# ENERDAY

# 11th Conference on Energy Economics and Technology

***Energy Efficiency and Demand Response***

# Book of Abstracts

**8th April 2016**

Technische Universität Dresden, “Festsaal” of the Faculty of Business and Economics
Schumann-Bau / Hülsse-Bau, Münchner Platz 3, 01069 Dresden, Germany

Contact / Registration:
Mandy Bauer, TU Dresden, EE[2], enerday@ee2.biz, tel.: +49-(0)351-463-39771, www.ee2.biz

*Kindly supported by:*

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# Foreword

Dear participants of the 11th 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 11th Conference on Energy Economics and Technology, focusing this year on Energy Efficiency and Demand Response.

Despite the current low energy prices, energy efficiency and demand response continue to offer a valuable means for addressing several ongoing challenges facing both the German and the European energy markets, e.g. an increased dependence on energy imports, the need to mitigate climate change and the integration of fluctuating renewable energies. Energy efficiency reduces primary energy consumption, decreases energy imports and thus directly reduces greenhouse gas emissions. Increasing flexibility on the demand side also aids in facilitating the integration of renewable energies and is a prerequisite for well-functioning future energy markets.

In the spirit of ENERDAY, several questions with regard to the topic "*Energy Efficiency and Demand Response*" are of interest:

- How to further stimulate energy efficiency measures and how can barriers be overcome?
- How flexible is the demand side in a long and short-term horizon and how can the flexibility potential be leveraged?
- What role does demand response play with regard to power prices and the integration of renewables?
- What are the current and future key technologies in this context?
- What technologies may be important in accompanying these efforts, e.g. storage?

The 11th Conference on Energy Economics and Technology ("ENERDAY") addresses challenges with regard to energy systems, markets and policies with a special focus on issues related to "energy efficiency and demand response". The main themes of the conference include empirical analysis, fundamental modelling approaches, best practice examples, policy and market design as well as technology-specific aspects. 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 supporter of this conference DREWAG, the municipal utility of Dresden, as well as to our sponsor Robotron Datenbank-Software GmbH. Additional support is received by TU Dresden Institutional Strategy, financed by the Excellence Initiative of the German federal and state governments.

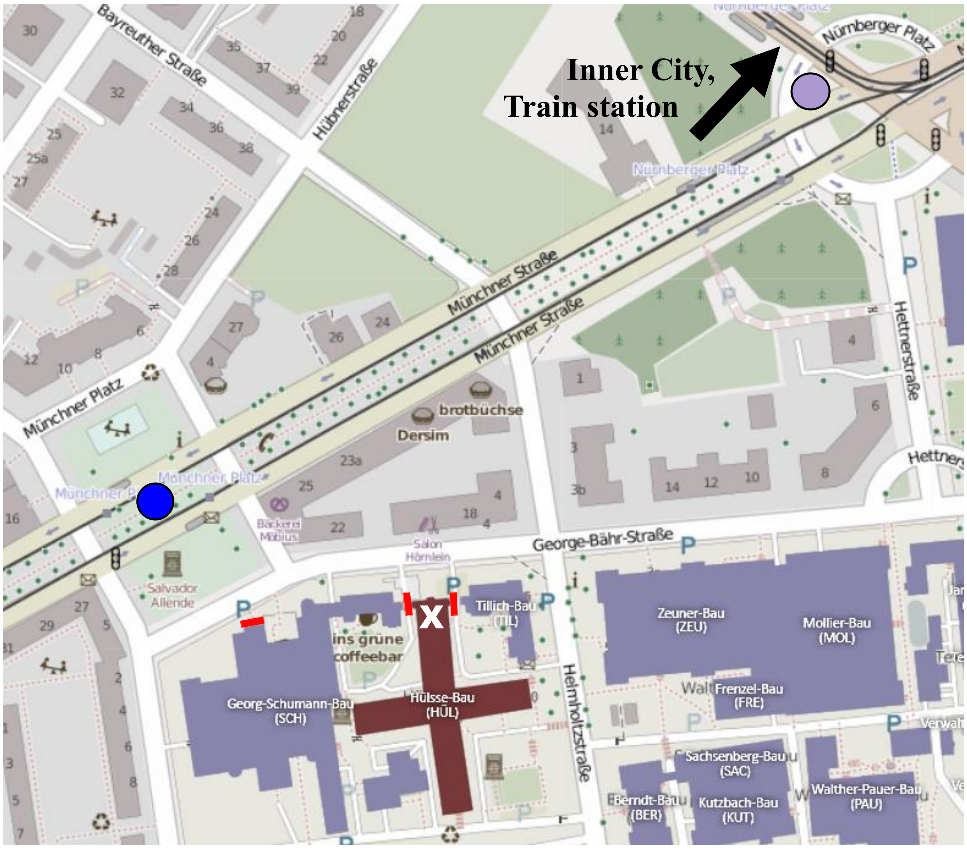
As the organizers of the conference, we were particularly delighted about the high level of interest shown by the research community, which is reflected in the internationality of the participants and the number of papers submitted. In light of the more than 110 submissions and their quality, we have decided to extend ENERDAY this year from the usual three to four parallel sessions. Nonetheless, we were still forced to rigorously evaluate the submissions which resulted in an acceptance rate of approximately one third. Therefore, 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, Christian von Hirschhausen, Mandy Bauer
& EE2 organizing committee

# Conference Location

Technische Universität Dresden, "Festsaal" of the Faculty of Business and Economics, Schumann-Bau / Hülsse-Bau, Münchner Platz 3, 01069 Dresden, Germany




**X** **ENERDAY** registration

Building entrances

Tram station: Münchner Platz Line 3

Tram/Bus station: Nürnberger Platz Line 8 and Line 62

**By car:**

From the **West** (Leipzig, Chemnitz): At the motorway interchange 77b-Dreieck Dresden-West follow the signs A17 to "Prag". Leave A17 at exit 3-Dresden Südvorstadt. Drive on B170 in direction Dresden and follow the signs to „Plauen". Drive on "Nöthnitzer Straße", turn right into "Georg-Schumann-Straße" and drive up to "Münchner Platz".

From the **East** (Bautzen, Berlin) leave A4 at exit 81a-Dresden Hellerau and drive on B170 in direction Dresden-Zentrum. After the main train station keep straight, following the tram (No.3). Turn right into "Münchner Straße" and drive up to "Münchner Platz".

Try to find a parking lot around "Münchner Platz" or within the university area.

**By tram / bus:**

From the **airport** take the S-Bahn line S2 on the lower ground floor of the terminal building and drive up to the main train station ("Hauptbahnhof"). Then take the tram No. 3 (direction: Coschütz) and get off at "Münchner Platz".

From the **North** or the **Inner City** take the tram No. 3 (direction: Coschütz) and get off at "Münchner Platz" or take the tram No. 8 (direction: Südvorstadt) up to "Nürnberger Platz".

From the **West** take the bus No. 62 (direction: Weißig / Fernsehturm) up to "Nürnberger Platz".

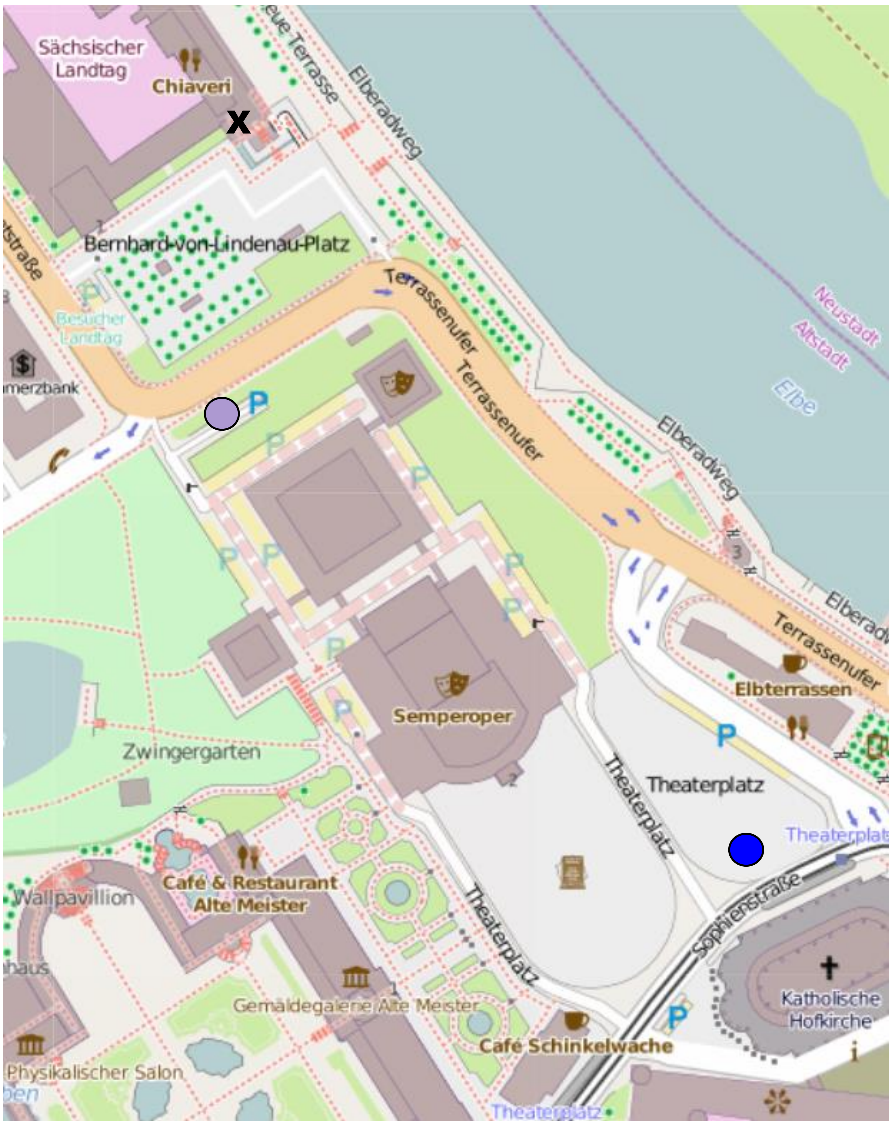
From the **East** take the bus No. 62 (direction: Löbtau) up to "Nürnberger Platz".

# Conference Dinner

**Friday, 8 April 2016, 7 pm**

Chiaveri im Sächsischen Landtag, Bernhard-von-Lindenau-Platz 1, 01067 Dresden, Germany

www.chiaveri.de




Tram station: Theaterplatz, Line 8

Basement garage Semperoper

**Chiaveri**

**By car (about 15 minutes):**

Drive along the "Münchner Straße" in direction Dresden-Zentrum. Keep left and follow the B170. At "Pillnitzer Straße" (before the bridge) turn right, then immediately turn left into "Steinstraße" and then turn left into "Terassenufer". Follow the street about 900 meters and try to find a parking lot or basement garage around Theaterplatz.

**By tram / bus (about 25 minutes):**

Tram Line 8 (direction: Hellerau) will take you directly from the University to the Conference Dinner (tram leaves every 10 minutes). The tram leaves at the corner of „Münchner Straße"/„Nürnberger Straße" (see map conference location). Get off after seven stops at „Theaterplatz". Walk in the direction of the Semperopera along Terassenufer about 300 meters.

