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Keywords: Flow Based Market Coupling, Optimization, Generation Shift Keys, minRAM

Abstract

Europe's increase in electricity production from renewable energy resources (RES) in combination with a signif-icant decline of conventional generation capacity has spawned political and academic interest in the transmission system's ability to accommodate this transition. Central to this discussion is the efficiency of capacity allocation and congestion management (CACM) policies between and within electricity market areas that are interconnected byshared and synchronized transmission infrastructure.To facilitate unrestricted cross-border electricity trading in the presence of finite physical transmission capacity,European system and electricity market operator inaugurated flow-based market coupling (FBMC). FBMC is a coordinated multi-stage process that requires detailed forecasts and network models, which are typically not or only partially disclosed by the system operators. Academic publications that synthesize FBMC in model frameworks agree on a three-step process – D-2 (basecase), D-1 (day-ahead) and D-0 (redispatch) – but differ greatly in some core assumptions. Further, FBMC effectiveness for a future renewable-dominant generation mix is typically overlooked in the current literature. Our work provides a comprehensive overview on existing FBMC approaches and assumptions and explicitly discusses the impact of high shares of intermittent generation. Theses discussions are supported by quantitative experiments on common test-systems and real-world data sets using the open-source Power Market Tool (POMATO). Further, we present a risk-and uncertainty-aware extension of the FBMC framework using chance constraints. Here, look-ahead stages (D-2 and D-1) of the FBMC process internalize statistical information on load and RES uncertainty. Preliminary results show that a carefully parametrized FBMC process can remain effective even with high shares of intermittent generation, when it is robustified against forecast uncertainty.

Session 11:00 – 12:15
Flexibility / Decentralized energy systems

Virtual Room: Watt
Chair: Christoph Zöphel

Assessing the value of demand response in a decarbonized energy system - a large-scale model application

Steffi Misconel, TU Dresden

Modelling Electricity Storage Needs in Europe: A Separation of Driver

Alexander Roth, TU Berlin

Exploring the trade-off between cost and security of supply for decentralized autonomous energy systems

Febin Kachirayil, University of Aberdeen

ASSESSING THE VALUE OF DEMAND RESPONSE IN A DECARBONIZED ENERGY SYSTEM - A LARGE-SCALE MODEL APPLICATION

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Keywords: demand response, flexibility option, 100% renewable energy system, decarbonized power system, power system optimization model

Motivation

The European Green Deal announced the overarching aim of making Europe climate neutral until 2050. Regarding this ambitious emission reduction target, the power sector plays a crucial role, as the sector is responsible for around 25% of the GHG emissions in Europe. Additionally, the electrification of demand side sectors increases the importance of decarbonization measures for the electricity sector. For a sustainable transition, very high shares of renewable energy sources (RES) have to be integrated into the energy system. However, the intermittent nature of weather-dependent RES leads to an increasingly fluctuating electricity supply and induces a higher demand for power system flexibility, on both supply and demand side. Particularly, demand response (DR) is one promising option to increase load flexibility, since the increasing amount of stakeholder actively participating in energy supply and demand on regional level (e.g. distributed small-scale technologies) are also included.

Methods

This research presents extensive insights on the value of applying DR in a system perspective against the background of two strongly contrasting decarbonization pathways for a decentralized and centralized European energy system with a 100% renewable share and sector coupling. The pathways are characterized by structural differences concerning the combination of installed renewable capacities, the acceptance for activated DR potentials and different electricity, heat and hydrogen demands. The objective is to determine the potential role of DR and its impact on the optimal combinations of flexibility options in a decentralized vs. centralized scenario framework model-endogenously. Therefore, openly available data and hourly time series of country-specific DR potentials are implemented into a large-scale linear optimization model. Sensitivities concerning varying shares of DR availability are used to identify main influencing factors on selected components of the electricity system such as the capacity and generation mix,

storage requirements, renewable integration and their market value factors, CO_2 emissions and total system costs.

Results Model results show a higher reduction of total system costs and CO2 emissions per activated DR unit in the PV dominated decentralized scenario (-55 MEUR/GWDR, -0.045 MtCO2/GWDR), compared to the wind dominated centralized scenario (-39 MEUR/GWDR, -0.037 MtCO2/GWDR). The outcomes conclude that the daily PV feed-in characteristics have a higher correlation with the time pattern of load shifting and shedding DR appliances than wind feed-in characteristics.

Modelling Electricity Storage Needs in Europe: A Separation of Drivers

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Keywords: power system modelling, flexibility provision, electric storage, renewable energies

Motivation

Wind and solar PV are the most relevant renewable energy sources in many European countries when it comes to decarbonizing the European economy. Increasing the share of such variable renewables in electricity demand requires increasing flexibility in the power system to deal with the variability of sun and wind. The literature identifies interconnectors and electricity storage as substitutes to a certain degree. Our paper intends to disentangle this trade-off. In the literature, such systematic account of the trade-off between spatial and temporal flexibility and, especially, a systematic account how spatial flexibility influences the need for temporal flexibility is missing. We contribute to filling this gap. This analysis is carried out in the context of the research project Modezeen, supported by BMWi.

Methods

In an application to central Europe, we aim to shed light on how and why the level of interconnectivity with neighbouring countries influences domestic storage requirements. Specifically, we separate the drivers for storage requirements in interconnected vs. “autarky” settings: (1) differences in countries’ load profiles, (2) differences in renewable generation profiles, and (3) differences in generation portfolios. To disentangle why and how spatial flexibility shapes the need for temporal flexibility, we use the Dispatch and Investment Evaluation Tool with Endogenous Renewables (DIETER). This is a numerical optimization model of the European electricity system. It minimizes total system costs of providing electricity for one year in an hourly resolution and includes temporal flexibility options such as short-term batteries, pumped-hydro storage, long-term power-to-gas storage as well as hydropower reservoirs.

Results

Preliminary results show, in line with the literature, that storage requirements for electricity in Europe decrease with increased interconnection. Storage needs are highly heterogeneous and strongly depend on the assumed weather patterns. We find that existing, hence differentiated, weather patterns do not strongly decrease the need for storage compared to a counterfactual

scenario with uniform weather in all Europe. Differentiated demand patterns in contrast have an effect. In both cases, energy and power requirements are affected differently.

