ENERDAY

12th Conference on Energy Economics and Technology

Market and Sector Integration - National and European Perspectives

Book of Abstracts

27th April 2018

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Foreword

Dear participants of the 12th ENERDAY Conference on Energy Economics and Technology,

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 ENERDAY, the 12th Conference on Energy Economics and Technology, focusing this year on *Market and Sector Integration from National and European Perspectives*.

Europe has committed itself to ambitious climate policy targets. With the year 2020 fast approaching, it is an important juncture to conduct a preliminary evaluation of the target achievement across Europe and determine 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. Against this background, this year´s ENERDAY conference is devoted to discussing the fundamental issues facing market and sector integration in Europe, including:

- how well are European markets integrated and which challenges are still to overcome?,
- what role does sector coupling play with regard to electricity systems, the integration of renewables and the targeted policy goals?,
- how well is the system integration of renewables working and how best can this be achieved?,
- what energy efficiency measures should be taken and which barriers still need to be overcome?,
- how can flexibility on the demand side be leveraged and which regulatory issues need to be resolved?

The 12th Conference on Energy Economics and Technology ("ENERDAY") provides a platform for discussing the pressing issues surrounding energy systems, markets and policies, with a special focus on "system, market and sector integration from a national and a European perspective". 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. Thus, ENERDAY aims to 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 DIW Berlin, the German Institute for Economic Research, and 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 DREWAG, the municipal utility of Dresden.

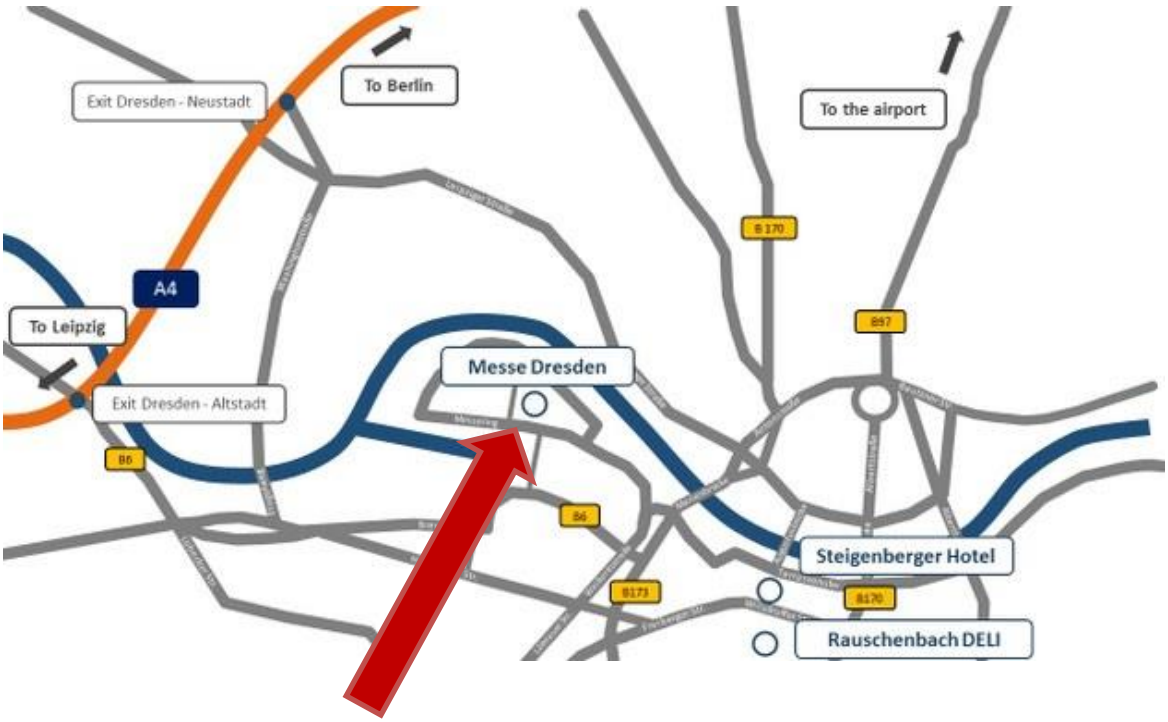
As the organizers of the conference, we were again delighted about the high level of interest shown by the research community, which is reflected in the internationality of the participants and the number of papers submitted. We hope you enjoy the high quality of the research presented. In this spirit, we are pleased to be able to contribute to facilitating a fruitful exchange of ideas and approaches and their practical application in the field of energy economics. 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 conference and an enjoyable stay in Dresden and its surroundings,

Dominik Möst and Christian von Hirschhausen

& EE2 organizing committee

Conference Location



MESSE DRESDEN GmbH
Messering 6
01067 Dresden

By public transport:

from Dresden main station:

- using tram 10 (MESSE DRESDEN-bound)
- exit for concerts and events: “Messering, HALLE 1” stop
- exit for other events: “Messering, HALLE 1” stop or “MESSE DRESDEN” stop (please check beforehand)

from airport Dresden:

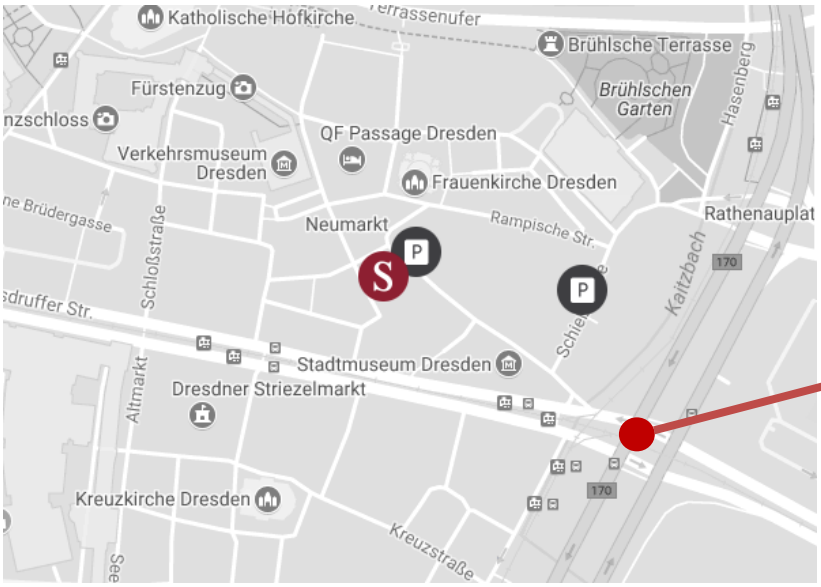
- Dresden Airport station - Saxony's only underground S-Bahn station - is on the lower ground floor of the terminal building.
- rhythm: every 30 minutes
- using S-Bahn S2 (Heidenau/Downtown-bound) to “Bahnhof Mitte”
- from “Bahnhof Mitte”, use tram 10 (MESSE DRESDEN-bound)
- exit for concerts and events: **"Messering, HALLE 1"** stop or **"MESSE DRESDEN"** stop (please check beforehand)

More information:
https://www.messe-dresden.de/en/visitors/arrival-parking

Gala Dinner

Friday, 27 April 2018, 7 pm

Steigenberger Hotel, Neumarkt 9, 01067 Dresden, Germany



By public transport:

from Dresden main station:

- Dresden Hauptbahnhof
  Distance: 1.6 km
  Estimated taxi fare: € 10 (one way)
- Local public transport: Tram N° 3 (direction Wilder Mann) or 7 (direction Weixdorf) to "**Pirnaischer Platz**" (3 stations).

from Dresden Messe (Conference Location):

- Tram N° 10 to direction Striesen to Bahnhof Mitte
- Tram N° 1 to direction Prohlis to "**Pirnaischer Platz**"

More information:
https://www.steigenberger.com/en/hotels/all-hotels/germany/dresden/steigenberger-hotel-de-saxe/location-direction

Conference program on Friday, 27th April 2018

Pre-Conference-Dinner **Informal Get Together**	Thursday, 26 April 2018, 7 pm	Rauschenbach Deli, Weisse Gasse 2, 01067 Dresden
Conference	Friday, 27 April 2018, 8:30 am	Messe Dresden, Via Mobile 7 (see Venue Information)

8:30	Registration, Coffee & Tea
8:45	**Opening Address** (Room: Hamburg Conference Hall) Prof. Dr. Dominik Möst, TU Dresden Prof. Dr. Christian von Hirschhausen, TU Berlin
9:15	**Keynote Speech** (Room: Hamburg Conference Hall **Monitoring of the Energiewende: Why Germany is presently not on track?** Prof. Dr. Georg Erdmann, TU Berlin

10:00 **Coffee & Tea**

10:30 - 11:50	**Flexibility in energy systems** Room: Hamburg Hall Chair: Michael Zipf	**Sector coupling and policy implications** Room: Rotterdam Hall Chair: Tony Klein	**Market design options and renewables** Room: St. Petersburg Hall Chair: Constantin Dierstein	**Economics of consumer behavior** Room: Florenz Hall Chair: Samarth Kumar
10:30	**Optimal investments in Flexibility Options – An Analysis of Interactions and Sensitivities** Christoph Zöphel, Technische Universität Dresden	**Linking GCAM with specialized power system models to assess Norwegian energy and climate policy in European context** Linn Emelie Schäffer, SINTEF Energy Research	**A Probabilistic methodology for adequacy assessment under uncertainty for a multi-region system** Thomas Kallabis, Universität Duisburg-Essen	**The Economics of Prosumage: Quantification of Business Opportunities in Germany, California, India, and South Africa** Philipp Zorn, TU Berlin
10:50	**European Power System Long-term Development with Flexibility** Hector Marañon-Ledesma, Norwegian University of Science and Technology	**Sector coupling in Germany – Scenario paths modelled with REMod-D** Christoph Kost, Fraunhofer ISE	**Assessing the adequacy of a 100% renewable European power system** Will Zappa, Utrecht University	**Shifting intraday electricity usage through time-of-use tariffs** Martin Péclat, University of Neuchâtel
11:10	**How flexibilities support sector coupling - the integration of more renewable energies** Holger Wiechmann, EnBW Energie Baden-Württemberg AG	**ElecXit: The Impact of Barriers to Electricity Trade after Brexit** Joachim Geske, Imperial College Business School	**Prospects for an Electricity Market 3.0: How to head towards a Democratic and Competitive Electricity System** Reinhardt Haas, Vienna University of Technology	**Innovations in Wind Energy Sector** Dali Laxton, Center for Economic Research and Graduate Education – Economics Institute (CERGE-EI)
11:30	**Techno-Economic Analysis of Flexible Heat Pump Controls** Lars Nolting, RWTH Aachen University	**Institutionalization for Long-term Energy Policy** Nick Pruditsch, Technische Universität Dresden	**Optimal Pricing, Subsidies and Solar Panels: a two-sided market approach** Raúl Bajo-Buenestado, University of Navarra	**Digital peer-to-peer energy communities in Germany – creating a decentral energy world?** Frederik Plewnia, Technische Universität Dresden

11:50	**Keynote Speech** (Room: Hamburg Conference Hall **The role of natural gas in the European energy transition** Prof. Ruud Egging, NTNU Trondheim

12:30 **Lunch**

13:40	**Keynote Speech** (Room: Hamburg Conference Hall, **Sector coupling – an energy economic perspective** Johannes Henkel, 50Hertz Transmission GmbH

14:25 **Short 5-Minute-Break**

14:30 - 15:50	**Pathways towards sustainable energy systems** Room: Hamburg Hall Chair: Carl-Philipp Anke	**Modelling and Simulation of Energy Markets** Room: Rotterdam Hall Chair: Hannes Hobbie	**Short-term balancing of renewables** Room: St. Petersburg Hall Chair: Steffi Schreiber	**Energy and prices** Room: Florenz Hall Chair: Christoph Zöphel
14:30	**Emission Pathways towards a low-carbon energy system for Europe - A model-based Analysis of Decarbonization** Konstantin Löffler, Technische Universität Berlin	**Economic comparison of different electrofuels for energy scenarios in 2035** Philipp Runge, Friedrich-Alexander-Universität Erlangen-Nürnberg	**The Economic Benefit of Improved RES Forecasts** Jonas Savelsberg, Universität Basel	**Analyzing the Relationship of German Retail Fuel Prices and Oil Prices** Sebastian Kreuz, BTU Cottbus-Senftenberg
14:50	**Designing an operational market for grid supporting use of electric flexibilities in distribution network** Erik Heilmann, Universität Kassel	**Dynamic State-Induced Price Components in Power Markets** Leonard Göke, RWTH Aachen University	**Unit Commitment under Imperfect Foresight – The Impact of Stochastic Photovoltaic Generation** Jens Weibezahn, Technische Universität Berlin	**Forward Premia in Electricity Markets: a replication study** Silvester van Koten, University of Economics Prague
15:10	**Exploring Energy Pathways for the Low-Carbon Transformation in India** Luise Lorenz, Technische Universität Berlin	**Easy-to-implement Cognitive Algorithms for Electricity Spot Price Prediction - An Open-source. Open-access Approach** Lissy Langer, Technische Universität Berlin	**Who balances Nordic wind? – An Analysis Using the Concept of Relative Balancing Contributions** Richard Scharff, Vattenfall	**Modelling the wind auctions as a participation game** Jan Vávra, University of Economics in Prague
15:30	**Enabling China's Low-Carbon Energy Transformation Through Expanding its Transmission Grid** Hans Hosenfeld, Technische Universität Berlin	**Producers, Retailers and Risk-Averse Consumers** Elisa Trujillo-Baute, University of Barcelona	**Integration of Power-to-Gas Conversion into Dutch Electrical Ancillary Services Markets** Víctor García Suárez, Delft University of Technology	**Rockets and Feathers in Germany's Gasoline Market: The Effect of Increased Market Transparency** Marco Horvath, RWI - Leibniz-Institut für Wirtschaftsforschung e.V