# Conference program on Friday, 8th April 2016

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| **Informal Get Together** | **Thursday, 7 April 2016, 7 pm**<br>Café Central, Altmarkt 6, 01067 Dresden |

**Conference Program**

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| 8:30 | Registration, Coffee & Tea |
| 9:00 | **Opening Address** (Room: Faculty Assembly Hall)<br>Prof. Dr. rer. nat. habil. Gerhard Rödel, Vice-Rector for Research, TU Dresden<br>Prof. Dr. Dominik Möst, TU Dresden, Chair of Energy Economics<br>Prof. Dr. Christian von Hirschhausen, TU Berlin, Workgroup for Infrastructure Policy (WIP) and DIW Berlin |
| 9:30 | **Keynote Speech** (Room: Faculty Assembly Hall, Chair: Prof. Dr. Christian von Hirschhausen)<br>**Rebound – The Achilles Heel of Energy Efficiency?**<br>Prof. Dr. Reinhard Madlener (RWTH Aachen University) |
| 10:15 | Coffee & Tea |

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|---|---|---|---|---|
| 10:45 - 12:05 | **Potential of Demand Response**<br>Room: Fac. Assembly Hall<br>Chair: Christoph Zöphel | **Energy Efficiency 1**<br>Room: A03<br>Chair: Julia Michaelis | **Congestion Management and Market Design**<br>Room: B37<br>Chair: Matthew Schmidt | **Power Prices and Tariffs**<br>Room: Dresden Memorial<br>Chair: Samarth Kumar |
| 10:45 | **Prospects of Electricity Demand and Demand Side Management Potentials of Residential Customers**<br>Jörg Dickert (TU Dresden) | **Investments in Energy Efficient Technology: Survey-based Evidence on the Behavior of German Manufacturing Firms**<br>Philipp Massier (Centre for European Economic Research) | **Coordinating Cross-Country Congestion Management**<br>Dr. Friedrich Kunz (DIW Berlin) | **Wholesale price volatility: the effect of uncertain wind feed-in**<br>Thomas Möbius (Brandenburg University of Technology) |
| 11:05 | **How much flexibility can Demand Response applications provide the electricity system?**<br>Theresa Müller (TU Dresden) | **Consumer Inattention and Energy Efficiency: The Causal Effect of Label Elements**<br>Stephan Sommer (RWI) | **Assessing the impacts of market-designs on investments in flexible technologies**<br>Nikolas Hary (MINES ParisTech; Microeconomix) | **Risk premia in electricity spot markets – New empirical evidence for Germany and Austria**<br>Niyaz Valitov (University of Wuppertal) |
| 11:25 | **An assessment of the achievable potential of large-scale Demand Response**<br>Antoine Verrier (Paris Dauphine University) | **How do companies differ in their investment behaviour for energy efficiency? Comparing the iron & steel and cement sectors with survey results and cluster analysis**<br>Thomas Ketelaer (FZ Jülich) | **Electricity market design: Policy coordination**<br>Prof. Dr. Hannes Weigt (University of Basel) | **Trading behavior on the continuous intraday market ELBAS**<br>Richard Scharff (KTH Royal Institute of Technology; Vattenfall) |
| 11:45 | **Plant-specific bottom-up analysis regarding the feasibility of DSI potentials in the industry sector in Germany**<br>Nikolai Klempp (University of Stuttgart) | **Impacts of Energy Efficiency and the Value Chain on Corporate Financial Performance**<br>Anne Bergmann (TU Dresden) | **Tender Frequency and Market Concentration in the Balancing Power Market - The Case of Germany**<br>Frank Obermüller (ewi Energy Research & Scenarios) | **Optimal retail tariff design for electricity markets with high shares of renewable energy**<br>Andreas Knaut (University of Cologne) |

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| 12:05 | Lunch |
| 13:15 | **Keynote Speech** (Room: Faculty Assembly Hall, Chair: Prof. Dr. Dominik Möst)<br>**The EnBW Pilot Project „Flexible Power-to-Heat“**<br>Dr.Holger Wiechmann (Energie Baden-Württemberg AG) |
| 14:00 | Short 5-Minute-Break |

| 14:05 - 15:25 | **Demand Response for Renewable Integration**<br>Room: Fac. Assembly Hall<br>Chair: Theresa Müller | **Energy Efficiency 2**<br>Room: A03<br>Chair: Daniel Schubert | **Infrastructure, Systems and Policy**<br>Room: B37<br>Chair: Hannes Hobbie | **DSO & Distributed Renewable Energy Sources**<br>Room: Dresden Memorial<br>Chair: Michael Zipf |
|---|---|---|---|---|
| 14:05 | **Demand response an option for reserve power?**<br>Dr. Rainer Enzenhöfer (TransnetBW GmbH) | **Identifying the influence of design parameters on energy performance of residential buildings by sensitivity analysis**<br>Kamran Naeiji (TU Berlin) | **Impacts of a German coal phase-out on the German electricity mix and prices**<br>Hasan Ümitcan Yilmaz (Karlsruhe Institute of Technology) | **DSO revenues from Local Balancing Cluster with active demand side**<br>Rafał Dzikowski (Lodz University of Technology) |
| 14:25 | **Steering demand response and renewables in distribution grids via network charges?**<br>Christine Brandstätt (Jacobs University Bremen) | **Can Energy Efficiency Save Energy? An Economy-Wide Rebound Effect Simulation for Turkey**<br>Tugba Somuncu (Istanbul Technical University) | **Influence of balancing reserves on the electricity infrastructure in Europe until 2050**<br>Casimir Lorenz (TU Berlin) | **Reactive power provision from the distribution grid and its effects on redispatch cost**<br>Fabian Hinz (TU Dresden) |
| 14:45 | **Potentials of industrial load management in Germany**<br>Victoria Orioli (Siemens AG) | **Economic Analysis of Energy Refurbishment in Buildings**<br>Isidoro Tapia (European Investment Bank) | **Let lignite take a backseat – The lignite phase-out in the context of the German transmission grid extension**<br>David Gunkel (TU Dresden) | **Distributed Renewable Energy Sources with Demand Response Integration in Low Voltage Distribution Grid**<br>Jernej Zupančič (University of Ljubljana) |
| 15:05 | **Field of Tension between Energy Efficiency and Flexibility**<br>Anna Gruber (Forschungsgesellschaft für Energiewirtschaft mbH) | **The impact of innovation on industrial energy efficiency and how to promote it through supporting policies**<br>Silvia Sanz (Durham Business School) | **Interaction Effects between different Types of Energy Generating Capacities - A Firm Level Study**<br>Nora Schindler (Vienna University of Economics and Business) | **Potential contribution of residential demand response to a fossil-free electricity system reserve**<br>Jonas Katz (Technical University of Denmark) |

15:25 Coffee & Tea

| 16:00 - 17:20 | **Pricing, Incentives and Demand Response**<br>Room: Fac. Assembly Hall<br>Chair: Fabian Hinz | **Electric Vehicles and Demand Response**<br>Room: A03<br>Chair: David Gunkel | **Renewable Integration**<br>Room: B37<br>Chair: Christoph Brunner | **Gas**<br>Room: Dresden Memorial<br>Chair: Philipp Hauser |
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| 16:00 | **Analysis of Incentive-based Demand Response Mechanism**<br>Dr. Robert Basmadjian (University of Passau) | **Demand response technologies as optimal storage options in 2030**<br>Benedikt Eberl (Forschungsgesellschaft für Energiewirtschaft mbH) | **Innovative market integration of renewable electricity**<br>Sebastian Bothor (TransnetBW GmbH) | **Shaking Dutch Grounds Won't Shatter the European Gas Market**<br>Prof. Dr. Franziska Holz (DIW Berlin; Hertie School of Governance) |
| 16:20 | **Demand Response Potential of End-users Facing Real Time Pricing**<br>Dr. Yiqun Ma (University of Groningen) | **Future load shift potentials of electric vehicles in different charging infrastructure scenarios**<br>Tobias Boßmann (Fraunhofer ISI) | **Optimal trade-offs between Energy Efficiency improvements and additional Renewable Energy supply: A review of international experiences**<br>Mattia Baldini (TU Denmark) | **The Economics of Natural Gas Storage in Europe**<br>Dr. Andreas Schröder (Uniper Global Commodities SE / E.ON) |
| 16:40 | **Real-time Electricity Pricing with Heterogeneous Consumers and Variable Renewable Energy Supply: Welfare and Distributional Effects**<br>Christian Gambardella (PIK) | **Reserve provision by electric vehicles in Germany: model-based analyses for 2035**<br>Wolf-Peter Schill (DIW Berlin) | **Electricity storage and flexibility requirements on the road to decarbonization in European electricity**<br>Clemens Gerbaulet (TU Berlin) | **Options for diversifying the European Union's natural gas market**<br>Simon Schulte (University of Cologne) |
| 17:00 | **Investment Incentives for flexible Demand Options under different Market Designs**<br>Mirjam Ambrosius (University of Erlangen-Nürnberg) | **Uncertainties in Optimized Scheduling of Electric Vehicle Charging**<br>Zongfei Wang (Karlsruhe Institute of Technology; Helmholtz Research School on Energy Scenarios) | **Is a multiplicative RES surcharge a good instrument to leverage DSM?**<br>Lyuba Ilieva (Frontier Economics Ltd.) | **Strategic Behavior in Global LNG Markets: Outlook for the Asia-Pacific Region**<br>Philipp Feister (TU Dresden) |

19:00 Conference Dinner (Chiaveri im Sächsischen Landtag, Bernhard-von-Lindenau-Platz 1, 01067 Dresden)

# Content

# Keynote 9.30 – 10.15

**Room: Faculty Assembly Hall**
**Chair: Prof. Dr. Christian von Hirschhausen (TU Berlin)**

## Rebound – The Achilles Heel of Energy Efficiency?

Prof. Dr. Reinhard Madlener (RWTH Aachen University)

Rebound effects have sparked considerable academic, policy and press debate over the effectiveness of energy efficiency policy and the actual merit of energy-efficient technologies. In recent years, the debate has been fueled by numerous new theoretical and empirical rebound studies which, however, also brought to light further issues and unanswered questions. At the same time, there seems to be a lack of understanding of how to treat and measure crucial aspects, such as potential energy savings and the energy services impacted by an efficiency increase. Furthermore, there is a still a need for more clarity and understanding regarding how to move from micro to macro levels of analysis and reporting. In terms of policy-making, the key message – and crux of the problem – is that there is no such thing as a simple formula for all dimensions of energy rebound.

# Session 10.45 – 12.05
# Potential of Demand Response

**Room: Faculty Assembly Hall**
**Chair: Christoph Zöphel (TU Dresden)**

**Prospects of Electricity Demand and Demand Side Management Potentials of Residential Customers**
Jörg Dickert (TU Dresden)

**How much flexibility can Demand Response applications provide the electricity system?**
Theresa Müller (TU Dresden)

**An assessment of the achievable potential of large-scale Demand Response**
Antoine Verrier (Paris Dauphine University)

**Plant-specific bottom-up analysis regarding the feasibility of DSI potentials in the industry sector in Germany**
Nikolai Klempp (University of Stuttgart)

# Prospects of Electricity Demand and Demand Side Management Potentials of Residential Customers

Joerg Dickert[1], Peter Schegner[1]

[1] *TU Dresden, 01062 Dresden, Germany, {joerg.dickert; peter.schegner}@tu-dresden.de*

**Keywords:** Demand side management, Efficiency, Home appliances, Residential electricity demand

In the past, conventional power plants produced electricity following the load of the customers. This is called "Supply Side Management". In contrast, renewable energy generation supplies electricity depending on the availability of sun or wind. Therefore, the loads have to become more flexible and consume electricity as it is produced. The process is called "Demand Side Management" (DSM). In the residential sector, the utilization of some general home appliances such as washing machines, tumble dryers, dishwashers as well as refrigerators and freezers can be shifted for some hours. On the on hand this requires the acceptance of the customers and on the other hand a form to control the appliances. The control requires a kind of information and communication technology (ICT) and thus has energy consumption by itself and adds complexity to the system.