Exploring the trade-off between cost and security of supply for decentralized autonomous energy systems

Febin Kachirayil[1], David Huckebrink[2], Jann Michael Weinand[3], Max Kleinebrahm[3], Valentin Bertsch[2], Russell McKenna[1]

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Keywords: Security of Supply, 100% Renewable Energy System, Energy System Modeling, Value of Lost Load

Motivation

Decentralized autonomous energy systems can enable the transition to a fully renewable energy supply while empowering local communities. However, energy autonomy leads to large cost increases due to the storage requirements to ensure the security of supply, particularly in the face of intermittent generation. Demand-side options allowing for load shifting or shedding can mitigate this cost increase. The Value of Lost Load (VoLL) describes the costs associated with an interruption of the power supply based on the value of the foregone energy services due to the shed load. It allows to investigate the trade-off between cost and supply security by translating a reduced security of supply into monetary terms.

Methods

First, a household-level VoLL is determined for all German districts that takes into account that the value of leisure varies based on the region and time of the day. The VoLL is then integrated into the energy system optimization model RE^{3}ASON as an option for load shedding. By considering the heat and electricity demand from the residential sector using a scenario analysis, the trade-offs between total system costs and security of supply are quantified. The analysis considers a system with imports as a reference case to be contrasted against systems that impose power autonomy, still allowing for fuel imports, and energy autonomy, i.e. an off-grid system, each with and without the VoLL.

Results

Two different case study municipalities in Germany are selected. For both, the impact of the VoLL on the cost increase due to energy autonomy and the security of supply is analyzed. The results show that the VoLL allows to cut the cost increase by about a third even while a security of supply

of >99% can still be ensured. Further, we show when the load is shed and which services are replaced by VoLL.

Session 11:00 – 12:15
E-Mobility

Virtual Room: Coulomb
Chair: Julia Gutierrez

Battery-electric vehicles: open-source modeling of time series data and their application in power system models

Carlos Gaete, TU Berlin

Evaluating policy instruments for the balancing of renewable energies using electric vehicles:
On the interplay between distribution and transmission grids

Anya Heider, Reiner Lemoine Institute

Cost-benefit Analysis of Residential On-Site E-Car-Sharing

Carlo Corinaldesi, TU Wien

Battery-electric vehicles: open-source modeling of time series data and their application in power system models

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Keywords: battery-electric vehicles, open data, electric mobility, power system model, smart charging, flexibility provision

Motivation

The fleets of battery-electric vehicles (BEV) are expected to increase substantially around the globe. This will have multiple effects on the power system as electricity demand increases, its temporal pattern changes, and a new potential source of flexibility becomes available. A growing literature of model-based studies aims to identify such effects of battery electric vehicles in future power systems from an economic and technical perspective. Such analyses require time-series of electric vehicles as a central input. Yet such data is scarce, often specific for small regions, and subject to data protection.

Methods

The purpose of our contribution is twofold. First, we introduce an open-source, python-based tool, *emobpy,* that flexibly generates battery-electric vehicle profiles based on mobility statistics, physical properties of vehicles, and customizable assumptions. A profile comprises four hourly time series: a vehicle's mobility, driving electricity consumption, grid availability, and, optionally, grid electricity demand. Second, we generate a series of BEV profiles for Germany and use them in the open-source power sector model DIETER to assess the effects of different charging patterns on the electricity system. We compare the effects of user-driven charging versus system-optimized charging on the total costs of the power system and integration of renewables in a mid-term future scenario with a large BEV uptake and ambitious renewables targets.

Results

Preliminary results show over-proportionately increasing costs to the electricity system on the BEV penetration in case of user-driven charging. Under system-optimized charging, the costs increase largely proportionally with BEV penetration. Here, charging mostly takes place in hours of high renewable generation. Additional flexibility is provided in a vehicle-to-grid (V2G)

configuration where charging and discharging of BEV are driven by a system-optimized approach. Here, total system costs reach a minimum between 5 and 10 million BEV and are even lower than in the reference scenario without BEV, despite additional electricity demand. For very high renewable penetration levels, total system costs remain below the reference scenario even in a scenario with 40 million BEV and V2G.

CV

Since November 2018, Carlos is a Research Associate in the Energy, Transportation, Environment Department at the DIW Berlin. He is also an associate member of the Sustainable Industrial System group at The University of Manchester. He received his PhD in July 2019 from The University of Manchester. His dissertation consisted of a sustainability assessment of electricity generation by implementing optimization models and life cycle assessment (LCA). He holds an Industrial Engineering degree and has about ten years of experience in economic, social, and environmental projects. His research has been published in Applied Energy, Journal of Cleaner Production, and Science of the Total Environment. His research interests include sustainable energy, energy transition and transformation, energy storage, e-mobility and sector coupling using life cycle assessment, mathematical optimization, and machine learning techniques.

Evaluating policy instruments for the balancing of renewable energies using electric vehicles: On the interplay between distribution and transmission grids

Anya Heider[1,2], Stephanie Halbrügge[3], Alexandra Märtz[4], Paul Neetzow[5], Martin Weibelzahl[3]

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Keywords: Electric mobility, infrastructure investments, renewable energy sources, smart charging

Motivation

Climate change calls for a worldwide reduction of CO_2 emissions. Therefore, major decarbonisation efforts must be realised both on the energy supply side (by integrating renewable energy sources (RES)) and on the energy-consumption side. In this context, the electrification of the mobility sector – mainly in form of electric vehicles (EVs) – promises significant emission reductions. However, to successfully decarbonize the mobility sector, EVs must be able to make use of the intermittent supply of RES. One possibility to match charging demand with electricity supply are smart charging and vehicle-to-grid technologies. While both RES and EVs are typically located at the distribution grid level, the transmission grid may be required to transport electricity over longer distances to balance regional deviations in supply and demand structure. Neither transmission grids nor distribution grids were originally designed for such complex regional and temporal interplay and therefore require large-scale investments.

Methods

In this paper, we want to assess the potential of EVs as new and highly relevant electricity consumers that provide flexibility to balance power demand and supply, while taking into account the interplay between the transmission and distribution grid. Based on an economic market model for the German power system that accounts for different policy options for EV (charging) and their effect on network investments on both the transmission and distribution grid level, we analyse the potential of EVs to balance the overall grid and reduce network investments when appropriate policy instruments are used to coordinate transmission and distribution grid. We compare the effect of different charging strategies on the distribution and transmission grid.