15:50 **Coffee & Tea**

16:20 - 17:40	**Strategic decisions and behaviour in power markets** Room: Hamburg Hall Chair: Matthew Schmidt	**Gas markets** Room: Rotterdam Hall Chair: Philipp Hauser	**System Operators and Congestion Management** Room: St. Petersburg Hall Chair: Dirk Hladik	**Energy efficiency and system stability** Room: Florenz Hall Chair: Thomas Walther
16:20	**Transmission and generation investment for a core market region within a larger electricity market** Jonas Egerer, Friedrich-Alexander-Universität Erlangen-Nürnberg	**The Importance of the Gas Infrastructure for Germany's Energy Transition** Theresa Eich, Frontier Economics Limited	**Aggregation of Temporal Representation of High-Resolution, Fundamental Flow-Based Market Coupling Input Data to Identify Typical Market Scenarios - A Systematic Evaluation and Selection of Relevant Cluster Algorithms** Martin Kittel, Technische Universität Berlin	**Frequency and persistence of low-wind events in Germany** Wolf-Peter Schill, DIW Berlin
16:40	**A Model based Market Power Analysis of the German Market for Frequency Containment Reserve** Samir Jeddi, ewi Energy Research & Scenarios gGmbH	**Diversification at any price – Economic assessment for reaching the EU diversification targets?** Simon Schulte, ewi Energy Research & Scenarios gGmbH	**Locational (In-) Efficiency of Renewable Power Generation in the Distribution Grid: A Spatial Regression Analysis** Tim Höfer, RWTH Aachen	**Energy Audits vs. – ISO Management Systems: a review of Austrian policy - Effectiveness of the internalization of identifying energy efficiency potentials and resulting savings rates** Christian Schützenhofer, University of Vienna
17:00	**Economic and Environmental Consequences of Market Power in the South-East Europe Regional Electricity Market** Verena Viskovic, University College London	**Integration of Electricity and Gas Market – Accounting for Interdependencies and Uncertainty** Thomas Möbius, BTU Cottbus-Senftenberg	**Trends in European Regulation / still struggling for the IEM** Christian Dobelke, TenneT TSO GmbH	**Revenue decoupling and energy consumption: Empirical evidence from the U.S. electric utilities sector** Victor von Loessl, Universität Kassel
17:20	**Electricity Prices under Climate Policy** Evangelos Panos, Paul Scherrer Institut	**Power to Gas: a crucial component for sectoral coupling and energy supply security** Michael Friedrich, Greenpeace Energy	**Price Zones and Investment Incentives in Electricity Markets: An Application of Multi-Level Optimization with Graph Partitioning** Mirjam Ambrosius, Friedrich-Alexander Universität Erlangen-Nürnberg	**Energy Security - a new perspective as a solution to present problems in energy market integration?** Krzysztof Ksiezopolski, SGH

17:40 **Closing Words in the Foyer of the Via Mobile 7, Messe Dresden**

Gala Dinner
Official Closing Event

Friday, 27 April 2018, ~7 pm

Steigenberger Hotel de Saxe,

Neumarkt 9,

01067 Dresden

Content

Keynote 9.15– 10.00

Room: Hamburg Conference Hall

Monitoring of the energy turnaround

Prof. Dr. Georg Erdmann[1]

[1] *Fachgebiet Energiesysteme, TU Berlin (Germany) Georg.erdmann@tu-berlin.de*

Keywords: Energy policy, emission targets, acceptance, scenarios, energy innovations

Motivation

Today is quite obvious that until 2020 most of the energy and emission targets the German Federal Government defined in 2010 will not be met. The major exception is the share of renewable electricity generation which has already exceeded the target of 35% of gross energy consumption in 2017. The present discussion of 2030 targets risks the same dissatisfying results if the reasons for the mixed performance of German energy policy are not well analyzed. The relevance of such an analysis has recently increased as the new federal government, according to recent media reports, openly recognizes the failure to meet relevant energy and emission targets until 2020.

Methods

The analysis has to distinguish between internal and external factors influencing the success or failure to meet energy targets. External factors are those which are outside the influence from domestic energy policy, such as demographic change, economic growth and global energy prices. To quantify this effect, scientific models that had been applied to determine the 2020 targets should be used in a back casting exercise. The remailing discrepancies to the 2020 targets are the result of internal factors – factors that are subject to decisions of the federal government, parliaments, political opinion and particular interest groups. Thereby the influence of individual interest groups depends on its organizational strength and the subject under concern.

Results

It is quite obvious that the federal government has initialized a rather large number of initiatives in recent years to reduce German greenhouse gas emissions, to increase renewables and energy efficiency. However, in contrast to the number of these initiatives their strength and intensity had been insufficient, mostly due to the opposition of parliaments, interest groups, industrial and private energy consumers. A rather great majority of the people in Germany supports the German energy turnaround as a project, but if it comes to concrete measures, the support largely disappears so that the federal government is forced to cut its plans. The exception is renewable electricity generation where state aid has passed 20 billion Euros per year. A similar effort towards climate neutral buildings or green transportation is rather unlikely in the coming years. Still the national emission goals for 2030 and beyond

are defined through international agreements and thus not subject to domestic decisions. A supposed way out of this dilemma is a kind of manipulation of assumptions used in scenario modelling: By under-stating demographic and economic developments and over-stating global energy and emission prices the expected pain of the energy turnaround seems to be smaller. Obviously the basic problem is the unwillingness of large parts of the society to accept today's pain of the energy turnaround. To overcome this problem, the recent discourse about possible benefits from energy innovations and job creation turns in the opposite direction.

Session 10:30 – 11:50
Flexibility in energy systems

Room: Hamburg Hall
Chair: Michael Zipf (TU Dresden)

Optimal investments in Flexibility Options – An Analysis of Interactions and Sensitivities
Christoph Zöphel, Technische Universität Dresden

European Power System Long-term Development with Flexibility
Hector Marañon-Ledesma, Norwegian University of Science and Technology

How flexibilities support sector coupling - the integration of more renewable energies
Holger Wiechmann, EnBW Energie Baden-Württemberg AG

Techno-Economic Analysis of Flexible Heat Pump Controls
Lars Nolting, RWTH Aachen University

Optimal Investments in Flexibility Options – An Analysis of Interactions and Sensitivities

Christoph Zöphel[1]

[1]*Chair of Energy Economics at TU Dresden, Germany, christoph.zoephel@tu-dresden.de*

Keywords: Renewable Energy, Flexibility Option, Investment Model, Energy Transition

Motivation

Since variable renewable energy sources (VRE) like photovoltaic (PV), wind onshore and offshore have dissimilar availabilities and generation characteristics a higher share of either wind or solar will lead to different flexibility needs in future energy systems. This in turn will have an impact on the optimal use of technologies to provide flexibility, i.e. to balance volatile electricity supply and demand. In a model-based approach this paper analyses the interaction between different (scenario-based) flexibility requirements and the role of a broad range of flexibility options on a multinational level.

Methods

To address the uncertainty of renewable capacity extension paths two scenarios with very high VRE shares in central-western Europe are developed and used to find optimal investments in flexible technologies. The two scenarios differ in their solar-to-wind ratio with a PV-share of 20 % (High Wind) versus 80 % (High PV). In combination with the adoption of a greenfield investment approach ELTRAMOD[1], a linear cost-minimizing European electricity transhipment market model, is extended for the integration of various flexibility options[2]. The technologies are grouped according to their application (flexibility on the supply side, on the demand side and by shifting energy respectively). The model is used in a first step to calculate the optimal investments in these grouped technologies separately and in a second step in a combination of all observed flexibility options. This scenario and model set-up therefore allows for the deduction of benchmarks as well as insights into interdependencies of flexibility requirements and provision in an optimized future energy systems. Since in this long-term analysis further uncertainties besides the VRE expansion paths can have a major impact on the results, various sensitivity analysis are carried out, particularly on future prices for emission certificates and investment costs for the technologies.

Results

The two discussed VRE portfolios cause very different flexibility needs. While the differences between a high wind versus a high PV scenario regarding the optimal installed capacities are smaller yet remarkably for the

[1] A model description is published in *Müller, T., Gunkel, D. & Möst, D., 2013. How does renewable curtailment influence the need of transmission and storage capacities in Europe? In 13th European IAEE Conference. S. 1–16.*

[2] Namely conventional as well as renewable flexible power plants, power to heat/to gas, transmission (here NTC) extension, storages, demand side management

separately analyzed flexibility applications, the combination of all observed technologies differ significantly. Besides further results storages play a major role in the PV-dominated energy system while this is true for NTC extension in the high wind scenario.

European Power System Long-term Development with Flexibility Uncertainty

Hector Marañon-Ledesma[1], Asgeir Tomasgard[2]

[1]*Norwegian University of Science and Technology, hector.maranon-ledesma@ntnu.no*

[2]*Norwegian University of Science and Technology, asgeir.tomasgard@ntnu.no*

An optimal planning of the energy transition is crucial to assess the right long-term investments. One important issue is considering the uncertainty about future crucial factors: energy policy, GHG emission regulation, regulatory frameworks, technology costs, demand uncertainty and population growth.

The so called "winter package" by the European Comission (EC) includes among other measures empowering electricity consumers, allow them to provide and consume flexibility. In that sense, Demand Response (DR) will have a role in the European distribution networks, electricity markets and the system as a whole. It is left to see what amounts of energy flexibility consumers will reach in this framework regulation. Since there are no binding targets on that respect, it is reasonable to consider scenarios with high and low consumer participation.

The question that we want to answer is how the power system develops considering the challenges and uncertainties of DR flexibility. By means of the European Model for Power Investments with Renewable Energy (EMPIRE), the long-term development of the power sector until 2050 is analyzed. The stochastic optimization model EMPIRE uses a multi-horizon approach that consists of decoupling the short-term operation and the long-term strategic dynamics. This allows handling each kind of uncertainty separately.

By changing the limits on potential DR capacities and DR investment costs, three possible development scenarios for DR are created. With a stochastic optimization multi-horizon model we study the impacts of long-term DR uncertainty.

The results of the stochastic solution show sensible DR investments before uncertainty is revealed. Due to the large solar capacities expected for 2035 and the support that DR can offer to RES integration, flexible consumers are system-wise efficient even when considering pessimistic scenarios. Flexibility supplied by DR loads partially substitutes battery storage capacity in each scenario and decreases system costs.

How flexibilities support sector coupling – the integration of more renewable energies

Dr. Holger Wiechmann[1]

[1]*Energie Baden-Württemberg AG*

The German energy transition and the associated expansion of renewable energies have already laid the foundation for Germany's decarbonisation. Now the sectors heat, cold and transportation are also to be included.

Currently, many are talking about sector coupling, but what exactly that means and what final energy levels are being spoken about is often unclear. The starting point here is the current national final energy demand of about 2,500 TWh/a. Electricity accounts for just over 20% of this. In order to achieve reasonably realizable RE targets, this current final energy demand must be at least halved. Also, the "remaining" final energy requirement of about 1,200 - 1,400 TWh (including storage losses) must first be generated with RE. For example, about 200 GW onshore, 75 GW offshore and 400 GW PV are required for this, or a correspondingly different production-side composition. These figures are in dramatic contrast to the current politically desired expansion goals. Examples include the current 15 GW offshore expansion cover or the 52 GW PV expansion cover.

In addition to the question of seasonal storage (winter-summer heating challenge), short-term flexibility and storage solutions (day-night PV delta or a few days of wind drought) are required to link generation and demand. Heat and cooling solutions offer a considerable theoretical potential of several 10 GW up to several 100 GW, which is also a technically relatively easy to raise potential. In district heating networks, considerable services have already been installed on P2H solutions in recent years. An intelligent flexibility management in conjunction with other flex options (for example from the transport sector or P2G), as EnBW has developed and tested, represents such a technical tool for implementation.

However, technology alone is not enough. Adjustments are also needed in the regulatory framework in order to be able to advance sectoral coupling. As long as, for example, only the current EEG levy is normally higher than the retail gas tariff, the sector coupling will not work. A consistent distribution of all energy turnaround costs (e. g. grid costs including grid expansion, storage costs, taxes, etc.) for all energy sources (oil, gas, electricity) paired with, for example, a CO2 emission-oriented allocation key could be a viable option.

The pilot project "Flexible Power to Heat" has shown that a mass-market-suitable network load management works, but a product cannot be offered economically, because on the one hand levies prove to be hurdles and on the other hand smart metering systems with control box function are still missing (keyword BSI).

Techno-Economic Analysis of Flexible Heat Pump Controls

Lars Nolting[1], *Aaron Praktiknjo*[1]

[1]*Institute for Future Energy Consumer Needs and Behavior, E.ON Energy Research Center, RWTH Aachen University, LNolting@eonerc.rwth-aachen.de*

Keywords: energy efficiency; heat pump; flexibility; simulation model

There exists a gap between flexibility needed within the German energy system and flexibility being actually provided. This can be concluded by current amounts of and costs for grid stability measurements. Based on increasing market shares, high efficiencies, and advancing communication technologies heat pumps (HPs) can be seen to be the core technology to connect the heat and the electricity sector and thereby fill the flexibility gap. We contribute to the scientific discussion by conducting a MODELICA simulation of three different *realistic and easily applicable* HP control methods in order to assess both their efficiency effects and their economic potentials: (1) dual tariff based control algorithm, (2) control scheme based on day-ahead spot market prices, and (3) residual load based control for future scenarios. The applied control strategies are wether state-of-the-art or likely to be applied in near future and can be realized with current HP control systems. The guiding research questions within our manuscript are as follows: *Are currently applicable HP control methods that provide flexibility profitable from an efficiency and cost perspective? Does the ecological and economic profitability change for a more advanced HP control method for flexibility provision in the year 2030?* Our findings imply that high efficiency losses occur. Further, unappropriate tariff structures lead to economic disadvantages for flexible HP controls compared to non-flexible ones.