The presented research shows aspects of the evolution of the electricity demand in Germany, predicts future energy efficiency gains for home appliances and derives trends for future electricity demands for general appliances as well as novel applications such as electric vehicles, heat pumps or air conditioning. It is shown that the DSM potential of general home appliances is in the same range as the consumption of the ICT and small compared to the novel applications. Therefore, it can be concluded that it is much more reasonable to apply DSM to electric vehicles, heat pumps and air conditioning using the advantage of their storage by means of the batteries of electric vehicles or the heat and cool reservoirs of heat pumps and air conditioning than using general appliances. It is found that the load shifting potential of each novel application is 5 to 10 times higher than the DSM potential of all efficient general home appliances. The complexity is reduced by the decreased number of controlled appliances as well.

# How much flexibility can Demand Response applications provide the electricity system?

Theresa Müller[1]

*[1] TU Dresden, Chair for Energy Economics, Münchner Platz 3, 01062 Dresden, Theresa.Mueller@tu-dresden.de*

**Keywords:** Demand Response, Availability, Electricity Sector, Demand Response Modelling

The structure of the existing electricity system enables it to satisfy demand at all times. It is based on the rule *supply follows demand*. However, due to the increasing share of intermittent electricity generation from renewable energy sources, (more) flexibility from the demand side is needed. Several applications that can either shift or shed their load have been identified in different studies related to the German electricity system (e.g. Klobasa 2007; VDE 2012 or ewi 2012). All of these studies focus on deriving the maximum available DR-potential available in Germany. However, this potential cannot be fully exploited at any given moment because the availability of most applications depend on the ambient temperature and/or time of day. As Figure 1 illustrates, the total available DR potential varies according to the season and hour of the day. Furthermore, the maximum DR potential is not necessarily available during peak times or when feed-in from renewables is low. For example, in Germany demand is at its highest in the morning and evening hours during winter whereas the maximum DR potential is available at night during winter due to the use of storage heaters. Moreover, the feed-in from PV is usually the highest in the daytime during summer. However, during these hours most DR applications are already in use. Thus, the potential load increase energy consumers can provide is quite limited at this time of day. These examples clearly show that the maximum DR potential is not necessarily available when needed.

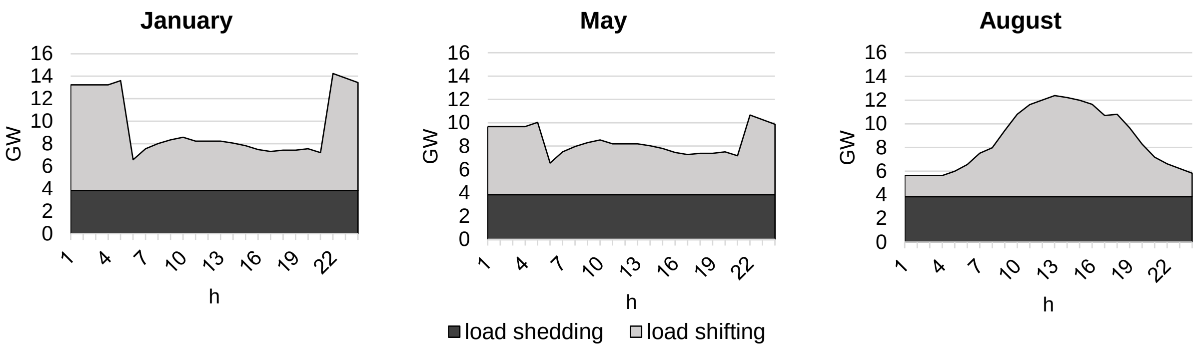


*Figure: Cumulated DR-potential in Germany for exemplary hours in January, May and August (Own calculations)*

In addition, the dispatch of DR-applications is restricted by the period of interference, the shifting time and the number of interventions. For these reasons, the flexibility that DR can provide to the electricity system is limited. Against this backdrop, the presentation addresses the following research questions:

1) To what extent does the dispatch of DR-applications change the residual load curve?
2) Is the available DR-potential completely exploited for offsetting the fluctuations in the electricity system?

In order to address these questions, the Electricity Market Model ELTRAMOD[1] was adapted and used. All relevant technical restrictions of DR-applications that determine their dispatch were implemented in the model. One part of this presentation focuses on these aspects and shows the most important restrictions for modelling DR and how they are applied in ELTRAMOD. Furthermore, a case study for the German electricity sector, which is characterized by a share of renewable power capacity of around 60%, was performed. Initial results show that employing DR flattens the residual load duration curve only slightly due to its limited availability and the presence of technical restrictions. Changes in the positive peak of the residual load duration curve are more considerable than in the negative peak because more DR-applications are available during positive peak times than during times with high feed-in from renewables. The entire RES surplus cannot be completely absorbed by DR commitment. Furthermore, the total available DR potential is not fully exploited, even though no costs for activating them were considered. In fact, the exploited potential of several DR applications amounts to less than 50%. Hence, in some cases the temporal availability of DR potential differs from the time it is needed. For these reasons, from a system perspective it is not efficient to exploit the entire DR potential and thus the focus should be redirected toward utilizing the most relevant applications.

**References**

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VDE, 2012. *Demand Side Integration - Lastverschiebungspotenziale in Deutschland*, Frankfurt am Main.

[1] A model description is published in Müller et al. 2013.

# An assessment of the achievable potential of large-scale Demand Response

Antoine Verrier[1]

[1] *Paris Dauphine University, Chair of European Electricity Markets,*
*Place du Maréchal de Lattre de Tassigny 75016, Paris, France,*
*verrier.antoine@gmail.com*

**Keywords:** Demand Response, Electricity market modelling, Stochastic programming

Demand Response is often seen as an appealing option to ensure the equilibrium of electricity markets in case of high penetration of intermittent renewable energy sources. The European power sector could therefore greatly benefit from large-scale deployment of Demand Response, both in terms of cost and enhanced security of supply. However, despite an important amount of available flexible loads, the potential of Demand Response in Europe is far from being tapped. One fundamental reason is the uncertainty around the economic viability of the enabling technologies needed to trigger Demand Response. We tackle the business case of a Demand Response provider by quantifying its expected annual revenues from a real-time energy market. Our contribution is twofold. First, we explicitly include customer-based constraints that might limit the activation of Demand Response, such as maximum number of Demand Response events and their duration. Second, we take into account the uncertainty arising from the total residual demand, highlighting the opportunity cost for the Demand Response provider to trigger an event at a certain point in time.

Our paper is structured as follows. The first section explains how Demand Response is modelled. In particular, we motivate the approach of modelling Demand Response as a storage unit, while paying a special attention to what differentiate Demand Response from a standard electricity storage. A customer segmentation is also presented. In the second section, we present the electricity market model we use to carry out our study and we introduce the dedicated resolution method, namely the Stochastic Dual Dynamic Programming algorithm. Section 3 presents a case study on the French power system. Two scenarios are analysed: one based on the current electricity mix, one based on a 2030 electricity mix/demand projection. Annual market revenues are estimated and compared with the annual fixed costs of enabling technologies. The last section concludes.

# Plant-specific bottom-up analysis regarding the feasibility of DSI potentials in the industry sector in Germany

Nikolai Klempp[1], Martin Steurer[1,2], Kai Hufendiek[1], Bastian Baumgart[3], Burkhard Steinhausen[3]

[1] *University of Stuttgart, Institute of Energy Economics and Rational Use of Energy (IER), Heßbrühlstraße 49a, 70565 Stuttgart, Germany, nk@ier.uni-stuttgart.de*
[2] *Graduate and Research School Efficient Use of Energy Stuttgart (GREES), University of Stuttgart, 70565 Stuttgart, Germany*
[3] *Trianel GmbH, Krefelder Straße 203, 52070 Aachen, Germany*

**Keywords:** Demand side integration (DSI), load flexibility, renewables integration, industry sector, bottom-up analysis, feasibility of DSI potentials

Demand side integration (DSI) offers a high and rapidly available potential for integrating increasing shares of distributed and volatile electricity production in the existing energy system. The use of flexible demand resources of industrial production sites is characterised by low specific activation costs due to high shiftable loads per production site and often existing control and communication systems [1].

While existing theoretical-based studies often assess the DSI potential as of sheddable or shiftable load, only few take additionally into account temporal and economic parameters as well as plant-specific constraints [2-4]. Due to the heterogeneous technical, economic and organisational situation at industrial production sites a plant-specific analysis is purposeful, which has also been addressed by the German federal government [5].

This study aims to improve the data basis of the DSI potential in the German industry sector regarding technical possibilities as well as economical chances and constraints at a plant-specific level. Consequently, it contributes to identify DSI potentials which can be realised economically.

An extensive interview-based bottom-up analysis of over 200 production sites of selected industry branches is conducted and the data is structured to match currently tradeable products of energy markets such as balancing reserve products or short term spot trading. Finally, the specific data is extrapolated to branch-wide economically feasible DSI potentials and validated with top-down data.

For the detailed bottom-up analysis the industry branches of container glass, cement, paper, copper, zinc, silicon, graphite electrodes and castings are selected. In average per branch, plant-specific data of 65 percent of all production sites with technically suitable technologies for DSI are recorded. Economically feasible DSI potentials are identified at 80 percent of all production sites, but in average only 27 percent are utilising their potentials today. Reasons for it are vast and mostly specific for every branch or even production site, emphasising the necessity of bottom-up analysis which take into account technical, economical and organisational reality of industrial production sites.

**References:**

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[2] German Energy Agency (ed.): Integration of Renewable Energy Sources in the German Power Supply System from 2015 – 2020 with an Outlook to 2025. Berlin 2010.
[3] Apel, R.; Stötzer, M.; Styczynski, Z.; Scheven, A. von et al.: Demand Side Integration – Lastverschiebungspotential in Deutschland. Frankfurt am Main 2012.
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[5] German Federal Ministry for Economic Affairs and Energy: An Electricity Market for Germany's Energy Transition (White Paper). Berlin 2015.

# Session 10.45 – 12.05
# Energy Efficiency 1

**Room: A 03**
**Chair: Julia Michaelis (Fraunhofer Institute for Systems and Innovation Research ISI)**

**Investments in Energy Efficient Technology: Survey-based Evidence on the Behavior of German Manufacturing Firms**

Philipp Massier (Centre for European Economic Research)

**Consumer Inattention and Energy Efficiency: The Causal Effect of Label Elements**

Stephan Sommer (RWI)

**How do companies differ in their investment behaviour for energy efficiency? Comparing the iron & steel and cement sectors with survey results and cluster analysis**

Thomas Ketelaer (FZ Jülich)

**Impacts of Energy Efficiency and the Value Chain on Corporate Financial Performance**

Anne Bergmann (TU Dresden)

# Investments in Energy Efficient Technology: Survey-based Evidence on the Behavior of German Manufacturing Firms

Andreas Löschel[1], Benjamin Johannes Lutz[2], Philipp Massier[3],

[1] *Center of Applied Economic Research Münster (CAWM), University of Münster, Am Stadtgraben 9, 48143 Münster, Germany, email: andreas.loeschel@wiwi.uni-muenster.de*
[2] *Centre for European Economic Research (ZEW), Centre for European Economic Research (ZEW), L 7,1, 68161 Mannheim, Germany, email: lutz@zew.de*
[3] *Centre for European Economic Research (ZEW), Centre for European Economic Research (ZEW), L 7,1, 68161 Mannheim, Germany, email: massier@zew.de*

**Keywords:** Energy efficiency; Manufacturing industry; Investment behavior

The use of energy from conventional sources involves negative externalities of local and global scale. Accordingly, investments in energy efficiency offer economic and social benefits through the reduction of costs, environmental damages, and import dependencies. Thus increased energy efficiency is a crucial goal of energy and climate policies. The manufacturing sector accounts for a large share of energy use (and as a consequence emissions) and hence plays an important role to reach these goals and increase energy efficiency. But the firms' investment behavior deviates from the social and private optimum (Jaffe and Stavins, 1994; Allcott and Greenstone, 2012). Recent empirical literature has shown that firms from the manufacturing sector are subject to the so called "energy efficiency gap". Martin, Muuls, de Preux, and Wagner (2012) as well as Boyd and Curtis (2014) show that management practices affect the energy efficiency of firms depending on the applied management scheme.