For these charging strategies, we determine the available flexibility to shift load and assess grid congestion and necessary grid investments.

Results

We gain insights on the interplay of TSOs, DSOs and EV owners with respect to the deployment of flexibility that is inherent to EV charging processes. We evaluate different charging strategies and policy instruments with respect to their ability to promote a smart balancing of RES and EV in the German power system. In fact, our results promise significant potentials for network investment and system cost reductions.

Cost-benefit Analysis of Residential On-Site E-Car-Sharing

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Keywords: Electric Mobility, Mixed-Integer Optimization Model, E-Car-Sharing, Flexible Energy Systems, Prosumer

Motivation

Electric vehicles are a necessary alternative to conventional cars to meet the global and national targets set in the 2016 Paris Agreement. Furthermore, the concentration of traffic in urban centres leads to pollution and poor air quality in cities. The growing popularity of electric vehicles is slowly fading these effects, but multiple obstacles hold the rapid expansion of electric cars back. One of them is that the acquisition costs are higher than an automobile with an internal combustion engine. E-car sharing concepts seem to be a promising practice to face this challenge, as ownership costs can be spread among many users. Various studies have shown the positive impact of different e-car-sharing approaches on urban sustainability (Roblek, Meško, & Podbregar, 2021). Especially when it comes to residential buildings, the added value of shared mobility gets visible as parking space can be reduced while maintaining the mobility offer. This work is part of the Car2Flex project and investigates the feasibility and economic benefits of residential on-site e-car-sharing.

Methods

This work proposes a simple and complete method to describe residential energy management systems' optimal operation with different technologies and set-ups, as shown in Figure 1.

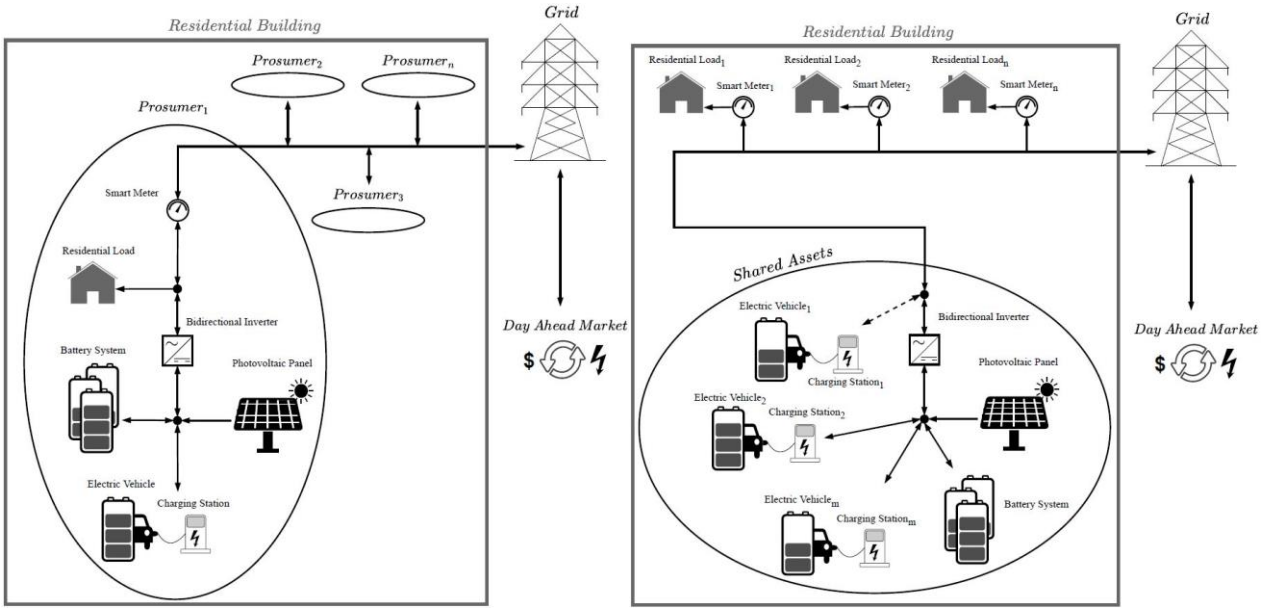

Figure 1: Individual (left) and Sharing (right) set-up of one residential building

A mathematical optimization problem is defined to determine the optimal investment of each inhabitant in various set-ups and multiple technologies, such as photovoltaic panels, electric cars, charging stations (unidirectional and bidirectional ones) and batteries. Furthermore, considering the grid costs, the trading on the Day-Ahead spot market is optimized to minimize the overall costs. Moreover, in this work, the case of a sharing approach, as shown in Figure 1 (on the right), is simulated. In this case, a joint investment is made, and different methods are investigated to share the costs and the resulting earnings.

Results

This work presents a comprehensive overview of modelling residential energy management systems and evaluating optimal investments in different set-ups and multiple technologies. Furthermore, the potential of residential on-site e-car-sharing for a real-life use case with measured data is investigated. Comparing the considered technologies in different set-ups, we identify various diversities and potentialities. Applying the e-car-sharing approach, we observe how the number of the required electrical vehicles decreases ($m < n$ in Figure 1) and how the joint investments in photovoltaics and batteries can be more profitable for all the stakeholders involved.

Acknowledgement

The Car2Flex project is supported with the funds from the Climate and Energy Fund and implemented in the framework of the RTI-initiative “Flagship region Energy” and is part of the research initiative “Green Energy Lab”.

Session 13:15 – 14:30
Environmental Policy Instruments

Virtual Room: Volt
Chair: Michael Bucksteeg

EU Emissions Trading at Crossroads

Andreas Schröder, ICIS

The European Market for Guarantees of Origin for Green Electricity:
A Model-Based Evaluation of Future Price Scenarios

Reinhard Madlener, RWTH Aachen

The impact of carbon prices on power sector emissions:
insights from a model-comparison experiment

Oliver Ruhnau, Hertie School

EU Emissions Trading at Crossroads

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Keywords: Carbon, EU ETS, MSR, emissions

Motivation

The ongoing reform process around the EU Emissions Trading System (EU ETS) keeps markets busy and prompted significant price moves with carbon prices recently crossing 40 EUR/t. Much of the current market nervousness is attributed to the lack of foresight on Europe's 2030 target translation into EU ETS rules and on the role of the market stability reserve (MSR), currently a major price driver.