Session 10:30 – 11:50
Sector coupling and policy implications

Room: Rotterdam Hall
Chair: Tony Klein

Linking GCAM with specialized power system models to assess Norwegian energy and climate policy in European context

Linn Emelie Schäffer, SINTEF Energy Research

Sector coupling in Germany – Scenario paths modelled with REMod-D

Christoph Kost, Fraunhofer ISE

ElecXit: The Impact of Barriers to Electricity Trade after Brexit

Joachim Geske, Imperial College Business School

Institutionalization for Long-term Energy Policy

Nick Pruditsch, Technische Universität Dresden

Linking GCAM with specialized power system models to assess Norwegian energy and climate policy in a European context

Linn Emelie Schäffer[1], Christian Skar[2], Stefan Jaehnert[3]

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[2]*NTNU, christian.skar@ntnu.no*
[3]*NTNU, Stefan.Jaehnert@sintef.no*

Scenario studies are a useful method to provide knowledge and decision support on the long-term development of the energy system. In this study we assess a set of energy scenarios to address Norwegian energy and climate policies considering European and global polices. The scenarios are developed with a bottom-up methodology involving several stakeholders [1]. Furthermore, these scenarios are closely linked to the Shared Socioeconomic Pathways, which are part of the transition pathways for IPCC [2].

A broad variety of energy- and power system models can be used to assess potential developments of the energy system and how global and regional policies affect the development of the power system on a national level. As climate change is a global challenge, models with large geographical coverage and numerous sectors, such as integrated assessment models, are useful to evaluate the full impact of political measures. However, to include such a large scope in the modelling, it only allows for a low level of details. Specialized models focusing on a smaller geographical region and specific parts of the energy system can include more details, but lack the interaction with other systems and sectors.

To analyse the development of the European energy system and the impact on countries different types of models are integrated in the analysis. In a first step, the integrated assessment model, GCAM, provides contextual assumptions and the results are linked with a more detailed model of the European power system, EMPIRE. GCAM results such as annual electricity consumption and fuel prices are broken down to a national level and used in EMPIRE. EMPIRE computes optimal investments in generation, interconnectors and energy storage at national levels. In a second step, results from EMPIRE are linked to hydrothermal power system models to analyse the role of Norwegian hydropower in the different scenarios.

The work is done as part of the centre for environment-friendly energy research, CenSES [3].

References:

[1] Jaehnert, S. 2016. CenSES energy scenarios. Design process and scenario description. Report TR A7590, SINTEF Energy Research.

[2] van Vuuren, D. P. and T.R. Carter. 2014. Climate and socio-economic scenarios for climate change research and assessment: reconciling the new with the old. *Climatic Change*, 122, 415-429.

[3] CenSES – Centre for Sustainable Energy Studies. 2011. Norwegian University of Science and Technology (NTNU). url: https://www.ntnu.no/web/censes/censes.

Sector coupling in Germany – Scenario paths modelled with REMod-D

Christoph Kost[1], Andreas Palzer[1], Philip Sterchele[1]

[1]*Fraunhofer ISE*

The energy transformation is starting to trigger developments in heating, mobility and industry sector after the first focus on renewables in the electricity system. We have developed and operated the energy system model REMod-D for over 6 years now to show with a highly temporal resolution approach the development of integrated transformation paths. The energy system model REMod-D is an energy model which uses a simulation and optimization approach to analyze the transformation path from today to 2050 by operating the complete energy system integrated in a single model on an hourly basis. With this model approach, optimal decarbonization strategies can be conducted by evaluating each technology in the different sectors against each other. In this paper we will present scenarios for the energy system in Germany with four different scenario pathways to 2050. Compared to other studies, four different scenarios will be shown with the same Co2 emission reduction target, but with four very different structures of the energy system. In addition to a baseline -85% scenario, a hydrogen scenario and a PTL/PTG scenario will be presented. As a consequence on these scenarios, an active scenario is shown which include additional measurements on efficiency, imports and coal-phase out to facilitate the energy transformation. The paper concludes with policy recommendation how to carry out an accelerated sector coupling in Germany. The Paper is based on results which we published with Acatech ESYS in November 2017.

ElecXit: The Impact of Barriers to Electricity Trade after Brexit

Joachim Geske[1], Richard Green[2], Iain Staffell[3]

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Keywords: Brexit, electricity market disintegration, trading frictions

Motivation

The United Kingdom has decided to withdraw from the European Union, in the process known as Brexit. While future relations with the EU are still to be negotiated, it is conceivable that the UK will leave the EU Single Market for electricity. This paper examines the longer-term (2030) consequences of this electricity market disintegration, which might imply that planned interconnection projects would be abandoned, and market rules changed. In particular, the British electricity system might leave the system of market coupling, reverting to separate arrangements to decide interconnector flows.

Methods

A model of these market frictions is integrated into the multi-country trade equilibrium model DESSTINEE. In detail due to different market closing dates in the UK and France, an early commitment and the anticipation of market prices is required to determine interconnector capacity demand. Anticipation errors must be considered by traders when determining the demand for interconnector capacity. The standard deviation of the anticipation error was calibrated with DESSTINEE for the base year 2010 as 0.2 GW. We ran DESSTINEE for 10 GW interconnector capacities (pre-Brexit expansion plans) and 5 GW (new build impeded) and both with and without frictions. We find that market frictions reduce welfare significantly, 2/3 from halting planned interconnection projects and 1/3 from market decoupling.

Results

We are not suggesting that abandoning the successful system of electricity market coupling is a likely outcome of Brexit, but wish to illustrate the costs of doing so. Preliminary results find that an abandoning of 5GW planned interconnector capacities and market decoupling might cause a loss in welfare of €1 billion. Two-thirds of these losses are caused by the reduction in interconnector capacity and one-third by market decoupling. So either friction contributes significantly to these losses in a scenario of 2030, while the impact of capacities is higher.

Institutionalization for Long-term Energy Policy

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Keywords: Energy Policy, Governance Research, Intertemporal Policy-Making, Long-termism, Institutionalization

Motivation

The transformation of the European energy system(s) towards a sustainable and climate-friendly energy supply will take generations to complete. This requires not only long-term objectives, but also long-term governance modes and policy measures. In political systems characterized by short-term nature, the challenge is to ensure that policy-makers adopt and pursue such long-term objectives, modes and measures. The goal of this research is to provide more clarity around these issues by (1) defining long-term policy measures and assessing specific governance modes, (2) mapping and evaluating the institutionalization processes that allow such policies to have long-term effects, and (3) assessing institutions and institutional mechanisms that effectively lead to long-term energy-policy measures and strategies.

Methods

The energy policies of Germany and the UK are analyzed using case study and comparative research methods. With regard to the assessment of specific governance modes and institutionalization processes, policy analysis and a combination of document studies and systematic review are applied. In terms of evaluation, proposals for institutions promoting long-term policy actions taken from the literature are subjected to a qualitative assessment. Using causal inference strategies allows identifying the institutions responsible for long-term energy policies and governance empirically.

Results

As a result, three things can be shown: (1) The understandings of the term long-term vary depending on the subject under consideration and what long-termism is specifically referred to.

Purely in terms of time, periods between five and one hundred years are defined as long-term. (2) The evaluation of the institutional proposals shows that the institutional designs for long-term policy-making can only be changed in small steps. It is important to take into account, in particular, the impact on the democratic functioning of the respective political system. (3) It can be assumed that long-term energy policies and governance are affected by a combination of institutional and other influencing (economic, societal, juridical, etc.) factors.[3]

[3] The results presented correspond to the findings from the work on the current project at the time of transmitting the abstract (January 2018)

Session 10:30 – 11:50
Market design options and renewables

Room: St. Petersburg Hall
Chair: Constantin Dierstein (TU Dresden)

A Probabilistic methodology for adequacy assessment under uncertainty for a multi-region system

Thomas Kallabis, Universität Duisburg-Essen

Assessing the adequacy of a 100% renewable European power system

Will Zappa, Utrecht University

Prospects for an Electricity Market 3.0: How to head towards a Democratic and Competitive Electricity System

Reinhardt Haas, Vienna University of Technology

Optimal Pricing, Subsidies and Solar Panels: a two-sided market approach

Raúl Bajo-Buenestado, University of Navarra

A Probabilistic methodology for adequacy assessment under uncertainty for a multi-region system

Thomas Kallabis[1], Julia Bellenbaum[1], Benjamin Böcker[1], Christoph Weber[1]

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Keywords: Flow-based market coupling, Monte-Carlo simulation, quantile regression, security of supply, spatial correlation, stochastic characterization, system adequacy.

Motivation

Growing shares of electricity generation from renewable energy sources challenge the electricity system. In addition, the integration towards a European single market for electricity fosters electricity exchange between different countries. While the first development increases the importance of the monitoring of security of supply, the second development suggests a multinational approach for an assessment framework for such monitoring.

Methods

We propose a novel probabilistic methodology for the assessment of security of supply applicable to both isolated settings and interconnected areas. It is built on the characterization of relevant uncertainties such as infeed from renewable energy sources and demand using quantile regression based on historical time series. This characterization takes into account the spatial correlations of the uncertainties between the countries considered. Monte-Carlo simulation helps to capture the stochasticity of events with low probability of occurrence. Supply shortages identified for single countries in the isolated case – classified as critical situations – may be compensated by imports from neighboring countries. This potential is calculated by the help of PTDF-based optimal power flow calculations. Security of supply in either case is evaluated with indicators such as loss of load probability (LOLP) or expected energy not served (EENS). These are calculated for all countries and all time intervals independently for the respective time period under consideration (e.g. every hour of a year).

Results

The proposed methodology is applied to a case study comprising the CWE area in which flowbased market coupling is already fully implemented. We use historical data to assess the security of supply in the year 2020. First results indicate high levels of security of supply. Yet the results also shed a detailed light on the seasonal distribution of adequacy risks and key factors affecting them, notably the assumptions on planned power plant unavailabilities. In addition, a comparison between the isolated and the interconnected case reveals that LOLP and EENS are significantly reduced by interconnection.

Assessing the adequacy of a 100% renewable European power system

William Zappa[1], Martin Junginger[1], Machteld van den Broek[1]

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In light of the 2016 Paris Agreement to keep global warming well below 2 °C above pre-industrial levels and pursue efforts to limit the temperature increase to 1.5 °C above pre-industrial levels, emissions from Europe's power sector must fall essentially to zero, or even turn negative by 2050. This will require large-scale implementation of low-carbon technologies such as renewable energy sources (RES), nuclear power, and carbon capture and storage (CCS).

Previous studies have presented scenarios of a 100% RES power system for Europe in 2050. However, with a heavy dependence on variable renewable energy sources (vRES) like wind and solar photovoltaics (PV), the power system becomes reliant on fluctuating weather conditions, and few studies have checked whether a 100% RES power system would be reliable in the long- and short-term with detailed power system modelling. In this study, we model seven fully-RES scenarios for the European power system in 2050, assuming different levels of future demand and technology availability. For comparative purposes, we also model one scenario which includes other low-carbon but non-RES technologies such as nuclear and fossil fuels with CCS.

Based on our scenarios, preliminary results show that a 100% RES European power system could operate with the same level of system adequacy as today when relying on European resources alone, even in the most challenging weather year observed in the period from 1979 to 2015 (2010). However, transforming to such a system would require nearly double the amount of generation capacity as installed today, and nearly three-times as much cross-border transmission capacity. As one of the few providers of renewable dispatchable firm capacity, biomass would have a critical role in ensuring system adequacy in a 100% RES power system. Smart integration of heat pumps and electric vehicles, together with energy efficiency measures would be necessary to minimise the amount of biomass, generation and transmission capacity required. Furthermore, we find that while a 100% RES system would be able to deliver our electricity needs, it may not be sufficient to deliver the level of emission reductions necessary to achieve Europe's climate goals by 2050, as negative emissions from biomass with carbon capture and storage may still be required.

Prospects for an Electricity Market 3.0: How to head towards a Democratic and Competitive Electricity System

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Keywords: Democracy, Electricity market, flexibility. Liberalization, Variable renewables

Motivation

In the history of electricity systems in several countries different boundary conditions with respect to price formation in the market existed and exist. After the periods of state regulation and the first phase of liberalization currently the electricity system faces the third huge challenge: the change towards a more democratic and sustainable bidirectional system. This process is currently under way in e.g Germany, Austria, and California.

The major objective of this paper is to analyze and provide insights on how an electricity market 3.0 will bring about such a system with even higher shares of renewables.

Methods

Our method of approach is based on the cost-minimal coverage of residual load, which is the difference between final electricity demand and electricity generation provided by non-flexible sources modelled on an hourly base over a year.

Results

Most important is to introduce a system where price signals provide information about scarcity or excess capacities at every point-of-time by allowing temporarily shortage prices higher than short-term marginal costs and in times of excess electricity even negative prices. A very important element of such a market will be flexibility options. Yet this will only be done if the market is not distorted by centralized capacity payments.

In a complete market there will be a new core player, the balancing group (the "supplier") which is the logical market coordinator of the electricity supply chain and the organizer of competition between the different options, including a greater scope for demand participation by consumers needs to be included.

The final conclusion of this analysis is, that most important is to accept a paradigm shift in our understanding of the whole electricity system where no longer the generators are the core but the balancing groups respectively the supply companies.

Optimal Pricing, Subsidies and Solar Panels: a two-sided market approach

Raúl Bajo-Buenestado [1, 2], Markus Kinateder [1]

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Keywords: Capacity market, Electricity market, Welfare analysis, Energy policy, Risk analysis

We study the regulator's optimal transmission pricing problem in the presence of solar panel owners. The unique feature of such solar panel owners is that they might sell or buy, depending on the realization of the state (i.e. weather). We assume that the market is two-sided, where the grid is the (single-homing) platform, and the two types of end-users are generators and consumers, respectively. Solar panel owners are in one or the other side, depending on weather. A certain degree of correlation of weather realization is assumed among solar panel owners. This is due to the fact that, if it is "sunny" for a given solar panel owner, it is likely "sunny" for some other (nearby) solar panel owners. We find that solar panels are present in equilibrium only if a subsidy is granted to their owners. This result holds both if the amount of sunny hours is large and (even) if the amount of sunny hours is relatively small.

Session 10:30 – 11:50
Economics of consumer behavior

Room: Florenz Hall
Chair: Samarth Kumar (TU Dresden)

The Economics of Prosumage: Quantification of Business Opportunities in Germany, California, India, and South Africa

Philipp Zorn, TU Berlin

Shifting intraday electricity usage through time-of-use tariffs

Martin Péclat, University of Neuchâtel

Innovations in Wind Energy Sector

Dali Laxton, Center for Economic Research and Graduate Education – Economics Institute (CERGE-EI)

Digital peer-to-peer energy communities in Germany – creating a decentral energy world?