To better understand this so called "energy efficiency gap", we provide insights on the determinants of investments in energy efficiency of manufacturing firms based on microdata. In addition we shed light on the relationship between credit constraints as well as energy management practices and the energy efficiency investment behavior. We interviewed 701 managers of randomly selected German manufacturing firms. This unique survey data base contains information on firms' internal decision making processes and energy management practices as well as information on investments in energy efficiency. It is complemented by official microdata including general characteristics of firms as well as ratings from credit rating agencies. The combination of these data sources enables us to conduct a firm level correlation analysis. Preliminary results show that energy management practices as well as internal decision making processes effect the investment decisions regarding energy efficient technologies both in the production processes and the retrofit of buildings.

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# Consumer Inattention and Energy Efficiency: The Causal Effect of Label Elements

Mark Andor[1], Andreas Gerster[2], Stephan Sommer[3]

[1] *RWI, Hohenzollernstr. 1-3, 45128 Essen, andor@rwi-essen.de*
[2] *RWI, Hohenzollernstr. 1-3, 45128 Essen, gerster@rwi-essen.de*
[3] *RWI, Hohenzollernstr. 1-3, 45128 Essen, sommer@rwi-essen.de*

**Keywords:** Environmental certification, discrete choice experiment, energy efficiency, energy-using durables

Research from behavioral economics and psychology demonstrates that consumers tend to be inattentive to operating cost and neglect energy efficiency in purchase decisions of durables. Accordingly, inattention is proposed as one explanation for the so-called energy efficiency gap. As a response, many countries have introduced energy labels to increase consumers' attention to energy efficiency. Despite their wide application, however, little is known about the effect of specific label designs. Based on the EU Energy Efficiency Label, in this paper, we uncover which label elements can help to mitigate consumers' inattention to energy efficiency. Our analysis is based on a discrete choice experiment – which is framed as a purchase decision of refrigerators – among about 5,000 households. We implement treatments that vary the label design and find that households value differences in efficiency classes per se, independently of differences in operating cost, electricity consumption levels or any other attribute. Moreover, we show evidence that providing annual operating cost information increases the uptake of energy efficient appliances, while displaying information that is irrelevant for the purchase decision decreases it. Furthermore, increasing the salience of operating cost increases attention to it and at the same time reduces the valuation of energy class differences. With respect to heterogeneous effects, it bears noting that individuals with high incomes react less strongly to the provision of operating cost information. Furthermore, providing information, which is irrelevant for the purchase decision, increases the propensity to choose energy efficient appliances for individuals with a high educational level. Based on our results we conclude that simplifying the EU Efficiency Label by providing information on operating cost and removing irrelevant information could both reduce negative externalities associated with the generation of electricity and negative internalities. In addition, the fact that consumers employ decision heuristics may call for adjusting innovation policy.

# How do companies differ in their investment behaviour for energy efficiency? Comparing the iron & steel and cement sectors with survey results and cluster analysis

Thomas Ketelaer[1], Russell McKenna[2], Wolf Fichtner[2], Wilhelm Kuckshinrichs[1]

*[1] Forschungszentrum Jülich GmbH, Institute of Energy and Climate Research – Systems Analysis and Technology Evaluation (IEK-STE), 52425 Jülich, Germany, t.ketelaer@fz-juelich.de*
*[2] Karlsruhe Institute of Technology (KIT), Institute for Industrial Production (IIP) – Chair of Energy Economics, Hertzstraße 16, 76187 Karlsruhe, Germany, russell.mckenna@kit.edu*

**Keywords:** Energy efficiency, investment behaviour, survey, barriers, cluster analysis

Industrial energy efficiency can lead to competitive advantages but also faces challenges concerning investment, regulation and other issues. Technical or techno-economical potentials for saving options are identified in different studies, but they are often not seen in practice due to the presence of barriers. To gain a deeper understanding of the factors influencing investments in energy efficiency, company behaviour must be analysed in detail by considering the differences between sectors and the heterogeneity of companies.

Due to their importance in terms of energy consumption and $CO_2$ emissions, the iron and steel as well as the cement sector are analysed. Expert interviews and a telephone survey with 54 iron and steel and 25 cement companies were conducted. The survey addresses the companies' attitudes towards energy efficiency technologies and investments, as well as demand side management and the current implementation status of energy efficiency measures. Subsequently a cluster analysis based on the empirical data and on publicly available data (e.g. annual financial statements), identifies different types of companies. The resulting cluster groups are used to get a better overview of the differentiation in company typologies within and between the two analysed sectors. The cluster groups differ, inter alia, in number of employees, ownership and type of company.

The expert interviews and the quantitative survey give a good overview of the problems and challenges in the iron and steel and cement industries concerning progress in energy efficiency. Their problems and challenges and the investment behaviour differ partially. The cluster analysis supports the first findings that their problems, challenges and investment behaviour partly differ. Consequently, a profound analysis of energy efficiency investments in industry has to take into account the heterogeneity of companies. For example, differences between the sectors are found concerning the competence of energy managers and the rating of factors influencing investments. An expansion of the analysis to four other sectors and an agent-based simulation will be performed in a next step.

# Session 10.45 – 12.05
# Congestion Management and Market Design

**Room: B37**
**Chair: Matthew Schmidt (TU Dresden)**

**Coordinating Cross-Country Congestion Management**

Dr. Friedrich Kunz (DIW Berlin)

**Assessing the impacts of market-designs on investments in flexible technologies**

Nikolas Hary (MINES ParisTech; Microeconomix)

**Electricity market design: Policy coordination**

Prof. Dr. Hannes Weigt (University of Basel)

**Tender Frequency and Market Concentration in the Balancing Power Market - The Case of Germany**

Frank Obermüller (ewi Energy Research & Scenarios)

# Coordinating Cross-Country Congestion Management

Friedrich Kunz[1], Alexander Zerrahn[2]

*[1] DIW Berlin, Mohrenstr. 58, 10117 Berlin, Germany, fkunz@diw.de*
*[2] DIW Berlin, Mohrenstr. 58, 10117 Berlin, Germany, azerrahn@diw.de*

**Keywords:** Electricity, congestion management, network modeling, Europe

Electrical flows depend on the technical properties of the entire transmission network. Thus, a certain fraction of a transaction flows on the direct link between both transaction points, whereas the remaining fraction follows alternative routes. Nodal in-feeds and withdrawals, thus, have widespread implications on transmission flows in highly meshed electricity systems. While continental Europe is linked by a synchronous transmission network, the system is characterized by a patchwork of different, mostly national, transmission system operators (TSOs), electricity market specifications, and national jurisdictions. We employ a detailed two-stage model to simulate the operation of the Central Eastern European electricity market and network. Our model resembles the current European spot market design, consisting of a day-ahead spot market with uniform pricing and a subsequent curative congestion management phase. The application focuses on the central eastern European region, covering Germany, Poland, Czech Republic, Slovakia, and Austria in 2013. To account for international exchanges and flows, the remaining European countries are modeled on nationally aggregated levels. We define four cases of cross-country coordination, which differ in the degree of information sharing, the access to cross-country redispatch capacities, the geographical balancing areas, and the mode of cross-country allocation of network capacities for redispatch. Specifically, we analyze two limiting cases: no coordination (Case 1) and perfect coordination including multilateral redispatch actions (Case 4). In between, we take information sharing, for which actual vehicles exist by 2015, into account (Case 2), as well as possibilities for cross-border counter-trading (Case 3). Numerical results show the beneficial impact of closer cooperation. Specific steps comprise the sharing of network and dispatch information, cross-border counter-trading, and multilateral redispatch in a flow-based congestion management framework. Efficiency gains are accompanied by distributional effects. Closer economic cooperation becomes especially relevant against the background of changing spatial generation patterns, deeper international integration of national systems, and spillovers of national developments to adjacent systems.

# Assessing the impacts of market-designs on investments in flexible technologies

Nicolas Hary[1, 2], Vincent Rious[2, 3], Marcelo Saguan[2, 3]

[1] *MINES ParisTech, PSL - Research University, CERNA - Centre for industrial economics, 60 Boulevard Saint Michel, 75006, Paris, France*
[2] *Microeconomix, 5 rue du Quatre septembre, 75002, Paris, France. nicolas.hary@microeconomix.com*
[3] *Florence School of Regulation, Robert Schuman Centre for Advanced Studies, European University Institute, Via delle Fontanelle, 19, 50014 Firenze, Italy*

**Keywords:** Investment decisions, Flexibility constraints, Market design, Unit-Commitment model, System dynamics

The recent increase of intermittent renewable generation highlights the importance of the flexibility in power systems. Indeed, the question is not anymore to have an adequate level of capacity to supply demand but also to have enough flexible technologies to deal with the quick variations of load and generation. The system needs plants with fast ramping up and down times and which can switch on and off very quickly at a moderate costs. In theory, the market should give incentives to investors for developing these valuable technologies. However, such a result is quite uncertain in the current market designs. In particular, policymakers and researchers wonder if a new mechanism is needed to solve this issue, as it has been done in some countries with the adequacy issue and the implementation of capacity remuneration mechanisms. To answer this question, modeling a precise short term market is needed, in particular to assess the remuneration of flexibility. Moreover, the long term reaction of investors have also to be studied to assess to what extent the current market design give the correct incentives to invest in flexible technologies. Due to the importance of the dynamic of investments, such an issue has to be studied dynamically, in particular using system dynamics modeling (investors do not react in an optimal way to price signals, which can lead to investment cycles). However, this dynamic consideration is missing in the current literature. When long term decisions are studied taking into account flexibility constraints, it is generally using optimization models. This kind of model cannot consider the important dynamic aspects of generation investments and how the investors react to price signals.

This point is studied in this paper. Using a clustered Unit-Commitment model, we study different short-term market designs (e.g., depending on the way they consider and remunerate the non-convex costs, like start-up costs) and thanks to a system dynamics model, we assess how investors react to these short term remuneration (in particular, whether they invest in flexible technologies). As a result, we can compare the lack of flexibility (and its consequences, like shortages) for each studied market design. Following these results, we could also propose different improve market designs to solve this flexibility issue. In particular, it would be interesting to study if capacity remuneration mechanisms are correct ways to remunerate flexibility and solve this problem or if new additional mechanisms dedicated to flexibility only are needed.

# Electricity market design: Policy coordination
## *(working title)*

Nicolas Weidmann-Ordóñez, Frank C. Krysiak, Hannes Weigt [1]

[1] *University of Basel*

**Introduction**

Swiss electricity markets are subject to several large-scale changes. Market power is to be reduced with the second phase of market liberalization, renewables are intended to replace nuclear power, and substantial investments in the grid and short-term storage have to be made and funded. To facilitate these changes, a set of different policy and regulatory measures is already used or planned, such as feed-in tariffs, market deregulation, a potential introduction of capacity markets and possible changes to grid tariffs. These different instruments and regulatory changes are likely to strongly interact with each other. This paper aims at analyzing if and how political interventions in the electricity market could interact and how they may be coordinated with each other, particularly in the context of the intended second phase of liberalization of the Swiss electricity market.