Methods

We apply an agent-based model of the EU ETS accounting for allocation, auctions, compliance demand and speculative positions. The supply and demand balance rests on official statistics from EU sources supplemented with assumptions of behavioral trading patterns going forward. Scenario-based analysis simulates the impact of the policy reform on prices and market balance. We add detailed analysis of financial players' positions relating to data from reports published in the context of the financial market regulation (MIFIDII)

Results

Our modelling suggests that a review of the MSR settings remains particularly important for the middle part of the current trading period, mainly defining the market balance during the years 2024 to 2026. With the 2030 cap setting being revised, the MSR reduces its impact on the market balance and remains in place as a backstop in case of a system shock. Our modelling highlights that re-basing the cap at an early stage results in the most steady price trajectory bridging towards a higher climate ambition and decreasing the importance of the MSR as a scarcity provider. With early rebasing in place, we see EUA prices hitting the €80/t level towards 2030, while most other scenarios land in a €50/t to €60/t corridor towards the end of phase 4.

The European Market for Guarantees of Origin for Green Electricity: A Model-Based Evaluation of Future Price Scenarios

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Keywords: renewable energy, green electricity, policy, willingness to pay, power purchase agreement, Europe, guarantees of origin

Abstract

Because electricity is a homogeneous commodity, the origin of a specific MWh of delivered green electricity cannot be determined. Thus, Guarantees of Origin (GoO) were introduced in order to provide more transparency on the production of green electricity in Europe. The separation of electricity and GoO trade has resulted in a prosperous GoO market that is, however, still characterized by non-transparency and speculative behavior. Historical price movements seem to have occurred rather arbitrarily and thus cannot be employed straightforwardly for GoO price predictions. The aim of this paper is to first provide a review of the development of the European GoO market and an analysis of the historical GoO price development. Second, we introduce a new model that is based on an average company's ability to pay (ATP) for green electricity in a specific sector of the economy, computed as the ratio of profit and electricity costs, and a measure of environmental concern. This enables to determine future price developments of European GoOs for different renewable energy technologies in different countries up to 2040. The proposed model seems beneficial for various reasons. For instance, it may be used by regulators for determining whether the European GoO system is in need of reform. Other stakeholders, such as project developers or investors in renewable electricity production plants, can make use of the price predictions in order to calculate the profitability of their investments. Four different scenarios are considered, basing the ATP assumptions on structural data from Eurostat, and those on environmental concern on different NACE sectors' exposure to environmentally concerned consumers (private and commercial). We find that GoO prices, on average, can be expected to increase in the next years, at levels ranging from 1.77 to 3.36 €/MWh

in 2040. Coupled with a rising demand for green electricity and further standardization of issuance procedures as well as the projected price developments, GoO trading might indeed become a useful additional instrument for the promotion of green electricity production in the EU.

The impact of carbon prices on power sector emissions: insights from a model-comparison experiment

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Keywords: Carbon pricing, power sector, fuel switch, renewable energy, model uncertainty.

Motivation

Being the largest sector covered by the European Emission Trading scheme, the European power sector is one of the most-studied examples of carbon pricing. Existing analyses often use one individual model to study the development of carbon prices and emissions under a variety of assumptions. While parameter uncertainty is often addressed through sensitivity analyses, potential uncertainty about the models themselves remains unclear.

Methods

We study model uncertainty by running a structured model comparison experiment, where we expose five numerical power sector models to aligned input parameters. All models apply an hourly dispatch optimization to represent the partial equilibrium in the electricity market, given a large set of technical constraints, e.g., related to the cogeneration of heat. Some additionally model investment and decommissioning decisions.

Results

For the assumed carbon prices between 27 and 87 €/t, we find stark model differences despite identical input parameters. At 27 €/t, models estimate European power sector emissions to decrease to 390-650 Mt in 2030 (36-58% less than 2016). Most of the variation in these results is related to whether the models consider market-based decommissioning of coal- and lignite-fired power plants. Higher carbon prices of 57 and 87 €/t yield a further decrease in carbon emissions to 225-540 and to 180-490 Mt, respectively. The higher end of these ranges can be attributed to the short-term fuel switch captured by the dispatch-only models. The lower emissions

correspond to models which additionally consider market-based investment in renewables. Further studying country specific differences, we identify the representation of combined heat and power as a crucial driver.

Session 13:15 – 14:30
Load, efficiency and solar forecasting

Virtual Room: Ampere
Chair: Wolf-Peter Schill

Development of subsector electricity load profiles

Stephan Seim, TU Berlin

Analysis of energy-efficiency measures in multi-cylinder paper drying

Hélene Godin, Universität Stuttgart

Methodology to Improve the Predictability of Solar Energy Generation with Confirmatory Evidence from Germany

Kevin Forbes, UC Dublin

Development of subsector electricity load profiles

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Keywords: Long term electric load forecasting, Multiple Regression analysis, Subsector load profiles, Standard load profiles, Industrial and commercial loads

Motivation

The electricity demand in high temporal and spatial resolution has been and will be a critical factor in the assessment of transformation pathways for the future energy system [1]. For electricity load forecasts of industry and science in Germany, both internal and external studies [2], [3], [4] suggest that the current use of VDEW standard load profiles (SLP) is associated with significant structural deviations. As a result of the research project DemandRegio [5], we provide a possibility to reduce these deviations and depict a more differentiated and accurate mapping of electricity consumption, using newly developed subsector load profiles (*German: Branchenlastprofile*, BLP).

BLP can be used to replace partially outdated SLP [6] as well as input profiles for various energy system models [7], [8]. Moreover, BLP fill important data gaps [9] and transform personal and therefore sensitive load data into open, anonymized, averaged and usable data [8]. In addition, BLP provide an important reference to develop more detailed demand models with regard to underlying energy consuming applications. This increased level of detail allows to assess the technical potential of demand side response measures for specific commercial subsectors, which are under-explored currently [10].