Frederik Plewnia, Technische Universität Dresden

The Economics of Prosumage: Quantification of Business Opportunities in Germany, California, India, and South Africa

Maximilian Eissler[1], Charlotte Rochell[2], Philipp Zorn[3], Prof. Dr. Christian von Hirschhausen[4]

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Keywords: Prosumage, Self-Consumption, Residential Photovoltaics, Residential Storage, Economic Analysis, Battery Storage Profitability.

To gain an overview over possible developments in consumer level energy generation and storage we simulated the profitability of a range of different investments into household PV and battery installations in five distinct international locations. We found that while currently storage is not profitable, trends of rising retail prices and falling FITs could lead to a widespread uptake of storage installation when prices for storage systems fall to around 50 percent from early 2017 levels.

Shifting intraday electricity usage through time-of-use tariffs

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Keywords: Household electricity usage, Smart metering, Demand response, Randomized control trial, Difference-in-differences

Motivation

Solar energy production takes place at times when demand for electricity is not necessarily high. This mismatch might be reduced in several ways: electricity might be transported and consumed elsewhere, it might be stored for later consumption, or households could be encouraged to align their consumption with solar energy production. While the first two solutions are supply-side measures that imply high installation costs, the latter is a demand-side measure that might prove relatively inexpensive and quick to implement. The relevance of this topic is enhanced in the context of the energy transition, as renewable energies (in particular solar) are bound to gain importance in the energy mix.

Methods

From July 2016 to December 2017, we implemented a randomized control trial in which we encouraged households to shift their consumption towards the period of the day when production of solar energy takes place. Our intervention consisted in two types of modifications in the pricing scheme faced by households.

For the first treatment group (T1), the price of a kilowatt-hour was lowered from 11am to 3pm (and increased from 3pm to 11am) for the entire duration of the intervention. For the second treatment group (T2), the hours of solar production were set on a day-to-day basis, based on the day-ahead weather forecasts. From the standard price of 27 cents/kWh, a decrease of 15 cents/kWh was introduced during solar hours while an increase of 4 cents/kWh was set for the non-solar hours. For households in the control group, the price remained flat. To estimate the treatment effects, we use difference-in-differences regressions.

Results

Based on preliminary results, three observations arise:

1. Financial incentives impact electricity consumption patterns. Households seem to shift a small portion of their consumption during reduced pricing times and reduce overall consumption.
2. The response of households is relatively small in absolute value. This could be due to the relatively low price of electricity.

Group T1 seems to have reacted less reacted than group T2. A fixed and regular incentive seems to have less effect than a dynamic incentive.

Innovations in Wind Energy Sector

Dali Laxton[1]

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Keywords: Innovation, Levelized Cost of Energy, Renewable Technologies, Learning curves

Technological innovations occur in the wind energy sector and as a result, the unit cost of electricity production declines. However, the accuracy with which the innovation-driven unit cost reduction is measured in the literature, could be challenged. In this paper we use an engineering model to generate a long time-series of wind technology unit cost of electricity for different vintages in US. We refer to this data as innovation process. Our data is exclusive in a manner that it captures the purely engineering-driven innovation process and excludes other potential market, financial, geographic or climatic forces. Such data allows for careful evaluation of renewable energy support policies and their efficiency in spurring innovations for wind technology.

Using the innovation data, we compute the two-factor learning rate to be 3.2%, which indicates that with doubling of capacity, the unit cost of electricity reduces by 3.2%. Our estimate is robust to the choice of vintage sub-sample due to the smoothness and accuracy of the data. In addition, we construct a theoretical model in which an investor decides how much to innovate given the wind energy support policies. The results of the paper should inform policy recommendations in order to secure a higher innovation rate in the wind energy sector.

Digital peer-to-peer energy communities in Germany – creating a decentral energy world?

Frederik Plewnia[1], Edeltraud Guenther[1]

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Peer-to-peer energy communities and networks might be promising possibilities to support and drive an optimized decentral energy system. The idea for this model is rooted in the 'sharing economy' and centers around using digital platforms to locally share and trade energy with your neighbors or regional plants instead of getting supplied by a central energy utility in a top down energy world. In Germany, a range of companies recently begun to offer these 'energy community' or 'peer-to-peer energy trading' services to their customers. This paper uses business model theory to investigate how these P2P energy communities or platforms work and what value they can contribute to the current energy system in its transition towards sustainability.

Using qualitative case study method, seven case companies which offer digital peer-to-peer energy community platforms are analyzed based on several interviews and secondary data available from their websites, press releases, as well as news articles. Furthermore, to gain a more comprehensive picture of the phenomenon, stakeholders to these companies and research experts are interviewed for their experience and opinion on these new concepts. The grounded theory approach and inductive coding is used to filter and evaluate how digital P2P energy communities can contribute to a sustainable energy system under the current regulatory framework.

Results show that the business models established in Germany are not yet offering actual trading of energy with your local peer as this is not yet possible in the current regulatory landscape. Instead, they offer virtual forms of P2P energy trading deploying direct marketing tools and pooling supply and demand within balancing units. However, already now, these business models contribute to the transition towards the renewable energy system of the future in several ways. First, although not yet synchronizing local production and consumption, they already provide financial incentives for local installation and remuneration of renewable energies by establishing direct money flows between consumers, prosumers, and small-scale energy plant operators. Second, by establishing direct sales channels and consumer contact on P2P market platforms, they can help to integrate renewable energies into the market and to make them less dependent on subsidies. Finally, digital P2P energy networks can advance technological and digital development of an intelligent energy system as this is a necessary condition for optimal value extraction within their business models.

Keynote 11:50 – 12.30

Room: Hamburg Conference Hall

The role of natural gas in the European energy transition

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Keywords: Energy Transition, Natural Gas, Energy Security and Flexibility, Norway-EU relations

Motivation

Among fossil fuels, natural gas has the highest potential to contribute to the transition to a low-carbon energy system. Which roles natural gas will have and over what time horizon is not clear.

Methods

Summary of literature, reports, conference contributions and some model results.

Results

My presentation will provide an overview of

- main advantages and disadvantages of natural gas in the perspective of a low-carbon energy system.
- main drivers and outlook on the natural gas market over the next decades.
- possible roles for natural gas in different sectors
- boundary conditions for natural gas to have a role in the future energy system.

Keynote 13:40 – 14.25

Room: Hamburg Conference Hall

Sector Coupling – An energy economic perspective

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Keywords: Sector Coupling, Heat pumps, Electromobility

Motivation

With increasing RES shares and decreasing GHG emissions in the energy system two challenges gain importance:

- Integration of volatile RES generation is getting to its limits as generation is temporarily exceeding load (incl. DSM), storage capacity as well as export possibilities
- Decarbonisation of energy consumption in traffic and household has proven difficult and costly

The coupling of sectors via different available paths provides potential for the use of excess RES generation as well as of decarbonisation of the traffic and household sector.

Methods

The potential for sector coupling is estimated by analysing residual load as well as RES curtailment because of grid congestion. Implications on the energy system are analysed by case studies.

Results

Implications of sector coupling on total electricity consumption result to be low. For peak load there are significant implications which probably still can be handled without special actions. Looking at grid loading the most challenging situation will appear in low voltage grids. Here, smart control of load added to the system seems necessary in order to impede major congestion issues.

Session 14:30 – 15:50

Pathways towards sustainable energy systems

Room: Faculty Hamburg Hall
Chair: Carl-Philipp Anke (TU Dresden)

Emission Pathways towards a low-carbon energy system for Europe - A model-based Analysis of Decarbonization

Konstantin Löffler, Technische Universität Berlin

Designing an operational market for grid supporting use of electric flexibilities in distribution network

Erik Heilmann, Universität Kassel

Exploring Energy Pathways for the Low-Carbon Transformation in India

Luise Lorenz, Technische Universität Berlin

Enabling China's Low-Carbon Energy Transformation Through Expanding its Transmission Grid

Hans Hosenfeld, Technische Universität Berlin

Emission pathways towards a low-carbon Energy System for Europe- A model-based analysis of decarbonization scenarios

Konstantin Löffler[1], Thorsten Burandt[2], Karlo Hainsch[3], Pao-Yu Oei[4], Christian von Hirschhausen[5]

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Overview & Methods

In the wake of increasing concerns about greenhouse gas emissions and the adverse effects of global warming, the scientific and political debate about future energy scenarios is intensifying. Traditionally, energy system models relied on the trio of fossil fuels with carbon capture, nuclear energy, and renewables; the two former ones providing backup capacity in case of no wind and no sun. This pattern is now challenged by the availability of low-cost storage technologies and other flexibility options, providing the necessary flexibility to balance intermittent renewables. In addition, recent trends show that neither nuclear nor carbon capture technologies are likely to play a major part in decarbonizing the electricity sector (Lorenz et al. 2016; Kemfert et al. 2017). This has a tremendous effect on the future outlook of the global energy system. Given the tense global situation, Europe has to play a major role in leading the transition towards a largely decarbonized energy system.

This paper presents different scenarios based on the regional distribution of the available CO_2 budget to keep the global mean temperature well below 2° Celsius. To analyze these scenarios, the "Global Energy System Model" (GENeSYS-MOD) by Löffler et al. (2017) is used. The model uses a system of linear equations of the energy system to search for lowest-cost solutions for a secure energy supply, given externally defined constraints on greenhouse-gas (GHG) emissions. In particular, it takes into account increasing interdependencies between traditionally segregated sectors, e.g., electricity, transportation, and heating. For our approach, we aggregated European countries into 15 geographic regions, calculating energy- and resource-flows to meet power, heat and transport demands. Several European limits of emitting CO_2 corresponding to common emission pathways (1.5°C, 2°C, BAU) are analyzed. These emission budgets incentivize the need for investments into renewable energy sources. In the different scenarios, the available budget is then distributed to the various modeled regions via the use of different key indicators (GDP, population, current emissions).

Results & Conclusion

As a result, we were able to model a possible path towards a 100% renewable and climate-neutral global energy system in 2050. The power sector is leading the change to renewable energies with as much as 45% of electricity generation in 2020, rising to over 90% by 2035. Current results indicate that the next ten years represent a strong turning point towards renewable power generation with only about 30% being produced by conventional energy carriers in 2025. Both the heating and transportation sectors experience a slower rate of change, depending on the regional setting. Based on the model calculations, the global energy system towards 2050 mainly relies on wind power (39%), solar power (27%) and biomass (24%). Because the two main sources of energy, wind and solar power, provide energy in the form of electricity, we observe a strong sector-coupling between the power sector with the heat and transportation sectors (via the use of e.g. heat pumps, electric furnaces, battery electric vehicles, etc.).

The paper provides two major contributions: model-based calculations indicate that decarbonization can be attained at the lowest cost by a combination of renewable energies (mainly solar and wind), storage, and some peak-shaving through demand-side management. Second, by contributing a significant piece of modeling to the community, open-access with fully transparent code, data, and results, we contribute to the scientific debate and the transparency of analysis, thus strengthening the political debate with scientific substance.

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Designing an operational market for grid supporting use of electric flexibilities in distribution networks

Erik Heilmann[1]

[1]*Universität Kassel*

With a progressing energy transition, there will be a growing number of distributed energy resources in the distribution grid. These can be on the one hand renewable power plants like wind turbines and photovoltaic systems and on the other hand electric consumers, such as electric vehicles and heat pumps. As a result of this process, there is a huge need for grid enhancements in order to avoid technical problems. In distribution grids, the major problems expected are capacity congestions in electrical lines and transformers as well as overvoltages in some nodes of the grid. Today's approach of grid enhancement up to the last kilowatt power is economically inefficient and time- and resource-consuming.

Against the background of this soon-to-be situation, a number of practitioners and researchers proposed regional flexibility markets in order to use them in a grid supporting way. Flexibility, in this context, can be an electrical producer, consumer or storage that is able to adapt certain technical parameters (e.g., electrical power) in response to a critical grid condition. Although the concept of these so called 'regional flexibility markets' has been discussed much, there still exists no operational market according to the original idea.

The article at hand aims to describe a possible market design of a regional flexibility market. Such a market shall enable distribution system operators (DSO) to procure grid supporting flexibilities and therefore reduce operational cost in the short term and grid enhancement in the long term. For potential suppliers of flexibility, this market is an alternative to the established energy exchange trading and the balancing energy market.

The main challenge in the market design problem is that so far neither a tradeable product nor a trading mechanism of such a market exist. Thus, there is a wide range of possible design options that need to be canalized in a proper way.

Because the background of the market is a technical problem, the relevant technical conditions have to be identified and analyzed first. More precisely, the question has to be answered what technical behavior is needed to solve the technical problems in the grid as well as who can provide an adequate technical flexibility. Furthermore, an important issue that has to be solved in this context is the technical effectiveness of a flexibility. There exist physically based topological relationships defined by the structure of the grid between the offered flexibility options and a specific technical problem in the grid.

Based on these technical conditions, the market itself can be designed. In more detail, that is the traded products and the trading mechanism. The products can be described with their technical parameters, such as electrical power or energy, a time component, e.g., one day or one hour, and some rule-based parameters, such as minimum offer and so forth. The product design should be as standardized and easy as possible to simplify the trading processes. At the same time, it must be able to solve the technical problems in the background with regard to the aforementioned topological relationships. The trading mechanism or auction design contains aspects of organization (framework of the auction), traded goods (as a meta description), bids (rules and language of offers)

and contract award (solving the winner determination problem and pricing rule). Therefore, an implicit or explicit information of the local component (grid node) in each traded product is of outstanding importance.

With regard to auction theory, the designed auction can be described as a combinatorial multi-criteria multi-unit auction. Combinatorial in this context means that bidders can bid on combinations of items. Multi-criteria means that not only the price and quantity, but also other product parameters (here a local topological component) are relevant for the winner determination. Multi-unit means that the amount of the traded goods is bigger than one. This auction type is of a high complexity and so far has been little studied.

As a part of the BMWi funded project ‘C/sells’, the developed market design will be implemented in a field test in real subnetworks of the DSO “EnergieNetz Mitte” and will continuously be improved.