**Model**

The model covers any finite number N of regions with one supplier and one group of consumers of electricity in each region (see Figure 1). In the original state before the (full) liberalization of the market, all consumers can only buy electricity from the local supplier in their own region. As the market gets liberalized, consumers get the option to switch between suppliers. The hesitancy of consumers to switch between suppliers is represented in the model by an individual switching "cost" (ISC) that varies over the consumer group in a region. Further, it is assumed that consumers have only limited information about the retail price levels of the different suppliers in the market. This results in a situation where consumers that are willing to switch do not necessarily switch to the supplier with the lowest retail price in the market (as they would if they had (unrealistic) full information about prices) but to any supplier offering a retail price low enough depending on the respective ISC. The limited information about prices is represented in the model by consumers randomly receiving one offer from only one supplier. Depending on the level of ISC, the consumer then decides to switch to the new supplier or to stay with the current one. Repeating this procedure infinite times leads to an equilibrium where all consumers in the entire market end up with a supplier where they will not further switch.

In order to satisfy consumers' demands for electricity, suppliers have the option to buy (and sell) electricity on the spot market (orange arrows in Figure 1) and invest into generation facilities for own production. The available technological investment options comprise two stochastic renewable technologies (solar PV and wind), one projectable renewable technology (hydro), and one projectable conventional technology (gas). Investments into these technologies are represented in the model using an investment submodel. Building on a similar theoretical structure as in (Thoma, Krysiak 2012), the model is set up as a two stage model, where suppliers first make investment decisions and then set prices, both under the assumption of profit maximization. While there is full market power on the retail market

when suppliers set their prices, only partial market power exists on the spot market. Further, the model includes a set of policy instruments and regulatory measures, namely capacity markets,
feed-in tariffs, and transport costs. These measures and instruments can be applied simultaneously in order to analyze possible interactions and coordination options.

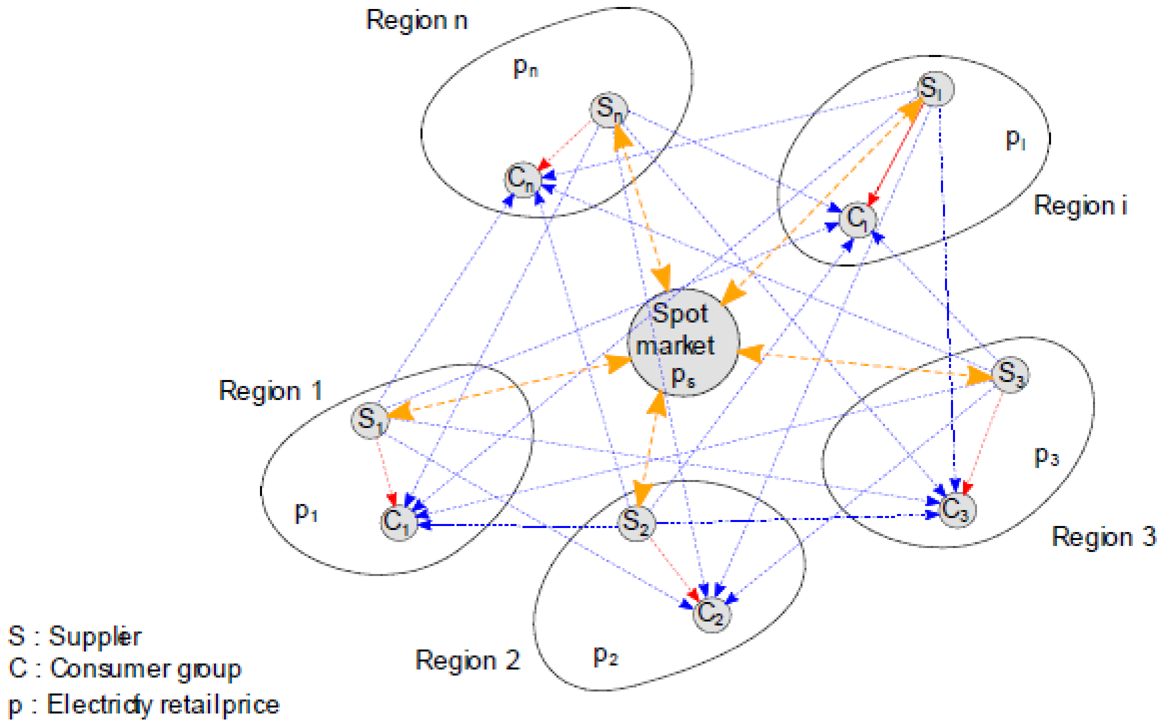


*Figure 1: Setup of the conceptual electricity market model representing N regions with one supplier and one consumer group in each region.*

**Results**

A number of interesting results could be educed out of the analysis with the conceptual electricity market model within the first project phase. The most important findings are summarized below:

- The existence of market power on the retail market as a consequence of the limited willingness of consumers to switch supplier results in price differences across the different regions. As Figure 1 (middle subfigure) shows, differences in retail prices increase with the level of hesitance to switch. Further, it can be shown that suppliers having a larger home customer base set higher prices compared to the competitors with a smaller consumer group in there region (see Figure 1, left subfigure). The reason for this outcome is that the large suppliers' total profit gain from charging higher prices from the home customers that are hesitant to switch exceeds the profit losses from losing some customers that are willing to switch to a competitor offering a lower price. At contrast, for the case of the small suppliers, the profit gains from attracting new customers from other regions with lower prices exceeds the profit losses due to price reductions in the home market.
- An "extreme" case can be observed when very small suppliers with only minor or even no existing customer bases enter the market and set aggressive low prices since the above mentioned effect of profit losses from reduced prices in the home market is negligible or inexistent. Such small

suppliers have a strong impact on the retail prices in the entire market since they force the larger suppliers to reduce their prices in order to not losing too many customers to the small competitor.

- Imposing transport costs on the retail prices when buying electricity from suppliers in other regions generally reduces the attractiveness of switching suppliers. As a consequence, in the presence of transport costs, large consumers can set even higher prices without losing customers and small suppliers have to further reduce their prices in order to still attract customers from other regions. Figure 1 (right subfigure) shows the impact of increasing transport costs on retail prices.
- Given the existence of market power on the retail market, sufficient competition on the spot market is of central importance to support an optimal allocation of investments into production facilities and hereby avoid distortions of investment decisions across the different regions.
- An optimal allocation of investments between the different regions of the market facilitated by a competitive spot market reduces the need for the coordination of political interventions. However, for the case of a not sufficiently competitive spot market, political interventions will likely need to be coordinated.

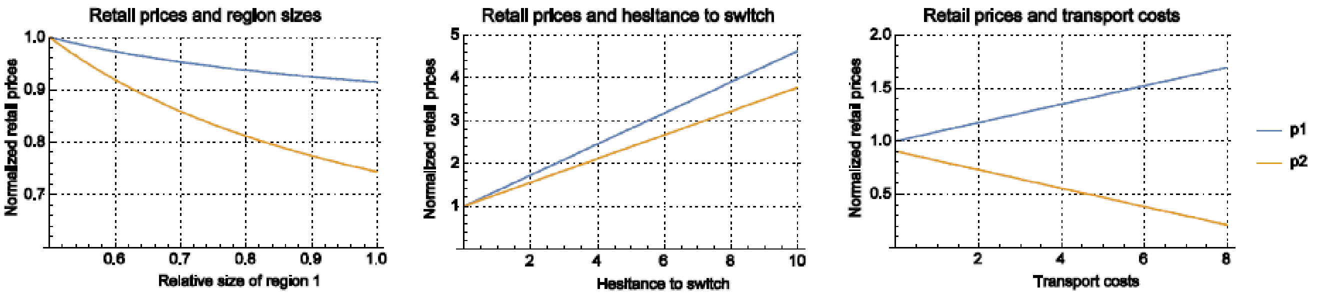


*Figure 2: Normalized retail prices as a function of the relative size of the largest region 1 (left subfigure), the hesitance to switch (middle subfigure), and the transport costs (right subfigure) for an electricity market with N=2 regions.*

# Tender Frequency and Market Concentration in the Balancing Power Market - The Case of Germany

Frank Obermüller[1], Andreas Knaut[1], Florian Weiser[1]

[1] *ewi Energy Research & Scenarios, Vogelsanger Str. 321, Cologne, Germany,*
*Frank.Obermueller@ewi.research-scenarios.de*
*Andreas.Knaut@ewi.research-scenarios.de*
*Florian.Weiser@ewi.research-scenarios.de*

**Keywords:** Balancing power markets, market concentration, provision duration, efficiency

Balancing power markets are an important mechanism to balance short term deviation of demand and supply and to ensure grid stability. The current market design in Germany is divided into three different balancing power markets (primary, secondary and tertiary balancing power) with different characteristics, e.g. provision duration.

There is an ongoing debate between scientists, electricity market actors, politics and regulators about shortening provision duration of balancing power markets in Germany. The Federal Ministry for Economic Affairs and Energy (2015) names "Shorten time between contract and delivery and/or reduce size of products" as a proposal to further develop balancing power markets. Furthermore, Müsgens et al. (2015) show that a shorter provision duration increases the efficiency of the markets.
On the other side, balancing power markets have strict pre-qualification criteria, e.g. technical minimum ramping speeds. This reduces the amount of potential bidders. Furthermore, we face pooling effects which reduce costs for operators with high amount of pre-qualified capacities in the balancing power markets. Therefore, balancing power markets can be considered as closed markets with a lack of competition due to a few big operators in Germany.

In this paper, we explore the effects of a shortened provision duration on the system costs and the market concentration of market participants. We derive our results by a numerical electricity market model with a blockwise power plant fleet and an underlying operator structure. We consider a weekly (current design), daily and hourly provision of primary and secondary balancing power to derive, e.g., classical market concentration indices like HHI, CR(n) and RSI. We find that a reduced provision duration indeed increase efficiency and reduces costs. But on the other side, a shortened provision duration can increase market concentration in some hours and thus may increase the danger of market power abuse. This effect may counteract the potential gains of reduced provision times.

# Session 10.45 – 12.05
# Power Prices and Tariffs

**Room: Dresden Memorial**
**Chair: Samarth Kumar (TU Dresden)**

**Wholesale price volatility: the effect of uncertain wind feed-in**

Thomas Möbius (Brandenburg University of Technology)

**Risk premia in electricity spot markets – New empirical evidence for Germany and Austria**

Niyaz Valitov (University of Wuppertal)

**Trading behavior on the continuous intraday market ELBAS**

Richard Scharff (KTH Royal Institute of Technology; Vattenfall)

**Optimal retail tariff design for electricity markets with high shares of renewable energy**

Andreas Knaut (University of Cologne)

# WHOLESALE PRICE VOLATILITY: THE EFFECT OF UNCERTAIN WIND FEED-IN

Thomas Möbius[1], Felix Müsgens[2]

[1] *Brandenburg University of Technology, Siemens-Halske-Ring 13, Cottbus, Germany, thomas.moebius[at]tu-cottbus.de*
[2] *Brandenburg University of Technology, Siemens-Halske-Ring 13, Cottbus, Germany, felix.muesgens[at]tu-cottbus.de*

**Keywords:** integration RES, long-term market equilibrium, uncertainty, wholesale price volatility

Increasing shares of intermittent electricity generation from renewable energy sources (RES) such as wind and photovoltaics bring structural changes to many electricity markets. Historically, a flexible supply side (mostly either thermal power stations or hydro storage) balanced a time varying demand. Today, increasing shares of intermittent RES generation depend on meteorological conditions (e.g. wind conditions or solar irradiation). Hence, the availability of these generation capacities on the supply side is both intermittent and uncertain.