Methods

BLP were derived from more than 1,100 metered load curves using a multiple regression method. The models were validated internally using 5-fold cross validation, an established validation method of machine learning science [11]. The external validation was carried out by evaluating load forecasts for 10 German DSOs as well as ENTSO-E loads for several years each [5].

Results

Using newly developed BLP, we succeeded to significantly reduce deviations in almost all load predictions, as demonstrated in Figure 1. Using SLP (left figure), the prediction residuals are significantly higher compared to using BLP (right figure). This corresponds with significant improvements of prediction accuracy measures for the ENTSO-E load as well as several DSO loads. Hence, the BLP of this dataset close several data gaps and can be seen as an updated extension of partially outdated SLP. The BLP have been recently published here [12].

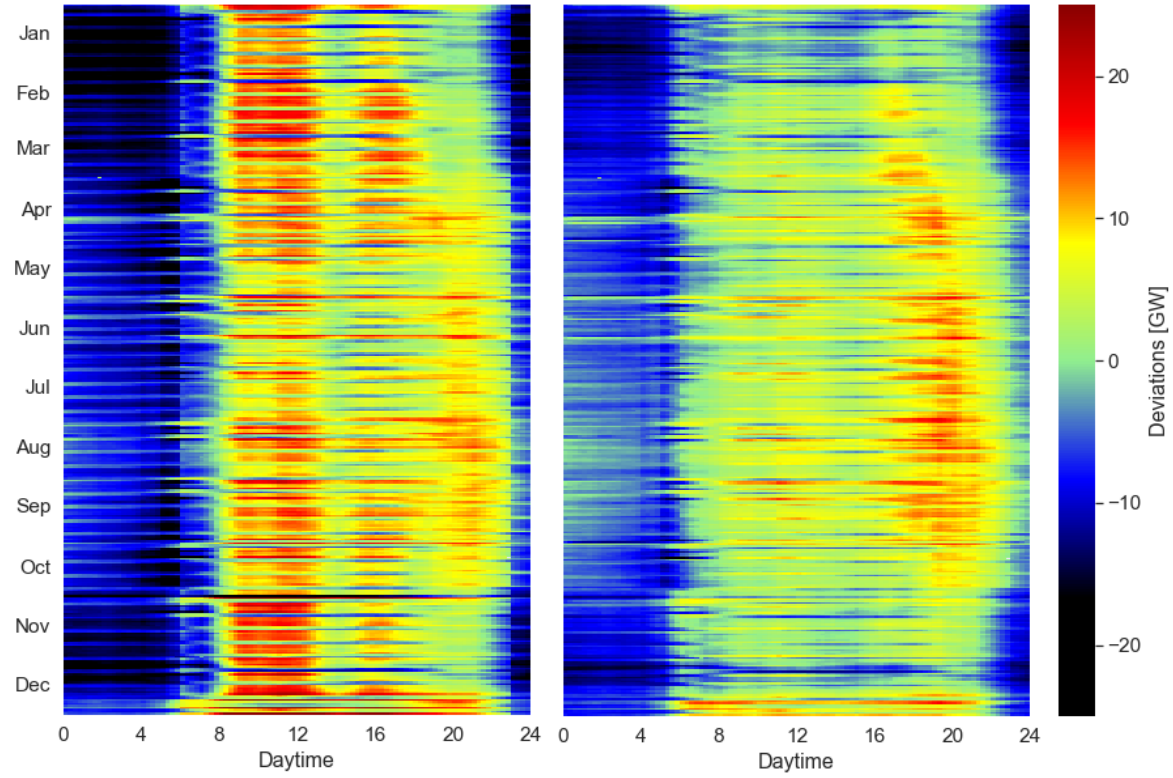

Figure 2: Residuals of the DemandRegio disaggregator tool forecasting the ENSTO-E load of 2019, using SLP (left) and subsector laod profiles (BLP) (right).

Analysis of energy-efficiency measures in multi-cylinder paper drying

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Keywords: Energy efficiency, Industry, Paper drying

Motivation

Paper drying is a heat-intensive process and is responsible for more than 65% of the energy demand of paper mills. Multi-cylinder drying is the most widespread paper drying technology. Energy-savings in paper drying can be achieved by reducing the amount of water to be evaporated in the drying process, decreasing the amount of energy needed for water evaporation, or increasing heat recovery. Adequate tools and frameworks are required to analyze the effect of energy-efficiency measures at those multiple levels for a given site.

Methods

An extended model of a multi-cylinder dryer section was developed as the combination of several modules encompassing the dryers, the hood, the heat recovery and the steam cascade. A calculation procedure was built on-top of the model to allow the quantitative assessment of the steam and electricity savings after the implementation of energy-efficiency measures.
The resulting framework was applied to a German paper mill to calculate the impact of energy-efficiency measures relevant at the analyzed site.

Results

The application of the framework to a German paper mill showed that a cumulated reduction of the heat and electricity demand respectively by 26 % and 7,4% is expected at the dry section for following selected measures: replacement of the film sizer with a curtain sizer, replacement of the drying cylinders made of iron cast with steel cylinders, and the installation of a closed hood around the dryer section. In certain cases, the cumulated effect of the measures is not equal to the sum of the effect of the individual measures. This highlights the importance of accounting for interactions when considering the implementation of several measures

A Methodology to Improve the Predictability of Solar Energy Generation with Confirmatory Evidence from Germany

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Abstract

As the energy transition proceeds, accurate forecasting of solar power energy generation will increasingly be seen as a necessary component of strategies to ensure the power grid's resiliency. Using data from the 50Hertz electric power system in Germany, this paper begins by observing that the current intraday solar energy forecasts do not fully reflect the day-ahead weather forecasts' information. The forecast errors also have the property of being autocorrelated. Based on those properties, an Autoregressive Moving Average with Exogenous Inputs (ARMAX) model is formulated. This modeling approach is widely used in financial economics, but its application in the atmospheric sciences seems somewhat muted. This modeling approach predicts solar energy generation based on the current forecasted solar energy generation and forecasted meteorological conditions. It also makes use of numerous ARMA terms that reflect the autocorrelative nature of solar energy generation.