Exploring Energy Pathways for the Low-Carbon Transformation in India - A Model-Based Analysis

Hans Hosenfeld[1], Alexandra Krumm[1], Linus Lawrenz[1], Luise Lorenz*[,1], Bobby Xiong[1], Konstantin Löffler[2], Pao-Yu Oei[1,2], Christian von Hirschhausen[1,2]

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Keywords: Energy System Modeling, Decarbonization, OSeMOSYS, GENeSYS-MOD, Renewables, Energy Transformation, India, Sector Coupling

Motivation

With a total population of more than 1.3 billion and emerging industry sectors, India's energy roadmap will have a significant impact on the global low-carbon energy transformation. Hence, it is crucial to design a wholistic energy pathway towards a low carbon energy transformation until 2050 including the power, heat, as well as transportation sectors. For this purpose, the open-source linear cost-optimizing model GENeSYS-MOD is applied.

Methods

Based on geographic, demographic, and economic assumptions, the model calculates an energy path until 2050. To achieve a higher resolution, India is segmented into ten sub-regions and a transformation in five-year steps from 2015 to 2050 is simulated. To allow a deeper understanding of theoretical transformation pathways, three scenarios are presented. The Limited Emissions Only (LEO) scenario is used as a benchmark scenario, which is based on the 450-ppm scenario of the IEA. Thereby a CO_2 emissions budget is set, and in contrast to the 100% RES scenario, conventional energy sources are allowed in 2050. The database for the Business As Usual (BAU) scenario is taken from the New Policies scenario by the IEA and follows a rather conservative path.

Results

The model results show that a transition towards a low-carbon energy system in the power, heat, and transportation sectors until 2050 is both technically feasible and economically achievable. Throughout the three scenarios, solar power will establish itself as the key energy source by 2050, given the model's underlying emission limits and restrictions. In the benchmark scenario, around 67% of India's 2050 power composition will be attributed to solar power, followed by wind generation (23%) and hydropower (6%). The biggest challenge for the renewable roadmap will be the lack of potential for renewable energies (RE) in metropolitan areas (e.g. Uttar Pradesh). To overcome those differences in RE potentials, there is a need to expand the transmission grid.

Enabling China's Low-Carbon Energy Transformation Through Expanding its Transmission Grid

Bobby Xiong[1], Luise Lorenz[1], Linus Lawrenz[1], Alexandra Krumm[1], Hans Hosenfeld[1], Thorsten Burandt[1,2], Pao-Yu Oei[1,2], Christian von Hirschhausen[1,2]

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Keywords: Energy System Modeling, Decarbonization, OSeMOSYS, GENeSYS-MOD, Renewables, Energy Policy, Energy Transformation, China, Sector Coupling

Motivation

Accounting for 29.5% of the world's total CO_2 emissions, China's energy roadmap will have a significant impact on the global low-carbon energy transformation in the coming decades. To assess China's ability towards a sustainable energy economy throughout 2050, the open-source linear cost-optimizing model GENeSYS-MOD is applied, considering geographic, demographic, and economic assumptions.

Methods

To project a wholistic energy path until 2050, including the power, heat, and transportation sector, China is segmented into eight sub-regions. Within the model, technological parameters, such as operational lifetimes, time slices, efficiency and availability factors are implemented. This research consists of three different scenarios, allowing a deeper understanding of theoretical transformation pathways. The Limited Emissions Only (LEO) scenario, based on the 450-ppm scenario of the IEA, is used as a benchmark. Thereby, a CO_2 emissions budget is set, and in contrast to the 100% RES scenario, conventional energy sources are allowed in 2050. The database for the Business As Usual (BAU) scenario is taken from the New Policies scenario by the IEA and follows a rather conservative path.

Results

Throughout the nation's energy transformation, solar power will dominate the energy mix with a share of 70% by 2050, followed by wind (17%) and hydropower (12%). China's current heavy reliance on fossil energy carriers in the process (high) heat sector, will slowly fade out in favor of biomass and power to heat technologies. Given the enormous imbalance of renewable energy potentials in the west and high energy demand along the coastal regions in the east of China, the model confirms the necessity of a strong transmission backbone grid.

Session 14:30 – 15:50
Modelling and Simulation of Energy Markets

Room: Rotterdam Hall
Chair: Hannes Hobbie (TU Dresden)

Economic comparison of different electrofuels for energy scenarios in 2035

Philipp Runge, Friedrich-Alexander-Universität Erlangen-Nürnberg

Dynamic State-Induced Price Components in Power Markets

Leonard Göke, RWTH Aachen University

Easy-to-implement Cognitive Algorithms for Electricity Spot Price Prediction - An Open-source. Open-access Approach

Lissy Langer, Technische Universität Berlin

Producers, Retailers and Risk-Averse Consumers

Elisa Trujillo-Baute, University of Barcelona

Economic comparison of different electrofuels for energy scenarios in 2035

Philipp Runge[1], Christian Sölch[1], Gregor Zöttl[1], Veronika Grimm[1], Peter Wasserscheid[2], Jakob Albert[2]

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Keywords: Electrofuels, Electricity Markets, Hydrogen Utilization, Mobility, Sector Coupling

Motivation

In 2015 the transport sector was responsible for about 24% of the global emissions of greenhouse gases (GHG). In order to achieve the transition to a GHG free world economy, as described in the Paris climate agreement, the mobility sector needs to be decarbonized. Electrofuels (e-fuels) enable CO_2-neutral mobility and are therefore an alternative to battery-powered electric vehicles. In addition, e-fuels are very easy to store and could become a key component of an integrated energy system. This paper compares the cost-effectiveness of Fischer-Tropsch diesel, methanol and Liquid Organic Hydrogen Carriers (LOHC).

Methods

The production costs of those e-fuels are to a large part driven by the energy-intensive electrolytic hydrogen production. In this paper, we use a multi-level electricity market model to calculate future hourly electricity prices for various electricity market designs in Germany for the year 2035. We then assess the economic efficiency of the different fuels under different future market conditions. In particular, we use the electricity price vectors as an input for a mathematical model of the entire process chain from hydrogen production and chemical bonding to the energetic utilization of the fuels in a vehicle. Within this model, we perform a sensitivity analysis which quantifies the impact of various parameters on the fuel production costs.

Results

We were able to show that, in addition to the purchase price for carbon dioxide and the electrolyzer's investment costs, the market design has an outstanding influence on the result. By changing the market design from an energy only to a nodal pricing system, the production costs of the fuels could be reduced by up to 40%. The results also suggest that the use of hydrogen, which is temporarily bound to LOHCs, is a favorable alternative to the more widely discussed synthetic diesel and methanol.

Dynamic State-Induced Price Components in Power Markets

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Keywords: Variable renewables, Dynamization, Energy market, Climate policy, Welfare analysis

Motivation

In most European countries, state-induced price components constitute the major share of electricity prices for consumers and are charged at a fixed rate. In this study we analyze whether switching state-induced price components to time-varying rates can support the integration of variable renewables (VRE) and, thus, help to efficiently achieve the overarching goal of a decarbonization of the energy system.

Methods

Based on game theory and linear programming, we introduce a novel simulation model of the power market. For the quantitative case study, the model is parametrized to represent a German energy system that meets the political objective to increase the generation share of renewables (RE) to 80% in 2050. The model comprises two stages that are repeatedly processed. The first stage represents the short-term power market and simulates the dispatch of exogenously determined generation capacities using linear programming. The second stage represents the long-term power market and simulates investment decision into capacities for an exogenously determined market outcome in the short-term via backward induction. An iterative algorithm carries out these steps until both are at a consistent Nash equilibrium.

Results

We find that dynamization supports the integration of VRE into the energy system. Even if dynamization is an efficient instrument to promote decarbonization as well, it is nevertheless highly dependent on the prevailing regulatory framework.

Easy-to-implement Cognitive Algorithms for Electricity Spot Price Prediction – An Open-source, Open-access Approach

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Keywords: Electricity Prices; EPEX; Forecasting; Neural Networks; Kernel Ridge Regression

Electricity prices are increasingly subjected to strong volatility due to growing shares of fluctuating and intermittent renewable energy sources. Integrating the demand side by the advancement of smart grid technology leads to new possibilities of market participation for an increasing amount of small players. Consequently, short-term price prediction becomes an important issue. However, having fewer resources available, these players rely on open-source easy-to-implement algorithms and open-access data to benefit from these developments. In this paper, hands-on pattern recognition algorithms for the short-term forecast of electricity day-ahead prices are developed, from scratch, using Python. Balancing the trade-off between prediction accuracy to unknown data on the one hand, and computational efficiency on the other hand, we develop algorithms with an adequate level of complexity. Special focus is laid on slowly expanding complexity by starting of with simple linear ridge regression, advancing to lasso regression and finally using kernel ridge regression in a radial basis function network. While considering the complexity of the algorithms, we indicate potentials regarding data volume as well as tuning through thorough model analysis. This way, we also like to propose steps to improve the selection and tuning process. With RMSE of up to 2.74 EUR and R2 up to 0.95, we show significant improvements, mostly due to exceptional performance on outlier classification.

Producers, Retailers and Risk-Averse Consumers

[1]Valeria Di Cosmo, [2]Elisa Trujillo-Baute

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The benefits of smoothing demand peaks in the electricity market has been widely recognised. European countries such Spain and the Scandinavian countries have recently given to the consumers the possibility to face the wholesale prices instead of having a fixed-tariffs determined by retailers. In this paper we develop a theoretical model to study the relations between risk averse consumers, retailers and producers, both in the spot and in the forward markets when consumers are able to choose between fixed tariffs and the wholesale prices. We calibrate the model with a real market case - Spain, using a change from quarterly auction-based retail price to TOU (spot, PVPC), and determine the "risk aversion parameter". Finally, we simulate agents behavior and markets performance, depending on consumers risk aversion and compare the results.

Our results show that the quantities the retailers buy in the forward market are positively related with the risk aversion of consumers and negatively related with the skewness of the spot prices. On the contrary, quantity sold forward by producers are positively related with the skewness of the spot prices (high probability of getting high prices increase the forward sale) and with the total market demand. In the retail market, the degree of consumers' risk aversion determines the quantity bought in the spot market (the more the consumers are risk averse, the more they buy at the fixed price determined by the retailers -auction in our case). Finally, the quantity sold by the retailers in the spot market is positively related with the consumers' risk aversion.

Session 14:30 – 15:50
Short-term balancing of renewables

Room: St. Petersburg Hall
Chair: Steffi Schreiber (TU Dresden)

The Economic Benefit of Improved RES Forecasts

Jonas Savelsberg, Universität Basel

Unit Commitment under Imperfect Foresight – The Impact of Stochastic Photovoltaic Generation

Jens Weibezahn, Technische Universität Berlin

Who balances Nordic wind? – An Analysis Using the Concept of Relative Balancing Contributions

Richard Scharff, Vattenfall

Integration of Power-to-Gas Conversion into Dutch Electrical Ancillary Services Markets

Víctor García Suárez, Delft University of Technology

The Economic Benefit of Improved RES Forecasts

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Keywords: Electricity Markets, rolling planning, dispatch model, forecast errors

With the growing share of intermittent renewable generation in many electricity markets, forecast accuracy and timing is becoming more important. In our paper, we aim to quantify the effect of improved RES-forecasts on wholesale market outcomes with regard to price levels, volatility and the provision of flexibility by conventional generators. Given the gradual improvement of forecast errors in recent years (see Figure 1), we expect to see an accompanying reduction in negative market feedbacks.

To derive a quantification of the impact of forecasting, we first analyze time series data on RES-forecasts from different bidding zones with high shares of renewables such as Germany or Texas. This allows us to identify improvements in forecast accuracy and timing. Second, we apply a set of different forecast technologies represented by average forecast errors derived from this data to a dispatch model using a rolling planning approach. The rolling planning model is based on the most recent version of the Swissmod model (Schlecht and Weigt 2014), using cost minimization to determine hourly dispatch, reserve provision and price levels under uncertain predictions of renewable power generation. For each level of forecast quality, we create a scenario tree based on auto regressive moving average (ARMA) simulations. The model is applied for selected time periods of one week and solved using rolling 48-hour blocks. In comparing system costs of the different forecast qualities, we are able to identify the economic benefit of forecast improvements.

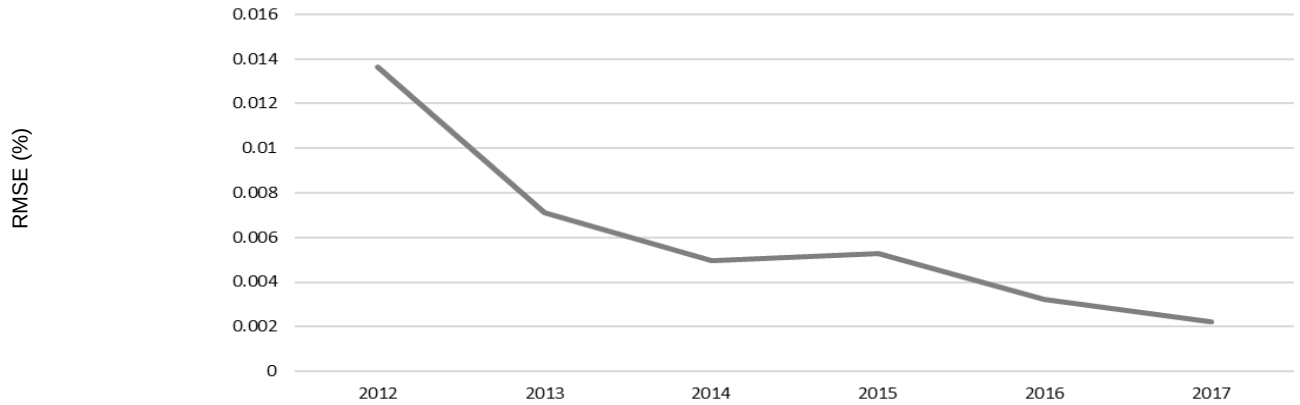

Figure 1: RMSE for wind forecasts in Germany, normalized by capacity (own calculations based on ENTSO-E data)

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Unit Commitment under imperfect foresight- The impact of stochastic photovoltaic generation

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Keywords: electricity system modeling, photovoltaic, stochasticity, forecast error, unit commitment, flexibility

Motivation

The deployment of RES, mainly wind and PV, has strongly increased over the last years. These two technologies inherit an explicit dependency on weather conditions, making short-term system operations more challenging, as the final output is uncertain and volatile. If deviations in the production of RES are not comprehensively anticipated in short-term scheduling decisions of conventional power plants, this might lead to an inefficient use of the power system. Hence, by anticipation of forecast errors, their scheduling must account for uncertainties in the system.