We develop and apply an electricity market investment and dispatch model. The model is formulated as a linear optimization problem (LP) which minimizes total costs of the electricity production in the underlying system. Key constraints are: generation has to equal demand in every hour, generation cannot exceed installed capacity, generation of running capacity must be above partial load requirement, and several other conditions capturing central techno-economic aspects of power systems. In order to account for uncertainty in the wind generation, we develop a stochastic programming model with recourse. By doing so, both the investment decision for installed generation capacities as well as the decision for unit commitment underlie imperfect information concerning the wind generation.

We find that the effect of intermittent RES on wholesale prices in a (partial) market equilibrium is not as clear-cut as some people may think. The result in an over-simplified textbook environment, where intermittent RES neither influence average prices nor price volatility, may be surprising at first glance. This changes when the model is set-up in a more realistic way. We find that both modelling RES-curtailment as well as uncertainty impact wholesale price volatility. In hours of wind curtailment, electricity prices are driven towards zero (the marginal cost of wind). This increases the volatility as such price levels do not occur without wind capacity. Furthermore, we find that the uncertainty concerning the short term wind production forces the system to a more flexible unit commitment decision in order to meet the final residual load.

# Risk premia in electricity spot markets – New empirical evidence for Germany and Austria

Niyaz Valitov[1]

[1] *University of Wuppertal, Gaußstr. 20, 42119 Wuppertal, Germany, valitov@wiwi.uni-wuppertal.de*

**Keywords:** Risk premia, Electricity markets, Spot prices

The process of liberalization in Europe and the growth of electricity from renewable energy sources led to a significant increase in trading activities on wholesale markets. Due to the fact that electricity cannot be economically stored and that forecasts of spot prices are often inaccurate, risk management plays an important role in forward markets. A risk premium in electricity markets, defined as the difference between the forward price and the expected spot price, is often paid as a compensation for bearing price and/or demand risks.

This paper provides new empirical evidence for risk premia in the German/Austrian day-ahead market by using data from October 2008 to November 2015. It contributes to the literature by investigating the impact of the introduction of negative electricity prices on the risk premium in forward markets. Furthermore, the relatively long observation period allows for testing the long-term stability of model parameters.

Following Viehmann (2011), risk premia are estimated by comparing hourly electricity prices of the European Power Exchange (EPEX) and of the Energy Exchange Austria (EXAA). The results suggest that risk premia are still paid in the German/Austrian day-ahead market, but their absolute value decreased remarkably. Negative electricity prices have a strong impact on the outcome and an upward bias in hours with negative prices can be observed. This result contradicts the theoretical considerations of Viehmann (2011) who expected larger negative premia. It can also be shown that the existence and development of risk premia cannot be explained by price risks alone as proposed by Bessembinder and Lemmon (2002). Results of rolling regressions indicate highly unstable parameters for the variance and skewness of spot prices. There is also some evidence that the market has matured: Forward prices tend to converge to unbiased predictors of subsequent spot prices.

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# Trading behavior on the continuous intraday market ELBAS

Richard Scharff[1,2], Mikael Amelin[1]

[1] *KTH Royal Institute of Technology, Teknikringen 33, Stockholm, Sweden, richard.scharff@ee.kth.se*
[2] *Vattenfall, Laboratorievägen 1, Älvkarleby, Sweden, richard.scharff@vattenfall.com*

**Keywords:** Intraday adjustment market, Distributed balancing, Bidding strategies, Integration of renewable energy sources, Market design

Intraday markets for electricity allow for trading of energy until shortly before the period of delivery. This offers market participants a possibility to reduce their expected imbalances and to offer own unused flexibility. Because this form of distributed balancing before the period of delivery can be profitable for market participants and beneficial for system operations, intraday trading is expected to gain more importance in future, especially with increasing shares of variable renewable energy sources in the generation mix.

So far, intraday markets are still a research field with many open questions. In this conference, we want to present our work that was recently published in Energy Policy (http://dx.doi.org/10.1016/j.enpol.2015.10.045). It contributes by a first analysis of intraday trades on ELBAS, one of the European intraday markets. The analysis gives a detailed picture on trading activity and price development and is intended to improve understanding of continuous intraday trading.
Findings include that trading activity differs significantly between price zones, that most trades occur in the last hours before gate closure and that market participants have to handle substantial price variations during the trading period. We also investigate imbalance settlement rules in the Nordic countries and studies which effects one- and two-price imbalance settlement systems have on the market participants' profitability of intraday trading.

# Optimal retail tariff design for electricity markets with high shares of renewable energy

Andreas Knaut[1]

[1] *Institute of Energy Economics at the University of Cologne, Vogelsanger Str. 321a, Cologne, Germany, andreas.knaut@ewi.uni-koeln.de*

**Keywords:** retail electricity tariff, renewable energy, electricity market

Based on economic theory it is clear that time-of-use contracts or real time pricing contracts in the telecommunications and electricity industry should lead to higher efficiency compared to flat rate tariffs. In reality, however, consumers are biased in their preferences towards flat rate tariffs (Krämer and Wiewiorra (2012)). In this paper, we argue that the choice of a tariff is largely determined by the associated transaction costs for producers and end consumers. With low transaction costs it may still be convenient for end consumers to stick to a flat rate tariff. However when efficiency losses are high switching from a flat rate tariff to a real time pricing contract may be optimal. Whereas in the past, price fluctuations were primarily based on the demand profile of end consumers, price patterns have changed in recent years due to the high share of production from wind and solar energy. This results in a disentanglement between the electricity price pattern in wholesale markets and the demand profile of end consumers.

In this paper, we investigate the optimal tariff design for electricity consumers in markets with high shares of renewable energy. Our analysis builds on the work of Borenstein and Holland (2005), who analyze the optimal tariff design in electricity markets based on conventional generation technologies. We extend the model, in order to account for the unique characteristics of renewable electricity generation. These are namely, short-term marginal generation costs of zero and the variability in generation based on weather conditions. Within the model, we are able to quantify inefficiencies that arise from a flat tariff design and to derive an optimal tariff design for retail electricity markets with high shares of renewable energy.

# Keynote 13:15 – 14.00

**Room: Faculty Assembly Hall**
**Chair: Prof. Dr. Dominik Möst (TU Dresden)**

## The EnBW Pilot Project „Flexible Power-to-Heat“

Dr. Holger Wiechmann (Energie Baden-Württemberg AG)

To accommodate high amounts of fluctuating RE within the energy system, innovative approaches to improve the balance of generation and demand must be developed in particular. Load management and the issue of utilizing flexibility will play a key role. The pilot project "Flexible power-to-heat" - a joint project between EnBW and Netze BW - addresses these aspects.

With the pilot project "Flexible power-to-heat", EnBW has developed and tested a coherent concept, suitable for mass marketization, to increase flexibility potentials. In particular, the focus is on efficient interaction between regulated and market areas. The principles of the grid traffic light classification system, which is accepted industry-wide and was co-developed by EnBW, form the starting point for development. Within the trial flexible, discrimination-free, market-driven and network-beneficial load management was implemented using the concrete example of existing electric heating devices. It could be shown that this kind of load management approach - similar to a virtual power plant – is also possible within this highly fragmented mass-market customer segment. At the same time, the implemented flexibility approaches can also be used in principle for many more applications like electric vehicles, battery storage or even small CHP.

The aim of the pilot project is to allow as much flexibility and potential for load transfer by any supplier, whilst avoiding local overloads in the distribution grid. Implementation of the concept with respect to network-usefulness takes place in the form of utilization factors (UF). These represent the load limit of the respective network section, within which potential suppliers can operate freely and shift energy consumption. The distribution grid operator non-discriminatorily provides all market participants with these UF factors based on projections and calculations. The UF approach therefore offers degrees of freedom to the market, which allows market-driven actions, for example, optimization of procurement, while safeguarding the convenience of the grid.

The results of the pilot project can be summarized as follows:

- Over 100 customer installations were optimized regularly during the pilot project. In fact, there have been over 2,000 accumulated customer optimizations in the last heating period (winter 2014/15) with targeted load shifts, which have demonstrated the actual functionality of the

system. In the current heating period more optimization will be done. Evaluations have shown that the given network restrictions can be reliably maintained by the UFs.
- From a sales perspective, focus must be placed on the "product potential" of the approach. Thanks to new tariff products, the rapidly increasing amounts of electricity from fluctuating renewable energy sources as well as additional demand services such as hybrid heating systems, battery storage, or E-mobility can be integrated efficiently in the energy system. These innovative tariff products could offer advantages when compared to the previous tariff offers for flexible customers.
- From the perspective of the distribution network operator, Netze BW, it was demonstrated that additional flexibility potential can be raised using the UF approach without overloading the existing grids. Although the risk of potential congestion might increase, it can be managed with appropriate measuring technology (smart grid). The UF approach could be a model for a more advanced §14a EnWG for interruptible loads.
- From a customer perspective, it was demonstrated that the feeling of comfort regarding heat supply was still reliably operated, or, with frequent daily loads, even improved.

In addition, it is most likely that more electric vehicles, battery storage, hybrid heating systems and automation systems will enter the market in the future. Therefore, the introduction of mass market load management systems is inevitable from an energy-logistics as well as network capacity point of view to ensure system stability. This means that the focus is on these great flexibility potentials for commercial and household customers.

Especially smart home solutions and energy management systems, with their equivalent or similar control algorithms, represent a danger for system stability due to their swarm-like behavior (higher concurrency than previously). On the other hand, these systems are particularly suitable thanks to their control potential, for integration in system-side central load and flexibility management. With the solutions approaches developed and tested within the pilot, EnBW is now basically in a position to develop a “grid friendly” load management suitable for mass market application.

With the energy approaches detailed within the pilot project, the expectations of customers regarding integration within the energy transition could be met. In addition, the current debate regarding the necessity of the use of flexibilities was supported and promoted by the pilot project with practical examples.

In my presentation I will give an overview about the pilot project focused on the principle of the utilization factor to prevent grid bottlenecks and the developments of the regulatory framework.

# Session 14.05 – 15.25
# Demand Response for Renewable Integration

**Room: Faculty Assembly Hall**
**Chair: Theresa Müller (TU Dresden)**

**Demand response an option for reserve power?**

Dr. Rainer Enzenhöfer (TransnetBW GmbH)

**Steering demand response and renewables in distribution grids via network charges?**

Christine Brandstätt (Jacobs University Bremen)

**Potentials of industrial load management in Germany**

Victoria Orioli (Siemens AG)

**Field of Tension between Energy Efficiency and Flexibility**

Anna Gruber (Forschungsgesellschaft für Energiewirtschaft mbH)

# Demand response an option for reserve power?

Enzenhoefer R.[1], Dütsch V.[2]

[1] *TransnetBW GmbH, Osloer Str. 15-17, 70173 Stuttgart, Germany, r.enzenhoefer@transnetbw.de*
[2] *TransnetBW GmbH, Osloer Str. 15-17, 70173 Stuttgart, Germany, v.duetsch@transnetbw.de*

**Keywords:** network reserve, load management, transportation network, Redispatch, congestion management

In the first half of 2015 30% of the electrical consumption in Germany has been supplied by renewable energy sources (RES) with more than 50% installed power capacity. With increasing RES, the necessity for more flexibility, e.g. by demand response, increases to counter-act the unsteady infeed by renewables. Already today German transmission system operators (TSOs) contract loads for ancillary services to balance frequency and dispatch congestions.