The model was estimated using 15-minute data over the period 1 Jan 2014 through 31 Dec 2017. There are 70,189 daylight periods in the sample. The full model has an explanatory power equivalent to an R-Square of 0.9984, an encouraging value. However, it should be noted that a model's true adequacy can only be determined by considering how well it performs on data that were not used in its estimation. The model is evaluated using out-of-sample data over the period 1 Jan 2018 - 30 Aug 2020. The 15 minute-ahead out-of-sample predictions have a weighted-mean-absolute-percentage-error (WMAPE) of about 3.84%, substantially less than the WMAPE associated with the intraday solar energy forecasts reported by the system operator over the same period.

Session 13:15 – 14:30
TSOs & Grid Operation

Virtual Room: Joule
Chair: Constantin Dierstein

What a Transmission system operator (TSO) can do and needs for Green Europe in 2050

Christian Dobelke, TenneT

Efficient concertation of reactive power resources

Erika Kämpf, Universität Kassel

Contrasting countertrading mechanisms: market effects between Germany and Denmark West

Manuel Eising, EIFER

What a Transmission system operator (TSO) can do and needs for Green Europe in 2050

Christian Dobelke[1] , Dr. Ingo Schmidt[1], Dr. Eva Marie Kurscheid[1]

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In December 2019, the European Commission announced its Green Deal ambition to develop Europe into the first climate-neutral continent by 2050. TenneT, Europe's first cross-border TSO, based in both the Netherlands and Germany, has formulated its own ambition to be one of the thought-leaders in designing, shaping and implementing a reliable, sustainable and affordable European energy system of the future. Living up to the ambition means taking own steps to become climate-friendly, but to a much greater extent taking a facilitating role with innovative projects.

Yet, also innovative projects that leave the beaten tracks need a stable and reliable regulatory framework. Especially in the context of the upcoming TEN-E legislation which drives an offshore network along the EU offshore strategy, new regulatory options are needed to ensure financial health of TSOs. At the same time, regulatory authorities can steer TSOs towards the Green Deal's interim targets via financial incentives. Triggered by the Green Deal target of CO2 neutrality up to the year 2050, incentives on RES infeed facilitation by TSOs might be promising.

The remaining challenge in all regulatory regimes is covering the gap between spending money and getting the money back via grid fees – TSOs need both equity and debt to bridge this gap. Green taxonomy is not the first topic that comes to one's mind when considering contributions to a greener energy system. Yet, to support and drive the growing trend of green financing, TenneT suggests issuing new green debt. TenneT aims to drive the development of the sustainable debt market by both supporting its growth from today < 5 % of total debt market volume and by supporting the development of new sustainable debt products.

Efficient concertation of reactive power resources

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Keywords: Competitive procurement, reactive power, risk, efficiency, remuneration, reliability, e-mobility, wind, PV, STATCOM, TSO/DSO

Motivation

Rules for efficient, competitive procurement and remuneration of reactive power (Q) are about to be developed for Germany. Given the massive changes in loading profiles expected due to e-mobility and storage especially in distribution systems, uncertainty with respect to Q utilization frequencies of Q compensating equipment increases. It is therefore desirable to have a mixed portfolio of Q capacity which also contains low CAPEX resources. For HV, integration of these resources is comparatively easy. However, massive addition of Q capacity from e-mobility and renewable power plants is also expected for MV. The common perception is that due to network restrictions the majority of MV resources can only be used for voltage management during times of relevant feed-in. This contribution addresses a quantitatively relevant niche, which is the reduction of cross-voltage level Q transport that occurs during times of low system loading. If Q provision from storage and variable renewables was available independent from active power (24/7), they could contribute to reducing times of critically high Q export from distribution systems. This application is compatible with the mostly limited MV ICT infrastructure.

Methods

The contribution provides a structured reasoning based on own analyses and literature results. Related methodologies include hierarchical optimal power flow analyses, cost benefit analyses, Markowitz portfolio selection, and principles of system operation and investment planning. From these, principles for efficient concertation of connection code requirements with competitive pricing resp. price cap mechanisms are derived.

Results

Summarizing, a set of measures is suggested that would allow to tap a certain share of future Q capacity potential from third party resources in a cost-efficient way. The contribution concludes with a short outlook on regulatory adaptations, such as output based regulation, that are suitable to acknowledge the new type of asset that is created by operational concertation of distributed Q capacity considering grid restrictions.

Abbreviations:

EHV	Extra high voltage
HV	High voltage
ICT	Information and communication technology
LV	Low voltage
MV	Medium voltage
Q	Reactive power
e-mobility	Electric mobility

Contrasting countertrading mechanisms: Market effects between Germany and Denmark West

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Keywords: cross-zonal congestion management, redispatch, countertrading, Germany, Denmark

Motivation

The European electricity market lays out in a zonal market design. Transmission System Operators (TSOs) must cope with internal grid congestions using remedial actions. Limited transmission capacity and increasing VRE shares, caused increasing congestion management volumes in Northern Germany and cross-border constraints between Denmark and Germany in recent years.

In 2017 the Danish and German TSOs, Energinet and TenneT, signed a joint declaration to gradually increase cross-border capacities between Denmark West (DK1) and Germany (DE) available for the day-ahead market by securing minimum capacities (Energinet and TenneT, 2018). In case this minimum capacity could not physically hold due to grid constraints, TSOs shall use countertrading[1] in order to prevent congestions in the grid while ensuring the agreed minimum trade level. The analysis at hand is two-fold: first, comparing the redispatch and countertrading mechanisms between DK1 and DE. Second, quantify the drivers for countertrading activation as well as the market effects from countertrading, in particular its efficiency.

Methods

Using publicly available literature, the distinct redispatch and countertrading mechanisms in DK1 and DE are compared and characterised. To perform countertrading, Energinet activates mFRR, while TenneT demands volumes from the German continuous intraday market. Next, data published by the TSOs on their own websites and on the ENTSO-E transparency platform is applied to perform quantitative analyses. To identify drivers for countertrading a first round of

[1] In contrast to the location-specific redispatch, countertrading means a location-unspecific measure performed by one or several TSOs in one or several bidding zones in order to solve physical grid constraints where the location of activated generation is not known within the bidding zone (Kłos et al., 2020).

data exploration is performed to select data which shows indications of correlation with countertrading volumes in the DK1-DE border. To assess the impact on market results, linear regression analyses between the previously mentioned markets and countertrading volumes are performed.