Methods

This paper uses the model stELMOD, incorporating the European multi-market regime (day-ahead, intraday, real-time balancing). An approach to simulate a time-adaptive intraday forecast is presented. Uncertainty of PV generation is incorporated by numerous multi-stage scenario trees, accounting for a decreasing forecast error over time. Thereby, a comprehensive assessment of scheduling costs, redispatch costs and amounts, flexibility needs of the power system, as well as power line usage can be carried out. To comprehensively assess the impacts of fluctuating renewable generation, different cases of stochastic RES infeed are considered.

Results

The preliminary results show an increasing need for more flexibility of the German power system in order to cover uncertain changes of both wind and PV generation. Updating information on both wind and PV generation with a single forecast leads to significant higher total system costs and triggers a tremendous increase in scheduling actions. The impact of capturing stochastic PV generation by different scenarios leads to a further decrease of scheduling actions, at the cost of higher balancing actions and more carbon emissions. Including improvements of both wind and PV forecasts by a scenario tree of possible manifestations, the scheduling costs could be significantly reduced in representative weeks for spring and summer.

Who balances Nordic wind? – An Analysis Using the Concept of Relative Balancing Contributions

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Keywords: wind power, flexibility, Nordic power system, hydro power, reglerbidrag

Motivation

As wind power is going to play a larger role in the future energy system, the operation of conventional power plants has to be adjusted in order to balance other patterns of variations. In addition, demand side patterns might change as well due to an expected growth of flexible and controllable loads, e.g. heat pumps, hydrogen production and electric vehicles. In the Nordic synchronous area of the European electric power system, hydro power is the central balancing resource, but – so far – its' operation is mainly directed to predominant load patterns (variations during a day, between weekdays and weekends, as well as partly to seasonal variations). Therefore, it is necessary to investigate the "gap" between the tasks "balance consumption" and "balance wind".

Methods

The analysis assesses the balancing contribution of power plants, import and exports as well as consumption during three time horizons ranging from one day to one year. Flexibility in these time scales is central from a Nordic perspective, because the system is dominated by hydro power which is well designed to smooth hourly variations, but restricted when it comes to longer time periods. In addition, the need for flexibility can compete between the same resources during these time scaled. In the analysis, hourly production, import/export and consumption data for each of the eleven price zones of the Nordic power system is used. Based on this, for each type of power plant in each price zone, shares are computed that show to which extent they have contributed to balance total Nordic wind power production, total Nordic load and total Nordic residual load. Here, we apply the concept of relative balancing contributions (Swedish: reglerbidrag) which is based on the covariance of each source and the time series that should be balanced.

Results

Some expected results include that hydro power contributes most in the intraday horizon, while nuclear power does not contribute at all in this horizon. Interesting is the detailed distribution between the eleven price zones as well as the results of the power exchanges on the interconnectors between the Nordic synchronous area and the neighbouring areas (Continental and Baltic areas as well as Russia).

Integration of Power-to-Gas Conversion into Dutch Electrical Ancillary Services Markets

Víctor García Suárez[1]

[1]*Delft University of Technology*

The synergy between the electricity and gas sectors, commonly referred to as Power-to-Gas, can originate promising flexibility options for power systems. The prospect of this sector coupling raises particular interest in a country like the Netherlands, where natural gas consumption is elevated and gas fired power plants constitute a substantial share of the annual electricity generation. Along the benefits provided by hydrogen storage, which can be directly used for industry or mobility purposes, or transformed into syngas for household consumption or electricity generation, the actual conversion of electricity into hydrogen by means of electrolysers can become a useful resource as grid ancillary services provider.

This paper focuses on the integration of large scale electrolyser capacity into the Dutch electrical ancillary services markets. A review of the current structure and mechanisms of balancing markets, voltage regulation and congestion management is presented, taking into account the effects of future market harmonization measures proposed by central Europe grid operators. The technical capabilities of electrolysers are also analyzed and further compared to the existing prequalification requirements to evaluate the adequacy of this technology. Furthermore, in order to illustrate the value of electrolysers for electrical network supporting duties, a small case study based on the Eemshaven area in the north of the Netherlands is presented. This section of the Dutch network includes the COBRAcable HVDC link and several offshore windfarms from the North Sea. Computer based simulations are performed with the Real Time Digital Simulator (RTDS) platform

Session 14:30 – 15:50
Energy and prices

Room: Florenz Hall
Chair: Christoph Zöphel (TU Dresden)

Analyzing the Relationship of German Retail Fuel Prices and Oil Prices

Sebastian Kreuz, BTU Cottbus-Senftenberg

Forward Premia in Electricity Markets: a replication study

Silvester van Koten, Vorname, University of Economics Prague

Modelling the wind auctions as a participation game

Jan Vávra, University of Economics in Prague

Rockets and Feathers in Germany's Gasoline Market: The Effect of Increased Market Transparency

Marco Horvath, RWI - Leibniz-Institut für Wirtschaftsforschung e.V.

Analyzing the Relationship of German Retail Fuel Prices and Oil Prices

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Keywords: cointegration, error correction model, retail fuel, oil price, diesel

Motivation

The relationship between retail fuel prices and oil prices is a widely discussed topic, which is usually related to questions regarding certain forms of market power in the retail sector. Since the early 1990s, research in that area has focused on econometric models to investigate the connection between retail fuel prices and oil prices for numerous countries and regions. Literature usually emphasizes price levels, but also the relationship between oil price changes and subsequent fuel price changes. The latter is usually described as testing for asymmetric responses, which means different adjustment speeds of retail fuel prices after oil price increases compared to oil price decreases.

Firstly, I test for the cointegration relationship and secondly for potential asymmetric cost passthrough between crude oil and retail diesel prices (‘Rockets and Feathers’) for the German market. For that purpose, I use station-specific data of about 6800 fuel stations from June 2014 to May 2016. The data is obtained from the market transparency unit for fuel within the German Federal Cartel Office.

Methods

I use standard methods to test for cointegration between station-specific German retail diesel prices and crude oil prices, which are e.g. OLS for optimized long-run relationship estimations. Furthermore, to answer the question of asymmetric cost pass-through from crude oil prices to retail diesel prices, I use asymmetric error correction models (ECM) with different settings (e.g. lag length selection indicators). I inspect my results regarding individual station characteristics, such as brand or location.

Results

My results show a high degree of cointegration, which means widespread stable long-run relationships between retail diesel prices and crude oil prices. Furthermore, my results show that asymmetric cost pass-through is given for just a small number of stations. First findings illustrate that the ‘Rockets and Feathers’- phenomena is more prevalent for high priced stations and dominating brands.

Forward Premia in Electricity Markets: a replication study*

Silvester van Koten[1]

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As a replication and robustness study, I run simulations testing the influential risk premium theory of Bessembinder & Lemmon (2002), highlighting the effects of alternate specifications of supply introduced in their paper: constant supply and adaptive supply. The risk premium theory links forward premia to the statistical properties of the anticipated distribution of spot power prices. My simulation results support Hypothesis 3 for both specifications of supply and don't support Hypothesis 4. I cannot replicate Figure 3 in Bessembinder & Lemmon (2002, p. 1361), and suspect that it's incorrect. The results support Hypotheses 1 and 2 for constant supply but not for adaptive supply. The dynamics of the forward premium are thus sensitive to alternate assumptions regarding supply, which may provide a tentative explanation for the mixed empirical support for these hypotheses.

* I thank, without implicating, Pär Holmberg, Andreas Ortmann, Sergey Slobodyan, Michal Zator and the participants of Dresden Enerday 2015 and the Mannheim Energy Conference 2015 for their helpful comments on an earlier draft. Special thanks to Henrik Bessembinder for his detailed and generous comments on an earlier draft of this paper. I also thank my research assistant Marek Zelenay for his excellent research support. All errors remaining in this text are the responsibility of the author. Financial support from GACR grant No. 15-03488S is gratefully acknowledged.

Modeling the wind auctions as a participation game

Silvester van Koten[1], Jan Vávra[1]

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Germany has recently implemented auctions for market premia to support wind generator projects as legislated in the Renewable Energy Sources Act (EEG). While the first auctions have been held, the precise workings of the incentives and their long-term outcomes are still unknown. A notable observation was that the majority of winning bids was by privileged bidders (as opposed to the other bidders, they did not have to make a pre-investment to be eligible for the auction).

The present paper addresses the incentives and their long-term outcome by modeling the auction as a participation game and, at a later stage, testing the model in an experiment.

We argue that the auctions are correctly modeled as a participation game due to the relatively strict eligibility requirement for bidders in the form of obtaining all necessary permits, which is effectively a form of sunk pre-investment. Potential bidders thus must make a decision to participate or not by making a sunk pre-investment. The number of bidders that decided to participate then enters the auction. We simplify the bidding process by assuming a simple peak-load pricing scheme (when supply by bidders is larger than demand, the price is equal to marginal cost, otherwise equal to the price cap).

The model predicts a trade-off of too many entrants (losses of unused sunk pre-investment) versus too few entrants (welfare losses due to too few wind generator projects being realized). The government can chose the prevalence of each trade-off by adjusting the price cap. Lowering the value of the sunk investment (and perhaps replacing it with the transfer in the form of a bond) lowers all losses. In addition, the model predicts that when some bidders are privileged in the sense of being eligible without pre-investment, then these privileged bidders will crow out the other non- privileged bidders.presenting the paper:

Rockets and Feathers in Germany's Gasoline Market: The Effect of Increased Market Transparency

Marco Horvath[1], Manuel Frondel[1], Alexander Kihm[1], Colin Vance[1]

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Keywords: Retail Gasoline, Rockets and Feathers, Competition, Error Correction Model.

Motivation

Demand for gasoline is highly inelastic in the short run, price increases and fluctuations may therefore have substantial effects on disposable income. One type of pricing dynamic, characterized by Bacon (1991) as the "rockets and feathers" phenomenon, has piqued special attention. This is the pattern whereby gasoline prices rise quickly – like a rocket – in response to positive oil price shocks, but fall slowly – like a feather – in response to negative shocks. The present analysis documents a change in the price setting behavior of retail gas stations following the introduction of a legally mandated on-line price portal in Germany.

Methods

We assemble a unique data set of daily fuel prices for over 5,000 stations in Germany. The data set is split into two time intervals of equal length, one covering from January 2012 until November 2013 (before the introduction of the on-line price portal), and the other covering from January 2014 until November 2015 (after the introduction of the on-line price portal). Error correction models, from which impulse response functions are derived, are estimated separately on each of these intervals and for each individual gas station.

Results

The impulse response functions reveal a striking change in the pattern of price pass-through: Prior to the portal's introduction, positive price asymmetry prevails, but this reverses to negative price asymmetry thereafter. Moreover, this pattern is found for both branded and unbranded stations. This reversal in price pass-through suggests that the portal achieved a principle aim of generating welfare gains for consumers.

Session 16:20 – 17.40
Strategic decisions and behaviour in power markets

Room: Hamburg Hall
Chair: Matthew Schmidt (TU Dresden)

Transmission and generation investment for a core market region within a larger electricity market

Jonas Egerer, Friedrich-Alexander-Universität Erlangen-Nürnberg

A Model based Market Power Analysis of the German Market for Frequency Containment Reserve

Samir Jeddi, ewi Energy Research & Scenarios gGmbH

Economic and Environmental Consequences of Market Power in the South-East Europe Regional Electricity Market

Verena Viskovic, University College London

Electricity Prices under Climate Policy

Evangelos Panos, Paul Scherrer Institut

Transmission and generation investment for a core market region within a larger electricity market

Jonas Egerer[1,2], Veronika Grimm[1,2], Thomas Kleinert[1,2], Martin Schmidt[1,2], Gregor Zöttl[1,2]

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Keywords: Electricity Market, Renewable and Network Investment, Cross-border effects

Motivation

Market liberalization in the electricity sector has resulted in larger integrated market regions, covering multiple countries. In addition, the development of renewable generation capacity increases the level of supra-regional electricity trade. On the other side, national regulation within its spatial responsibility, sets market rules and decides on investment levels in transmission as well as renewable generation capacity. In the context of the low-carbon transformation and with increasing market integration, national regulation on country level should consider the implications of neighboring market regions on its national decisions.

Methods

Representing this limitation in spatial decision power is mathematically more challenging than a system-wide perspective, but allows for better analysis of national decisions on market regulation and infrastructure investments. Building on a three-level model for the European electricity market, we develop a framework to analyze scenarios for the German energy transition in the electricity system until 2035.

Results

The results highlight how different developments (i.e., scenarios for electricity systems of the neighboring countries, cross-border market integration, changes in congestion management, etc.) affect the optimal regional distribution of renewable capacity and transmission investment in Germany. The work also discusses the possibility of additional back-up generation capacity in the absence of regional investment incentives for private investors in power plant capacity.

A model-based market power analysis of the German market for Frequency Containment Reserve

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Keywords: Balancing Power, MPEC, EPEC, Market Power, FCR

Motivation

When transforming the electricity system it is important to ensure a high level of security of supply. To maintain the frequency of the electricity system at a certain level, supply and demand need to be equal at all times. To balance short-term deviations the activation of Frequency Containment Reserve (FCR) is needed, which is controlled by transmission system operators (TSOs). A sustainable positive price development for balancing power seems to be unlikely, as future alternative supply structures especially for Frequency Containment Reserve (FCR) have not been found. In connection with the already high market concentration the analysis of market behavior is needed.

Methods

We propose a complementarity bi-level market model for FCR procurement in Germany to be solved by each generator, whose objective is to maximize his own profit. This model is constrained by capacity restrictions as well as the market-clearing problem of the TSO. Eventually, the profit maximizing problem of providers is formulated and a quantitative analysis of current and future market outcome is conducted. To evaluate the market process, the optimization problems as well as equilibrium problems and their solution approaches are examined.