In 2015, more than 260 days with remedial actions according to §13 (1) EnWG have been counted. One can see a clearly increasing trend over the past years, especially in redispatching power supply entailing the necessity of procuring network reserve in the Southern part of Germany. The current system analysis of the four German TSO forecasts a reserve demand of 8.2 GW for winter 2016/17 alone. In order to deal with this enormous task, national and international network reserves are contracted. TransnetBW alone has contracted approx. 3.2 GW (1.1 GW within the TransnetBW balancing block) reserve power. For the winter 2016/17 there is already approx. 4 GW contracted from neighboring countries.

The system operation reserves capacities based on congestion forecasts. Depending on the situation, this can be one or two days ahead of delivery. Reasons for that lead time are manifold, such as cold power plants which need at least six to eight hours for start-up, or procurement and nomination of cross-border transfer capacities in order to ship the electricity across borders. On top, due to unavoidable forecast errors, it is possible that already reserved capacities are dispensable or not readily available to cover the actual redispatch demand.

Thus, more flexible market-based options, such as demand response, should be investigated. Flexibilities that can quickly react in case of redispatch demands, until reserve power has been activated and substitutes the shorter and more flexible demand side products, as far as there is a longer dispatching need. Therefore, we would like to analyze how valuable load management can be for system operation of transmission grids, especially in the context of solving grid congestions to support or improve the flexibility of network reserves.

# Steering demand response and renewables in distribution grids via network charges?

Christine Brandstätt[1]

[1] *Jacobs University Bremen, Campus Ring 1,Bremen, Germany, c.brandstaett@jacobs-university.de*

**Keywords:** network charges, self-supply, distributed renewables, distribution grids

## Motivation

With the rise of distributed renewable energies coordination in distribution grids becomes more and more important. Demand response is seen as one key means to integrate additional renewables into the grids. It is widely discussed that with coordination can come from curtailment and interference rights for DSOs. Alternatively prices and charges could steer and thus coordinate users. Hence, the question arises which network charging schemes are appropriate to give good incentives for demand response and renewable energies. As part of the research project „CoNDyNet“ funded by the German Federal Ministry of Education and Research analyses this paper analyses the incentives for network friendly self-supply with various load-, capacity- and energy-based charging schemes.

## Methods

A model simulates network charges for a synthetic network under various charging schemes as a function of the penetration of self-suppliers. It also determines levellized cost of PV generation as a function of already installed capacity. The savings in network charges and energy cost for different types of network users indicate the incentives to invest in PV-based self-supply as compared to self-supply with regular and/or network friendly storage. Various charging schemes can hence be compared according to the efficiency of their incentives as well as concerning other advantages and drawbacks of the charging schemes, such as complexity and transparency.

## Results

The analysis reveals along the example of PV-based self-supply how some charging schemes deliver better incentives for demand response and renewable energy integration than others. It also reveals how the dynamic of increasing incentives for self-supply with increasing shares of self-suppliers is stronger for some charging schemes like net metering and charging based on estimated simultaneity. The paper provides important insights for designing network charges with good incentives for decentralized energy systems and enables policy makers to select adequate charging schemes.

# Potentials of industrial load management in Germany

Katja Barzantny[3], Edwin König[3], Jörg Meyer[23] and Victoria Orioli[13]

[1] *Speaker: Victoria Orioli, Siemens AG, Government Affairs Charlottenstrasse 57, 10117 Berlin, Victoria.orioli@siemens.com*

[2] *Jörg Meyer, Siemens AG, Head of Sustainability & Energy Management, Neuenhofstr. 194 52078 Aachen*

[3] *all authors Siemens AG*

**Keywords:** Demand Side Management, Industry, Load Management, Demand Response

Demand Response Management is increasingly mentioned in energy political discussions about the future design of the electricity market regarding the rising share of fluctuating renewable energies.

A study of Siemens analysed which demand response potentials exist in the industrial sector in Germany. Starting point is a view on the functioning of power balancing in the today's electricity market, on energy political objectives and an increasing need for a participation of the demand side in balancing the power system.

The analysis takes a look at the installed loads in the industry. It is distinguished between different potentials of industrial demand response and shows technical and economic limitations in the industry. A distinction is made between a) theoretical potentials, b) realisable potentials (taking into consideration a shift or renouncing of loads using technologies and processes which are applicable for load management and have a sufficient importance in the industry), c) realistic potentials (certain requirements are fulfilled; a flexibility factor for the chosen technologies and processes is assumed) and d) an economical potential (when economic incentives are sufficient).

The different types of potentials have been calculated for both chosen processes (steel, cement, chlorine, aluminum, synthetic materials production and paper) as well as crossover technologies over the entire industry sector in Germany. Besides, barriers for the use of a more flexible load management as well as requirements for participating in demand response management have been assessed.

# Field of Tension between Energy Efficiency and Flexibility

Anna Gruber[1], Serafin von Roon[2]

*[1] Forschungsgesellschaft für Energiewirtschaft mbH, Am Blütenanger 71, 80995 München, Deutschland, agruber@ffe.de*
*[2] Forschungsgesellschaft für Energiewirtschaft mbH, Am Blütenanger 71, 80995 München, Deutschland, sroon@ffe.de*

**Keywords:** Energy Efficiency, Flexibility, Demand Response, DSM, Industrial processes

Energy efficiency measures in the industrial sector contribute to the decarbonisation over the last years. For a successful transition towards an energy system with high shares of variables energy sources it is assumed that flexibility on the demand side will increase in value. The paper deals with the conflict and compliance potential of these two goals.
The analysis is conducted from two directions. At first the impact on the energy consumption of running industrial processes is calculated for seven specific applications. For this approach the change in the overall efficiency level is chosen as evaluation criteria. Secondly the effects of energy efficiency measures on the flexibility potential are discussed. Installed overcapacities are on one hand one of the key causes running processes flexible and on the other hand the reason for energy inefficiency. The different roots for overcapacities are depicted and the relating impacts of using these capacities for demand side management are assessed. Typical efficiency measures for specific cross-sectional technologies and the effect on the flexibilisation are identified.
The following table shows how different activation frequencies (10, 100, 1000 hours per annum) of the DSM potential have impact on the efficiency level. The analysis differentiates between positive DSM-potential (reducing the load and providing a positive contribution to the system balance) and negative DSM-potential (increasing the load and providing a negative contribution to the system balance).
In most applications and activation frequencies the impact on the efficiency level is less than 1 % and therefore below typical measuring accuracy. Critical efficiency losses can be assessed for pumps, ventilation systems and compressed air with yearly activation times of more than 1000 hours.
The second part of the analysis shows that the influence of energy efficiency measures on flexibility potential is a slight decrease in positive DSM-potential and an increase of the negative DSM-potential.

| **provision: 7.000 h/a** | | **call in h/a** | | | | | |
|---|---|---|---|---|---|---|---|
| | | **10** | | **100** | | **1000** | |
| | | **influence on** | | | | | |
| **allocation** | **technology** | **pos. potential** | **neg. potential** | **pos. potential** | **neg. potential** | **pos. potential** | **neg. potential** |
| energy intensive process | aluminium electrolysis | < -0,1 % | < 0,1 % | < -0,1 % | < 0,1 % | < -1,0 % | < 1,0 % |
| energy intensive process | chloralkali electrolysis | < 0,1 % | < -0,1 % | < 0,1 % | < -0,1 % | < 1,0 % | < -1,0 % |
| energy intensive process | electric arc furnace | < -0,1 % | < 0,1 % | < -0,1 % | < 0,1 % | -2,0 % | < 1,0 % |
| cross sectional technology | fan (ventilation system) | < 0,1 % | | < 1,0 % | | 5,0 % | |
| cross sectional technology | pump | < 0,1 % | < -1,0 % | < 1,0 % | -8,0 % | 6,0 % | -46,0 % |
| cross sectional technology | compressed air | < -0,1 % | < 0,1 % | < -1,0 % | < 1,0 % | -2,0 % | 5,0 % |
| cross sectional technology | power to heat | < -0,1 % | < 0,1 % | < -0,1 % | < 0,1 % | < -1,0 % | < 1,0 % |

- = decreasing overall efficiency
+ = increasing overall efficiency

*Table 1: Impact on the efficiency level for different activation times (provision = 7.000 h/a)*

# Session 14.05 – 15.25
# Energy Efficiency 2

**Room: A 03**
**Chair: Daniel Schubert (TU Dresden)**

**Identifying the influence of design parameters on energy performance of residential buildings by sensitivity analysis**

Kamran Naeiji (TU Berlin)

**Can Energy Efficiency Save Energy? An Economy-Wide Rebound Effect Simulation for Turkey**

Tugba Somuncu (Istanbul Technical University)

**Economic Analysis of Energy Refurbishment in Buildings**

Isidoro Tapia (European Investment Bank)

**The impact of innovation on industrial energy efficiency and how to promote it through supporting policies**

Silvia Sanz (Durham Business School)

# Identifying the influence of design parameters on energy performance of residential buildings by sensitivity analysis

Kamran Naeiji[1], Klaus Rückert[2]

[1] *Technische Universität Berlin, Berlin, Germany, k.naeiji@mailbox.tu-berlin.de*
[2] *Technische Universität Berlin, Berlin, Germany, Klaus.Rueckert@tu-berlin.de*

**Keywords:** Sensitivity analysis, Uncertainty analysis, Residential building, Energy performance, Influential parameters

In early design process of a building or when instructions, guidelines or regulations for optimization of the energy performance of a group of buildings is going to be prepared, there is no one fixed value for each input parameter and each of them can have a range of values. Moreover, some input parameters such as the schedule of indoor set point temperature, opening and closing the windows, presence of occupants, internal loads due to lighting and equipment are completely related to future occupant behavior and they are out of the designers' hand.
The aims of this paper is to assess the uncertainty of building energy performance due to uncertainty in input parameters besides identifying the most influential parameters on peak heating and cooling loads as well as annual heating and cooling energy consumption of a multifamily residential building located in hot and dry climate and urban area like Tehran by sensitivity analysis.
The Morris method is used for sensitivity analysis because of its low computational cost and capability to identify the importance of each input parameters, their positive/negative influence, linearity or non-linearity as well as their interaction with each other in a simulation model. To generate the different simulation model with different values of input parameters according to the Morris method as well as to analyze the output of simulations and perform the uncertainty and sensitivity analysis, a code in MATLAB program is written. To simulate the energy performance of simulation models, EnergyPlus version 8.1.0.008 is used.
The results show a high level of uncertainty in building energy performance due to variation in design parameters. The air change rate (ACH) and set point temperature are the two most influential parameters on both annual heating energy demand and peak hourly heating rate with a positive monotonic influence. The two most influential parameters on annual cooling energy demand and peak hourly cooling rate are the zone set point temperature and zone area with a negative monotonic influence.

# Can Energy Efficiency Save Energy? An Economy-Wide Rebound Effect Simulation for Turkey

Tugba Somuncu[1], Christopher Hannum[2]

[1] *Istanbul Technical University,ITU Isletme Fakultesi Macka, Istanbul,Turkey,somuncut@itu.edu.tr*
[2] *Istanbul Technical University,ITU Isletme Fakultesi Macka, Istanbul,Turkey,hannum@itu.edu.tr*

**Keywords:** Energy Efficiency, Rebound, Energy Labeling, Computable General Equilibrium Analysis

Energy efficiency is often considered as one of the most important tools for reducing use of energy resources. However in the literature there is an ongoing debate about certain offsetting impacts. These offsetting impacts are called take-back effects or rebound effects. In this paper we examine economy-wide rebound effects for Turkey. In the case of Turkey energy efficiency stands out as a crucial issue; because Turkey, as an energy importing country, wants to reduce energy consumption while maintaining economic growth. The purpose of this study is to find the extent to which obtaining higher levels of energy efficiency will result in a lower energy consumption level.