Results

The results reveal wind forecast in Germany as significant driver for countertrading activation increasing from 2019 towards 2020. The dominant situation continues to be the provision of downward regulation in DK1 with TenneT buying volumes in the intraday market. Regression analysis suggests, that countertrading using the German intraday market costs about 2 to 4 EUR/MWh more than day-ahead market. The more countertrading is conducted, the more energy TenneT has to buy in the DE/LU bidding zone and the higher the intraday prices are relative to the day-ahead price for the same delivery hour.

Session 13:15 – 14:30
Energy behaviour

Virtual Room: Watt
Chair: Jens Weibezahn

The potential of sufficiency measures to achieve a fully renewable energy system – a case study of Germany

Citlali Rodriguez del Angel, TU Berlin

The Effect of Descriptive Information Provision on Electricity Consumption: Experimental Evidence from Lithuania

Fissha Marye, University of Vilnius

Reducing energy consumption and carbon emissions of residential buildings through behavioral change

Tarun Khanna, MCC Berlin

The potential of sufficiency measures to achieve a fully renewable energy system – a case study for Germany

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Keywords: macro-energy systems, sufficiency, decarbonization, sector integration

Motivation

The current scientific and public debate on climate mitigation is focused on technological solutions, whereas lifestyle changes receive far less attention. Sensible reductions of final energy demand, referred to as sufficiency measures, could facilitate and accelerate the reductions of emissions. In this context, the concept of sufficiency provides valuable guidelines for creating narratives of low energy demand futures. Against this background, we analyze the potential of sufficient demand side reductions and their impacts on the supply side of a 100% renewable energy system in Germany.

Methods

The German energy system is modeled as an island system using a greenfield capacity expansion model. 100% of the energy demand in Germany is satisfied through renewable generation. Energy demand which can technically not be met by electricity is provided through electrolysis and methanation of renewable electricity. The energy system is split into three sectors: conventional electricity generation, mobility, and heat. Based on an extensive literature review, detailed sufficiency measures to reduce or shift energy demand in each of the considered sectors are derived. These assumptions are used to modify the exogenous demand assumptions of the model to quantify their effects on the costs and design of the system. For an independent quantification of effects, sectoral impacts are first modeled individually, before cases are run combining sufficiency measures for all sectors with different levels of ambition.

Preliminary results

Of all sectors considered, the mobility sector shows the highest potential for demand reductions based on the identified measures, followed by heat and electricity supply. In the reference scenario, preliminary model results show an overall capacity demand of approximately 960 GW of PV and 380 GW of wind power capacity. Demand reductions based on sufficiency assumptions

significantly reduce the necessary PV capacity of the German energy system. Correspondingly, total system costs are reduced by up to 20% in the high ambition scenario. The results indicate that there is a need to further study the potential impact on sufficiency measures and how they can be implemented in a way also sustainable from a social perspective

The Effect of Descriptive Information Provision on Electricity Consumption: Experimental Evidence from Lithuania

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Keywords: Electricity, Field experiment, Descriptive information, Smart meters, Household data, Lithuania

Motivation

Studies on the effects of information provision on residential energy use conclude that such information can promote households' energy-saving investments and conservation behavior. However, most of these studies are conducted in the U.S. or in other OECD countries, where households, on average, are richer, consume more electricity and have stronger environmental concerns. Furthermore, most of these studies analyze interventions in the form of social comparisons combined together with energy saving tips and other information. To the best of our knowledge, there are only few studies that aim to estimate the effect of *purely descriptive* personalized information provision on households' electricity use. Therefore, our study contributes to the literature by first conducting a filed experiment in Lithuania, a recent OECD member country, which is different from other old OECD countries in terms of income and energy intensity. Second, we estimate the effect of *pure* descriptive information provision on households' electricity use without combining it with other normative type of information, such as energy saving tips or goal setting.

Methods

We used a panel data collected one year before the experiment and one year after the experiment started in July 2016. We use difference-in-differences (DID) models estimated in OLS by using the standard fixed-effects estimator with Huber-White standard errors, which are clustered at the unit of household to account for serial correlation to get the ATEs.

Results

First, we find that, on average, descriptive information provision reduces electricity consumption by 0.661 kWh (or 8.6%) per day in Lithuanian households. This is equivalent to an annual energy savings of 241 kWh per household. Second, the quantile treatment effects (QTEs) results reveal

that a large reduction effect of descriptive information provision is observed at the highest percentiles of the electricity consumption. The higher the percentile, the higher the impact. Much higher reduction effects are observed for consumption levels above the 75th percentile.

Reducing energy consumption and carbon emissions of residential buildings through behavioral change

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Keywords: Energy and climate, Social norms and energy efficiency, Time of Use pricing, Policy Analysis, Buildings

Motivation

A lack of systematic efforts to quantify demand side solutions, in general, and specifically, interventions that foster behavioral change (feedback, social norms, monetary incentives etc.) towards reducing energy consumption, has led to a bias towards riskier supply side solutions in climate change assessments such as those by the IPCC.

Methods

We provide what we believe is the most comprehensive, machine-learning assisted, comparative meta-analysis of behavioral interventions targeting household energy consumption in residential buildings. We identify 122 studies and extract 360 effect sizes representing trials on 1.2 million households in 25 countries. Based on this comprehensive evidence base our analysis highlights which interventions work best, in what combinations and provides a simple emission reduction wedge.

Results

All the studied interventions reduce energy consumption of households, but monetary incentives are on an average more effective than behavioral interventions. Most importantly, for the first time we provide evidence from a meta-analysis supporting the hypothesis that deploying combinations of interventions together can increase the overall effectiveness pointing towards smart policy packages. Overall, we estimate a global carbon emissions reduction potential of 0.39 Gt CO_2 yr^{-1}, though deploying the most effective packages and interventions could result in greater reduction.