Results

The authors conclude that current market outcomes are beyond competitive levels. The costs for balancing power can be reduced by shorter contract durations, while an increase of strategic behavior must be tolerated. Prospectively, the investments in stationary battery systems for balancing power provision play an important role, as they cannot only decrease costs, but also have the potential of mitigating market power. At the same time, it can be seen that new technology-specific concentration rates hold considerable market power potential. Accordingly, a regulatory incentive for battery storage investments should be chosen wisely to ensure a sustainable positive price development.

Economic and Environmental Consequences of Market Power in the South-East Europe Regional Electricity Market

Verena Višković[1], Yihsu Chen[2], Afzal S. Siddiqui[3], Makoto Tanaka[4]

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Keywords: Market power, EU ETS, Carbon leakage, South-East Europe regional electricity market

Motivation

We study the effect of market power in electricity and CO_2 emissions permit markets in the South-East Europe Regional Electricity Market (SEE-REM), which comprises both EU members subject to the EU Emissions Trading System (ETS) and non-EU members exempt from it. While tighter emissions caps generally cause higher electricity prices and emissions leakage under perfect competition, it is not clear how a dominant firm can affect market outcomes by manipulating both electricity and permit prices.

Methods

We use a game-theoretic model with firms, consumers, and an independent system operator (ISO). Each profit-maximising firm owns several plants. Consumers are represented by inverse-demand functions. The ISO decides the nodal welfare-maximising imports/exports. The electricity market is cleared by equating supply and demand with endogenous determination of permit prices. We formulate two types of models: a perfect competition equilibrium model and a bi-level model, in which Enel is the Stackelberg leader. The former is rendered a quadratic program (QP), and the latter a mixed-integer quadratic programming problem (MIQP).

Results

We have two emissions scenarios: no cap (NC) and binding cap (BC) on ETS emissions (10% reduction from NC). Under QP-BC, a permit price of €8.64/t decreases ETS production, increases ETS electricity prices, and entices non-ETS production resulting in more exports to ETS. Consequently, 38.6% of the emissions reduction achieved in ETS is leaked to non-ETS. Under MIQP-NC, Enel withholds generation by 6% in order to raise prices and increases its profit by 1%. Under MIQP-BC, Enel further withholds its output and lowers the permit price to €6.55/t. This way, Enel raises electricity prices in Italy and increases its profit by 2.15% vis-à-vis QP-BC. However, in other ETS countries, the lower permit price translates into lower electricity prices. This inflates electricity consumption leading to higher non-ETS production and emissions, which increase leakage to 40.6%.

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Electricity prices under climate policy

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Introduction

We present a new fundamental electricity market model to explain key drivers of electricity prices under policy scenarios for coupled market areas, comprising in the current analysis the countries Germany, France, Italy, Austria, and Switzerland. We investigate how the currently most prevalent policy scenarios can influence long-term prices. We employ a technology-detailed game-theoretic Nash-Cournot equilibrium model since the price levels, and price volatilities on wholesale markets can deviate significantly from (marginal) cost-based model analysis. We show quantitative results on the impact of renewable deployment, fuel and CO2 prices on the electricity prices and trade patterns between the market areas.

Methods

We employ a technology-detailed game-theoretic Nash-Cournot equilibrium model. We model the day-ahead market with 24 hourly sub-markets in four yearly seasons (96 representative load periods in a year). The electricity plants are aggregated into technology clusters, and operating constraints (e.g. ramping rates, part load efficiency losses, start-up costs, minimum online/offline times, etc.) are approximated through a linearised relaxation of the unit commitment problem. The model also includes seasonal and diurnal storage technologies. A stochastic extension allows for capturing the variability of intermittent renewables.

Results

Electricity market prices in small market regions are mainly determined by the supply mix of the surrounding market regions. For all countries, gas-fueled plants are likely to have a stronger role as price-setters on the wholesale markets than today: the gas and CO2 prices are directly reflected in the wholesale prices in all scenarios in most of the load periods. In Germany, electricity prices are mainly driven by the gas and CO2 price. In France, market prices could drop because of increased domestic wind generation. Italy remains the region with the highest price in the future due to the large share of fossil-based generation.

Conclusions

Modelling of electricity wholesale market prices by a fundamental model requires the integration of technical and market details, as well as the representation of a markup of prices with respect to pure cost-optimization. It also requires capturing of seasonal and diurnal trading patterns between the market areas. Our results show that a game-theoretic model can analyse such scarcity price effects, even when the markup is not caused by imperfect competition, but by other external events, e.g. unexpected rise in demand.

Session 16:20 – 17.40
Gas markets

Room: Rotterdam Hall
Chair: Philipp Hauser

The Importance of the Gas Infrastructure for Germany's Energy Transition

Theresa Eich, Frontier Economics Limited

Diversification at any price – Economic assessment for reaching the EU diversification targets?

Simon Schulte, ewi Energy Research & Scenarios gGmbH

Integration of Electricity and Gas Market – Accounting for Interdependencies and Uncertainty

Thomas Möbius, BTU Cottbus-Senftenberg

Power to Gas: a crucial component for sectoral coupling and energy supply security

Michael Friedrich, Greenpeace Energy

The importance of the gas infrastructure for the German Energy Transition

Theresa Eich[1]

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Keywords: Sector coupling, future key technologies, Power-to-Gas, system costs

Motivation: We[2] evaluate how the existing gas infrastructure can make a sustainable contribution to a future energy system based on renewable energy.

By 2050, greenhouse gas emissions should be reduced by 80 to 95 per cent relative to their level in 1990. A clear policy requirement is that the majority of the greenhouse gas reduction be achieved using renewable electricity in the heat, transport and industrial sectors. However, the question remains unresolved as to how energy should be transported from where it is produced to the end-consumer, as well as how energy should be stored.

Against this backdrop we evaluated the impact of the long-term use of the gas infrastructure to transport gas produced from renewable energy (Power-to-Gas, "PtG") on the cost of the energy supply chain (electricity production, energy conversion, electricity and gas transportation, electricity and gas storage, and end-user applications).

Methods: Which future technologies and energy system will emerge during the energy transition depends on many economic, political and technical developments. We estimate three scenarios, each with a different degree to which the gas infrastructure can be exploited in 2050.

- One scenario assumes the continued presence of a gas infrastructure, which links energy generation to its final use. Here the widespread use of PtG technology would be required.
- In an alternative scenario PtG is only used for temporary storage of gas which is later converted back into electricity.
- In a third scenario PtG plays no role.

Results: Using existing gas infrastructure to transport green gas would reduce decarbonisation costs and boost acceptance and security of supply of the energy transition.

By 2050, overall net savings will amount to around EUR 12 billion per year (in real terms). These savings include lower investment in electricity networks and end-user applications of approximately EUR 268 billion by the year 2050.

[2]*Frontier Economics together with IAEW, EMCEL, 4 Management https://www.fnb-gas.de/files/fnb_gas_wert_von_gasinfrastruktur-endbericht.pdf,*

Diversification at any price – Economic assessment for reaching the EU diversification targets?

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Keywords: Diversification, EU gas market, Gas Target Model, COLUMBUS, economic assessment

Motivation

One important pillar of the European Union's third energy package was the establishment of the Agency for the Cooperation of Energy Regulators (ACER), an independent regulation authority with the vision to create a "competitive, secure European gas market that benefits all consumers". To achieve this vision ACER developed the Gas Target Model (GTM) in 2011. In 2014, ACER updated the GTM and introduced specific metrics to assess the functioning of the EU gas wholesale market reforms and hence the implementation of the network codes.

The research objective of this work is an economic assessment of the metrics ACER is applying to reach its vision of a competitive, secure European gas market. Thereby the following questions will be addressed:

- Does ACER set the right metrics to incentivize a 'well-functioning' EU natural gas wholesale market?
- What are the costs to reach the EU's/ACER's diversification targets with the suggested metrics (HHI, RSI, three sources per country)?
- Are there, from an economic point of view, better options to reach an appropriate degree of diversification?

Methods

To answer these questions the COLUMBUS model is extended and applied. COLUMBUS is an equilibrium market model formulated as a mixed complementarity problem. It simulates the global natural gas market. To estimate the costs that will occur to realize the metrics targeted by ACER the respective metrics are implemented into the COLUMBUS model, which is then simulated for 2025. Beside the respective metrics, also other options as market mergers are simulated.

Results

I am currently implementing the metrics into the COLUMBUS model and hence there are no results so far. However, on the ENERDAY first results would be presented.

Integration of Electricity and Gas Market – Accounting for Interdependencies and Uncertainty

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Keywords: electricity market, integrated energy system modelling, natural gas market, uncertainty

Motivation

A considerable amount of research has been oriented to economic modelling of European energy markets. To date, several studies have highlighted interdependencies between power generation and gas markets and demonstrated that linkages between the markets produce results systematically different from not-integrated modelling approaches. The focus of our work is to study the dynamics of competing investments in both electricity and gas markets. Our main contribution is incorporating endogenous investments in electricity generation capacities in an uncertain environment for gas-fired power plants. These uncertainties address the level of gas prices as well as their spatial and temporal variations.

Methods

We develop a stochastic programming model with recourse, which accounts for uncertainty and interdependencies between electricity and gas markets. Our methodology follows modelling techniques utilizing a linear programming formulation (LP) of a global cost-minimization problem to determine optimal investment decisions. The model includes all relevant infrastructure elements and cost estimators for energy production and transport for the European electricity and natural gas market models. As a key factor for uncertainty, we implement a varying natural gas demand on the consumer side apart from the electricity-producing sector. Hence, for each scenario we generate gas prices that differ in location and time.

Results

As a result, we develop a fundamental investment model which accounts for interdependencies between European electricity and gas markets. Compared to the approach when both markets are modelled separately as standalone systems, we analyze how spatial and temporal variations of gas prices influence both energy dispatch decisions and the relocation of optimal investments in electricity generation capacities.

We further implement an uncertain natural gas demand and thus, uncertainty regarding the realization of gas prices. Due to the application of a stochastic modelling approach, gas prices vary differently in the spatial and temporal dimensions depending on the underlying scenarios. Hence, we are able to observe a shift in the optimal investment allocation as well as a decreasing competiveness compared to other investment options.

Power to Gas: a crucial component for sectoral coupling and energy supply security

Michael Friedrich[1]

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Keywords: Power to Gas, Windgas, sectoral coupling, energy supply security, renewable energy

Motivation

Sectoral coupling is one of the key components for the future design of Germany‘s as well as Europe‘s energy system: Without sectoral coupling it will hardly be possible or utterly impossible to decarbonize all the economic sectors which still heavily depend on fossil fuels – such as the traffic sector (particularly cargo / container shipping traffic or air traffic), the industry sector (e.g. chemical industry) or heat supply. Energy transition has not yet taken place in these sectors, so carbon dioxide emissions have to be cut rapidly and dramatically.

Methods

Our findings are based on studies we commissioned, conducted by Energy Brainpool, an independent energy market institute with its fundamental energy market model Power2Sim, that simulates hourly electricity prices until the year 2050 for all countries of the European Union, Norway and Switzerland.

Results

A) Renewable gases such as hydrogen and methane are an important aspect of sectoral coupling. In Germany, they will be of systemic relevance for energy supply security once renewable energies provide 65 per cent of Germany’s gross energy consumption. This makes power to gas or windgas technology an crucial component to achieve the goal of Germany‘s coming government to reach this threshold by 2030.

B) The minimal electrolyser capacity that needs to be installed in Germany to guarantee energy security in a renewable energy system with all other flexibility options fully implemented amounts to 42,7 GW.

C) A future German energy system will be considerably cheaper with windgas / power-to-gas technology than without. The cost benefit adds up to between 11,7 and 17,4 billion euro annually.

D) Windgas technology is ready for roll-out. That can be managed economically feasibly, by starting the electrolyser production on a low level and rolling it out on larger scale when costs have come down and windgas becomes crucial for energy security. How that can be done, will be part of our presentation.

E) Finally, we would be able to present findings of a new study commissioned by Bundesverband Erneuerbare Energie (that has been supported by Greenpeace Energy) which analyses existing obstacles for sectoral coupling in Germany and identifies measures to overcome these hurdles.

Session 16:20 – 17.40
System Operators and Congestion Management

Room: St. Petersburg Hall
Chair: Dirk Hladik

Aggregation of Temporal Representation of High-Resolution, Fundamental Flow-Based Market Coupling Input Data to Identify Typical Market Scenarios - A Systematic Evaluation and Selection of Relevant Cluster Algorithms

Martin Kittel, Technische Universität Berlin

Locational (In-) Efficiency of Renewable Power Generation in the Distribution Grid: A Spatial Regression Analysis

Tim Höfer, RWTH Aachen

Trends in European Regulation / still struggling for the IEM

Christian Dobelke, TenneT TSO GmbH

Price Zones and Investment Incentives in Electricity Markets: An Application of Multi-Level Optimization with Graph Partitioning

Mirjam Ambrosius, Friedrich-Alexander Universität Erlangen-Nürnberg

Aggregation of Temporal Representation of High-Resolution, Fundamental Flow-Based Market Coupling Input Data to Identify Typical Market Scenarios - A Systematic Evaluation and Selection of Relevant Cluster Algorithms

Martin Kittel[1]

[1]*Technische Universität Berlin*

This research is dedicated to the identification of representative situations of Central Western European electricity markets. Due to the increasing share of intermittent renewable energy sources, European's power systems are exposed to rising temporal and spatial variability. When aggregating the temporal resolution of fundamental market data, the adequate representation of load fluctuations and variability in renewable energy generation is imperative. A thorough literature review identifies the cluster analysis as most appropriate aggregation technique. Multidimensional time series representing load and renewable energy generation of multiple countries are processed by a large number of cluster scenarios. The scenarios differentiate in terms of applied algorithm and further methodological cluster parameters. Scenario results are systematically evaluated by means of statistical and application-based error metrics. Results reveal salient cluster parameter. It becomes obvious that even a small number of representative market situation is sufficient to represent global characteristics and fluctuations of the fundamental data.

Locational (In-) Efficiency of Renewable Power Generation in the Distribution Grid: A Spatial Regression Analysis

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Keywords: Feed-in management, Spatial regression analysis, External effects, VRES

Motivation

This paper analyzes the negative external effects caused by electricity from variable renewable energy sources (VRES) fed into the distribution grid. The resulting external costs arise from the need for feed-in management, i.e. the intervention necessary when grid operators are forced to relieve grid overstress by temporary disconnecting of VRES power generation assets. During these times, the power plant operators receive remuneration for the electricity output which could have been produced if the distribution system operator (DSO) had not cut back their output. The resulting costs of the feed-in management for the DSO are passed on via the grid use tariffs and eventually have to be borne by the end-consumers connected to the distribution grid in question. This leads to higher grid use tariffs in regions with high amounts of renewable energies.

Methods

We conduct a spatial regression analysis which explains the occurrence of feed-in management by taking into account the spatial differences over time within a DSO's region. So-called Voronoi polygons are created around the DSO substations in the high voltage grid in order to construct meaningful grid zones. Temporal changes within a polygon, such as grid reinforcements, increased installed capacity of renewable energies, or decreasing load are addressed by incorporating data for the years 2013 till 2017.

Results

Preliminary analysis shows that the type of power plant, the voltage level in which the power plant is connected, and the load density are strongly correlated with feed-in management and that the magnitude of correlation varies among DSO regions. Further, we find that while some polygons are heavily affected by feed-in management, others are not affected at all.

Trends in European Regulation / still struggling for the IEM

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Keywords: IEM, European Regulation, Clean Energy Package, TenneT TSO

In 2009 the "EU-Regulation on conditions for access to the network for cross-border exchanges in electricity" entered into force, and many stakeholders in the energy sector hoped that it would provide the final momentum for the completion of the IEM. There has been great progress in day-ahead markets, refined capacity calculation and coordinated network planning, and not least the first wave of Network Codes has been completed. Yet, analyses like e.g. the ACER Market Monitoring Report still reveal dissatisfying results. The current drafts of the Market Regulation in the so-called Clean Energy Package (CEP) are without doubt an attempt to heal the shortcomings of the IEM so far, they provide rules on more centralized regional system operations, on minimum capacities between bidding areas, on the process to define bidding zones.

Motivation

With my team we're closely following the development of the CEP, not least in relation to the ongoing discussion about bidding zones and redispatch costs in Germany, to grid extension and to discrimination-free cross-border grid-access. We're assessing the consequences if the rules of the current CEP version will be implemented, what about costs, right or wrong incentives, market design?

Methods

Slide presentation, illustrating CEP provisions vs. up-to-date examples.

Results

A clearer view on practical consequences for Transmission System Operators (TSOs) if the CEP will become law in its current draft.

Price Zones and Investment Incentives in Electricity Markets: An Application of Multi-Level Optimization with Graph Partitioning

Mirjam Ambrosius[1], Veronika Grimm[2], Thomas Kleinert[3],
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Keywords: Electricity Markets, Price Zones, Investment Incentives, Multilevel Programming, Graph Partitioning

Motivation

With a growing share of renewables, regional price signals become more important as a possible remedy for dealing with network congestion. While some countries such as the United States use a nodal pricing approach in order to account for restrictions given by the physical transmission network, the European market is split into a limited number of zones with uniform prices where in most cases price zones coincide with country borders. However, additional bidding zones within the countries could enable better signaling of scarcities induced by the transmission network and are therefore under discussion. Still, it is not clear how many bidding zones would be beneficial and how exactly a market should be split in order to maximize overall welfare. This paper addresses the problem of determining the welfare-optimal bidding zone configuration for the German electricity market.

Methods

In order to gain insight into the best possible zoning of an electricity market and its impact on investment incentives, we use a multilevel optimization model, which determines the optimal configuration of price zones via graph partitioning. It incorporates the optimal determination of interzonal transmission capacities, generation capacity investment, spot market trading and redispatch. The model is solved to global optimality, using a decomposition approach that is specifically tailored for the effective solution of the resulting optimization problem.

Results

Our results show that market splitting with the right zonal configuration can lead to high welfare gains when compared to the case of a single price zone. Further, it can be beneficial with respect to welfare to restrict inter-zonal transfer capacity in order to increase price signals for spot market trading.

Session 16:20 – 17.40
Energy efficiency and system stability

Room: Florenz Hall
Chair: Thomas Walther (TU Dresden)

Frequency and persistence of low-wind events in Germany
Wolf-Peter Schill, DIW Berlin

Energy Audits vs. – ISO Management Systems: a review of Austrian policy - Effectiveness of the internalization of identifying energy efficiency potentials and resulting savings rates
Christian Schützenhofer, University of Vienna

Revenue decoupling and energy consumption: Empirical evidence from the U.S. electric utilities sector
Victor von Loessl, Universität Kassel

Energy Security - a new perspective as a solution to present problems in energy market integration?
Krzysztof Ksiezopolski, SGH

Frequency and persistence of low-wind events in Germany

Nils Ohlendorf[1], Wolf-Peter Schill[1]

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Motivation: The Paris Agreement calls for an extensive decarbonisation of the global economy. In this context, the expansion of variable renewable energy sources, in particular solar photovoltaics (PV) and wind power, will play a major role. While power generation from solar PV largely follows diurnal and seasonal cycles, wind power is subject to more irregular inter-annual as well as intra-annual fluctuations which give rise to security of supply concerns. In countries with growing shares of wind power, the occurrence of low-wind-power (LWP) events thus receives increasing attention. This is particularly true in Germany. Given the government's targets to expand the share of renewables in electricity consumption to at least 80% by 2050, the dependence of the German energy system on wind power is set to increase strongly in the future.

Method: Yet dedicated research on LWP events is sparse so far. We aim to fill this gap, focusing on onshore wind power. We examine the frequency, persistence, and magnitude of German LWP events, making use of reanalysis data for 36 full years (1981 to 2016) and state-of-the-art power curves. In doing so, we are using a weighting scheme considering the current spatial distribution of onshore wind power capacity in Germany (Fig. 1). We then look at different thresholds of capacity factors (2%, 5% and 10%) and two definitions of LWP events. Parts of our analysis focus on winter months. These appear to be particularly relevant, as power generation from solar PV is also relatively low in winter. In order to allow for the highest degree of transparency and reproducibility, we provide the source code and all input data of our analysis under dedicated open-source licences.

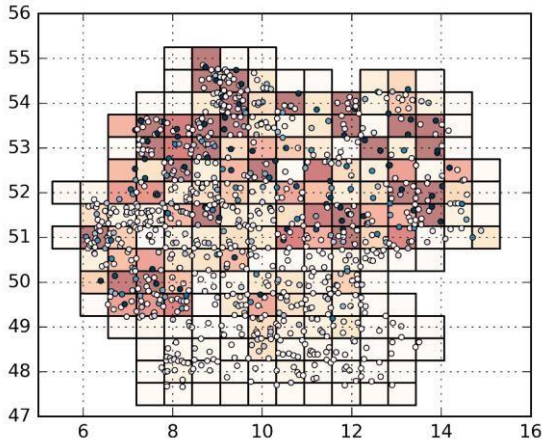

Figure 1: Installed wind power capacity and weighting

Results: For both LWP definitions, events are generally most frequent in summer (June-August) and least frequent in winter (December-February), independent of the duration. The results for spring (March-May) and autumn (September- November) are mostly close the annual average. The frequency of events for a given persistence is about 1.5-3 times higher for the MBT definition compared to CBT. For both definitions, the chosen threshold value has a strong effect. For example, a 10-hour event below a capacity factor of 2% (MBT) occurs on average once per winter. For a 10% threshold, there are 15 such events on average (Fig. 2).

Conclusions: Our analysis for

Germany shows that the likelihood for extreme LWP is generally smaller in winter than in summer, but power system planners should be prepared for extreme events also to occur in winter months. Further, the magnitude of low-wind power events differs strongly between the years. Studies only considering one year or a small sample of years are likely to underestimate the possibilities of lowwind power events and should thus not be used to inform policy makers with respect to power system planning.

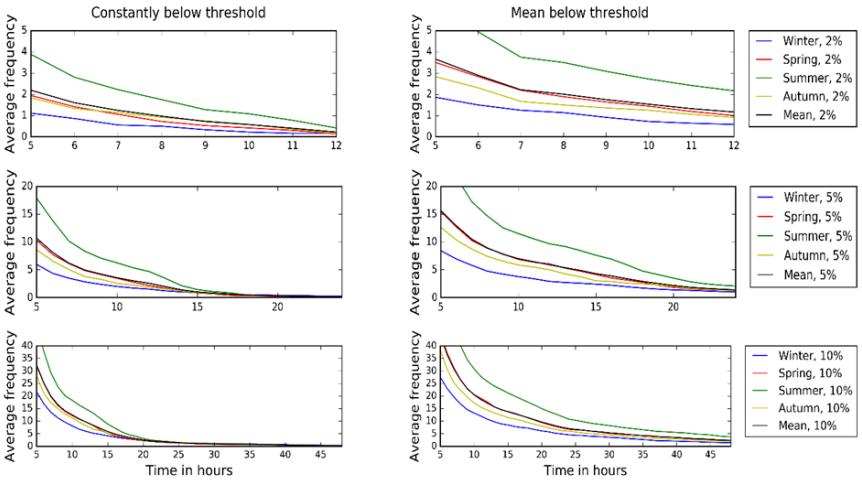

Figure 2: Average seasonal frequency and persistence of LWP events in Germany

Energy Audits vs. – ISO Management Systems: a review of Austrian policy

Effectiveness of the internalization of identifying energy efficiency potentials and resulting savings rates

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Keywords: energy gap, energy efficiency, management system,

Motivation

Literature documents many barriers to energy efficiency but few documented, working methods to overcome these barriers. In the case of firms this paper argues for and provides supportive data for one such working policy. We propose the internalization of the identification and organization process of efficiency measures and their implementation via standardized processes. These are so called management systems such as those documented in ISO 14.001 (environmental management systems) and ISO 50.001 (energy management systems). Moreover, we find supportive data of Austrian large firms.

Methods

Analytical: comparative analysis of documented energy efficiency barriers and prescribed management tools from ISO standards to circumvent them by simple management tools.

Quantitative: comparison of firms' resulting savings from enacting measures of the two cases: external energy audits and energy management as the firm deems appropriate vs. internal management system audits and a stringent energy management process.

Results

The hypothesis that the internalization of energy efficiency potential identification ("energy audits") via ISO standardized energy management processes results in more implemented measures and therefore higher energy savings is supported by the data. We found a 165% increase of savings compared to the base case of external audits and non-ISO certified energy management processes.

Revenue decoupling and energy consumption: Empirical evidence from the U.S. electric utilities sector

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Keywords: Decoupling, energy efficiency, stochastic frontier analysis, demand frontier function

Motivation

Energy efficiency marks a substantial resource to tackle increasing greenhouse gas emissions. However, in traditionally regulated energy markets, energy providers maximize their profits by selling electricity or heat as long as their marginal costs of production exceed their marginal revenue. This so called 'throughput incentive' fundamentally restricts the motivation of utilities to invest in energy efficiency. This paper therefore aims to investigate the effect of decoupling, which separates utilities' revenue from sales fluctuations, on electricity customers' energy demand and efficiency in the U.S..

Methods

To process the research question at hand, we follow recent developments in energy demand function modeling and Stochastic Frontier Analysis (SFA) estimation techniques that allow to account for persistent (time-invariant) as well as transient (time-variant) efficiency. Based on an aggregated energy demand function, we estimate a stochastic frontier function to detect underlying inefficiencies. We use two different models, namely a Mundlak adjusted Random Effects Model (MREM) and a True Random Effects Model (TREM), which allows the differentiation between persistent and transient efficiency. An unbalanced panel data set for the period of 2001 to 2015 that includes utility specific information regarding total sales, absolute customer numbers and consumption shares (commercial, industry and households) as well as state-level data regarding Cooling Degree Days (CDD), Heating Degree Days (HDD), real gross domestic product (GDP) and average electricity sales prices, builds the basis for our analysis.

Results

The estimation results allow the conclusion that both types of (in-) efficiency are of considerable size, which emphasizes the usefulness of the additionally gained information by the differentiated approach. Furthermore, we find the persistent inefficiency to be substantially larger than the transient inefficiency. Investigating the impact of implemented decoupling mechanisms on investor-owned electricity utilities' customers, we find a significant negative effect of decoupling true up plans on the electricity consumption of those customers.

Energy security – a new perspective as a solution to present problems in energy market integration?

Krzysztof Ksiezopolski[1]

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The energy security of the EU countries which today is largely built on the fossil fuels and on the centralized energy system is often perceived in the opposition to climate security. In other words, the efforts to reduce the greenhouse emissions that involve decarbonisation and decentralization of the contemporary European energy system are presented in many EU countries (and CEE region in particular) not only as a challenge but a threat to energy security. Consequently, there is still a little understanding of how energy-climate policy can enhance energy security and economic development in the long term. I see a need to introduce and develop a new perspective – a comprehensive approach to energy and climate security as a part of the solution to present turbulences in this areas of the EU policies and problems in energy market integration. I argue that from energy security perspective the energy-climate policy can be beneficial in both geostrategic and economic terms – among others it will reduce primary energy import dependency across the EU and decrease some vulnerabilities of the present energy system giving a strong foundation for economic growth. On the other hand, the actions taken in and by the European energy sector will determine the future of energy security. In the times of crisis in the EU the energy security policy (both in the field of security of supply and liberalization of the energy and gas market) unlike the climate policy has been reinvigorated. To some extent the European funds and investments in the energy sector (i.e. EEPR, PCIs) has been perceived as a solution to the economic problems. Now the more comprehensive approach to energy security and climate policy can become a solution to the growing problems in energy market integration. The paper will address the following questions:

1. What are the geopolitical and economic consequences of the climate policy for energy security of the EU countries? What are the challenges, threats and opportunities? What are the consequence for energy market integration process?
2. How can the climate security be combined with the energy security? Can we develop a comprehensive approach to those two dimensions of the European security?
3. To what extent it can be a solution in the times of growing uncertainties and crisis in the EU?