Session 13:15 – 14:30
Gas Infrastructure

Virtual Room: Coulomb
Chair: Hendrik Scharf

Assessing the Impact of Uncertainties on Infrastructure Developments in the European Natural Gas Market: A robust optimization approach
Matthew Schmidt, TU Dresden

Modelling the impact of the energy transition on gas distribution networks in Germany
Johannes Giehl, TU Berlin

Trial of Basic Control Strategies of Gas Supply and Distribution Networks to Allow Integration of Renewable Gases from Distributed Production
Johannes Ruf, DVGW

Assessing the Impact of Uncertainties on Infrastructure Developments in the European Natural Gas Market: A robust optimization approach

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Keywords: European Natural Gas Market, Uncertainty Modelling, Robust Optimization

Motivation

Natural gas is a key energy source in modern economies, finding application in heating, electricity generation as well as a feedstock for industrial processes. In Europe, the domestic production of natural gas is steadily decreasing coupled with an increasing worldwide consumption, meaning that Europe's dependence on natural gas imports is set to rise while competition for foreign resources concurrently increases. This uncertainty is likely to present infrastructural challenges as increased transportation capacities are required to facilitate the delivery of new gas sources, e.g. LNG. Furthermore, due to climate targets, the utilization of natural gas for electricity and heating applications is subject to considerable uncertainty. The intersection of these uncertainties poses questions about strategic infrastructure investments, e.g., Projects of Common Interest (PCIs), to ensure supply security.

Methods

While a variety of approaches, ranging from scenario-based analyses to stochastic programming, have evaluated uncertainties in the European natural gas market to date, the proposed analysis contributes to the literature by employing an adaptive robust optimization approach. Robust optimization involves the minimization of system costs under the worst realization within an uncertainty set. This approach can be valuable when confronted with long-term uncertainties where probability distributions are unknown, risk-averse investment is preferable or solutions exhibit strong sensitivity to minor changes in the assumptions or data sets. In the case study performed for the European market, adaptive robust optimization (ARO) is applied to a linear, bottom-up model of the European natural gas network for the year 2030. Drawing on research from Minguez & Garica-Betrand (2017) and Baringo et al. (2020), discrete polyhedral uncertainty

sets are employed. The sets are constructed to capture levels of uncertainty expressed in scenarios in the TYNDP regarding both demand and supply volumes. The degree of conservatism of the solution is controlled via uncertainty budget functions. The ARO model takes on the structure of a three-level optimization problem. In the first level, the cost-efficient investment decision is subject to the worst-case realization of the uncertain parameters in the second level and the recourse dispatch decisions in the third level, made to minimize the system costs and ensure feasibility.

Results

Investigating the pipeline and LNG regasification terminal projects in 4th PCI list, initial results indicate that under worst-case realizations of demand uncertainty, select projects are economically prudent from a system perspective. In the case of combinations of worst-case realizations of supply demand uncertainty, the proposed investment projects do not appear situated to economically ensure reliability of the European gas infrastructure. Further analysis currently being undertaken, the findings of which will be ready for the conference, aim to parse the underlying dynamics concerning the implications of supply and demand uncertainty as well as explore alternative investments that might prove economically efficient in a reliability context.

Modelling the impact of the energy transition on gas distribution networks in Germany

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Keywords: energy transition, heating transition, model network analysis, gas distribution grid, synthetic gas, defossilization

Motivation

The energy transition is leading to profound changes in all parts of the energy system. The reduction of fossil fuels in the heating sector is a major challenge for the energy sector. The changing heat-generating structure also affects its supply infrastructures. Impact on existing infrastructure in electricity is evident and subject to a lot of research. Gas distribution networks are not considered in most studies. Although, defossilization will change their role significantly. Assumption of gas as a bridge technology might lead to potential lock-ins or sunk costs. The central question is how gas distribution networks will change by 2050 as we move toward a greenhouse gas neutral (GHGN) energy system

Methods

The research question is answered by using a model network analysis to compute the infrastructure development and associated cost for existing GHGN scenarios until 2050. The supply task and the necessary network elements with their physical parameters are included in the model. The cost-optimal gas distribution network infrastructure is calculated for each county in Germany.

Results

The infrastructure analysis shows a declining need for gas distribution networks for all given GHG-neutral scenarios. In all-electric scenarios, the network length of the required grid infrastructure decreases to zero by 2050. Even in moderate scenarios with high shares of synthetic gas in the heating system, less gas distribution infrastructure is needed. The results of this paper can be used to support the necessary measures to ensure the contribution of gas distribution networks towards GHGN.

Trial of Basic Control Strategies of Gas Supply and Distribution Networks to Allow Integration of Renewable Gases from Distributed Production

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Keywords: smart gas grid, hydrogen feed-in, renewable gas, gas grid modelling, STANET

Motivation

The future role of methane gas as a significant energy carrier and the contribution of the existing natural gas infrastructure and its assets to a rapid, potentially partially disruptive but necessarily sustainable and socially just energy transition is one of today's most relevant research topics. This work focusses on possible controlling interventions to minimize implications caused by the integration of hydrogen on the grid level to which most gas consumers are connected to.

Methods

First, control mechanisms of the gas infrastructure were investigated within a field test followed by the modeling of the gas infrastructure and a simulation combining characteristics of discreet-event and quasi-stationary simulation. For the simulation part, the software STANET was used. In the experimental part, tetrahydrothiophene (THT) was fed into the gas grid of a German city at a gas transfer station and its concentration was measured at four pre-selected locations of the low-pressure grid. THT was injected instead of hydrogen for handling and measurement reasons. The obtained measurement data was then used to validate the developed gas grid model and to better understand the effects of the controlling interventions on volume flows and pressures.

Results

(a) The controlling interventions with existing equipment, (b) the online-measurement of the effects on the propagation of the trace gas, and (c) the simulation of interventions and outcome with a high-resolution node-edge-model were successfully demonstrated. The developed tools and findings of this work are the groundwork for the development of control strategies for grid areas with high penetration of renewable gases. Today's grid operation toolbox need to be extended and detailed. For highly meshed low-pressure network areas with supply from multiple pressure regulating stations, model-based approaches for intervention-planning and -monitoring seem promising.

Keynote 14:45 – 15:30

Virtual Room: https://tu-dresden.zoom.us/j/86212114942

Covid-19 - Merely an interruption or the death blow for the international coal market?

Prof. Dr. Pao-Yu Oei[1] & Paola Parra[2]

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