In order to estimate economy-wide rebound effects, we constructed an energy-economy computable general equilibrium (CGE) model for Turkey by creating a social accounting matrix (SAM) based on the 2002 Turkey Input-Output table from the Turkish Statistical Institute. We use a nested constant elasticity of substitution (CES) structure for production and household utility in which energy and capital are perfect complements and the energy-capital composite (e.g. building services) substitutes for labor and other intermediate goods with a Cobb-Douglas form. We define the rebound effect as percentage increase in total energy consumption over the expected (reduced) energy consumption level.

We separately introduce two energy efficiency policies which are being implemented in Turkey into our model. The first is energy certification for buildings which demonstrates their energy consumption level and groups them into 7 categories as A,B,C,D,E,F, or G. In accordance with this law newly constructed buildings must meet at least C level in order to qualify for building permit. We assume all existing buildings will be improved to C level from G while all new buildings will be in the C category. The second policy is mandatory energy labeling for household appliances, which is functionally similar to energy certification for buildings. We assume that energy efficiency in this bundle increases due to the policy with the same percentage increase as has been observed over the 10 years since the initial formulation of the policy.

Simulations for the both scenarios show rebound effect which ranges between 20- 25%. These results indicate that approximately 20 percent of energy savings due to improvements in the energy efficiency are lost due to the rebound effect.

# Economic Analysis of Energy Refurbishment in Buildings

Isidoro Tapia

*European Investment Bank*

The attention to EE has increased recently, recognizing the potential of the so-called “hidden fuel” as one of the largest untapped energy sources. The IEA estimates that EE has the potential to boost cumulative economic output by EUR 15 trillion, larger than the current combined size of the economies of the European Union.

Energy efficiency (EE) is the most cost effective and rational way of reducing emissions and improving the security of the energy supply. However, the economic impact of EE projects is sometimes diffuse, difficult to estimate and captured by multiple agents.

However, significant differences among EE subsectors exist, with the estimated level of “realised gains” ranging from below 20% (buildings) to above 40% (industry). The larger potential for EE investments exist in buildings, which remains relatively untapped due to (i) investments in buildings are less attractive given the relatively longer payback periods and (ii) the split incentives between those making the investments and those capturing some of the associated benefits.

Refurbishment projects in buildings represent a particular case of EE projects. Refurbishment projects have two distinguishing features. First, they typically involve both investments directly related to EE and other type of investments. Second, EE investments generate not only energy savings and reductions in GHG emissions, but also other concrete and quantifiable economic benefits, such as the reduction of operating costs and the increase in property values. Consequently, the usual CBA analysis needs to be modified to reflect both features.

This paper presents a methodology to estimate the economic impact of refurbishment projects in buildings. On the costs side, only those investment costs directly related to energy efficiency must be included in the CBA analysis. Consistently, on the benefits side, only those benefits directly attributed to EE investments must be included. Among the benefits, as a general rule, only energy savings and the reduction in GHG emissions are included. Other concrete and quantifiable economic benefits directly related to EE investments, such as the reduction of operating costs and the increase in property values, are included only on a case-by-case basis, subject to the availability of reliable data and a robust estimate for the specific projects. Therefore, the methodology presented follows a prudent approach to calculate the economic returns of EE investments based on the current evidence.

Using the discussed methodology, this note also estimates the *ex-ante* economic impact of building renovations in reference projects in all EU countries. In general, the results are encouraging since they present positive and significant economic returns, with very few exceptions. These estimated impacts can be interpreted as a conservative approximation of the overall economic return of the projects, with little downside expected deviations.

# The impact of innovation on industrial energy efficiency and how to promote it through supporting policies

Silvia Sanz [1], Antonio Ciriello[1, 2]

[1] *Durham Business School, Mill Hill Lane, Durham, UK, silvia.sanz@durham.ac.uk*
[2] *Politecnico di Milano, Piazza Leonardo Da Vinci 32, Milan, Italy, Antonio.ciriello@areva.com*

**Keywords:** Energy Efficiency, Energy Innovation, Energy Technology, Key Indicators, Energy Policy

In the past years, many studies have been performed to demonstrate how innovation increases energy efficiency in several sectors such as transport, household, service and agriculture. However few standardized approaches have aimed to promote and implement energy saving technologies in the industry. In some cases, the deployment of energy efficiency programs have been more focused on tax incentives than on long term improvement strategies.

The aim of this paper is to carry out a comparative analysis of the application of new technologies, processes and strategies into energy-intensive industrial consumers using scoring methodologies in order to identify the impact of energy efficiency solutions on the field of industrial processes.

This analysis is linked to the institutional framework, discussing the potential effect of incentive regulation and technology policies on the implementation of innovative solutions. Recommendations are given aiming to promote programs and standardized approaches towards sustainable energy efficiency strategies in the industry sector.

# Session 14.05 – 15.25
# Infrastructure, Systems and Policy

**Room: B37**
**Chair: Hannes Hobbie (TU Dresden)**

**Impacts of a German coal phase-out on the German electricity mix and prices**

Hasan Ümitcan Yilmaz (Karlsruhe Institute of Technology)

**Influence of balancing reserves on the electricity infrastructure in Europe until 2050**

Casimir Lorenz (TU Berlin)

**Let lignite take a backseat – The lignite phase-out in the context of the German transmission grid extension**

David Gunkel (TU Dresden)

**Interaction Effects between different Types of Energy Generating Capacities – A Firm Level Study**

Nora Schindler (Vienna University of Economics and Business)

# Impacts of a German coal phase-out on the German electricity mix and prices

Hasan Ümitcan Yilmaz[1], Quentin Bchini[1], Dr. Dogan KELES[1], Prof. Dr. Wolf FICHTNER[1]

[1] *Institute for Industrial Production (IIP), Chair of Energy Economics, Karlsruhe Institute of Technology, Hertzstr. 16, 76187 Karlsruhe, hasan.yilmaz@kit.edu, www.iip.kit.edu*

**Keywords:** coal phase-out, renewable integration, Energiewende

Germany is considering phasing out coal-fired power plants to fulfil its carbon dioxide emission targets and has already decided to move eight lignite plants into a strategic reserve, the so-called climate reserve, and to decommission them in the forthcoming years. However, replacing an important share of production mostly with intermittent renewable energy sources might affect the security of supply. The major questions are: how much back-up capacity will be necessary and what will be the role of European integration in compensating for this lack of flexibility?

A study from Agora Energiewende (Agora Energiewende, 2016) has highlighted 11 principles for a successful German coal phase-out. Heinrichs & Markewitz analysed the impacts of coal phase-out scenarios using a German energy system model but demonstrated that there are more cost-efficient options to reach the carbon mitigation targets. We chose to extend the geographic scope to Europe and focus on the German electricity mix as well as prices and exchange flows.

Total phase-out scenarios for coal based on the age of the existing power plants for Germany have been developed. The scenario shown in Figure 1 has been implemented and analysed applying the Perseus-EU model (Rosen, 2008 and Möst & Fichtner, 2010) which simulates the whole European energy market.

The objective of the model is to minimize total system costs under a set of constraints that are among others the obligation to cover the demand, to reach a European renewable production target and not to exceed a GHG emissions cap.

The model results indicate that there is a substantial price increase between 2015 and 2025 in the phase-out scenario due to an important loss of capacity in the first years (see Figure 1 and Figure 2). This increase leads to significantly higher prices between 2020 and 2035 compared to the scenario without a coal phase-out (BAU Scenario). Another important result is that between 2020 and 2035, in the coal-phase out scenario, Germany relies strongly on electricity imports. In 2040 wind represents the highest share of the total generation in both scenarios with a significant amount of gas power plants ensuring backup capacity.

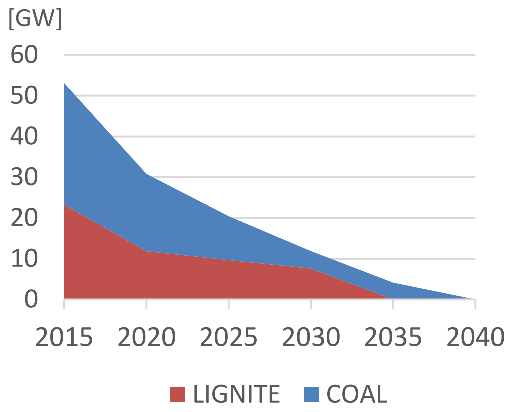


*Figure 1: Coal and Lignite phase-out scenario for Germany*

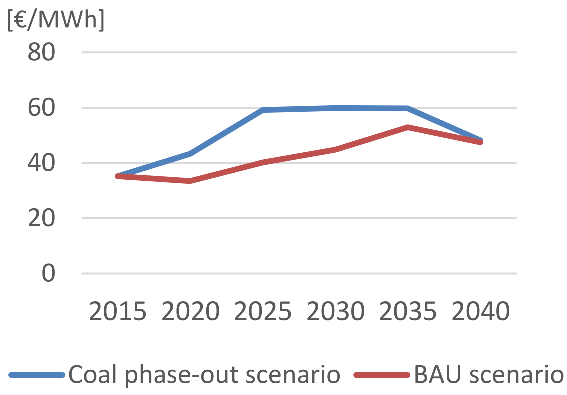


*Figure 2: German electricity prices until 2040*

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# Influence of balancing reserves on the electricity infrastructure in Europe until 2050

Casimir Lorenz[1, 2], Clemens Gerbaulet[1, 2]

[1] *TU Berlin, Strasse des 17. Juni 135, 10623 Berlin, Germany, cl@wip.tu-berlin.de*
[2] *DIW Berlin, Mohrenstr. 58, 10117 Berlin Germany.*

**Keywords:** Balancing, Reserves, Control Power, Renewable integration, Electricity sector modeling

To be in line with the recent Paris Agreement the electricity sector requires far-reaching transformation of the electricity generation infrastructure. Possible pathways for the generation infrastructure until 2050 have been subject of many studies. These studies focus on availability of nuclear/CCS, cost assumptions for different technologies, HVDC interconnection or storages and demand side management. Currently few studies focus on the implications of balancing reserves for a future generation infrastructure, despite the fact, that very high shares of fluctuating RES will increase the required amount of balancing reserves in the long term. At the same time this balancing reserve demand influences the required power plant capacities.

We develop a dynamic electricity sector model which includes endogenous investments into conventional and renewable generation capacities while accounting for endogenous balancing reserve demand increase and necessary balancing capacity provision. This also includes the possibility of balancing reserve exchanges between countries. The model is based on an investment model that has been further developed to include balancing provision, balancing exchanges and balancing demand calculations.

Preliminary calculations indicate that results are highly sensitive to the assumptions regarding the possibilities of renewables to participate in the provision of reserves. Even with a very high share of renewables, balancing reserves can be provided without conventional dispatchable capacities, when excess renewable capacities are available. Nevertheless this requires additional renewable capacities, which lead to a cost increase compared to the scenario without any reserve requirements. Without the possibility of renewables to provide positive reserves, cost will increase significantly and dispatchable generation capacities are mainly used to provide reserves. This results in a tradeoff between the investment into dispatchable biomass, storages and excess renewable capacities. If possibilities for the provision of reserves through renewables are limited, the exchange of balancing capacity becomes more important. This highlights the necessity to foster cross-border balancing cooperation and the participation of fluctuating renewables in providing reserves.

# Let lignite take a backseat – The lignite phase-out in the context of the German Transmission grid extension

David Gunkel[1]

[1] *TU Dresden, Chair of Energy Economics, Münchner Platz 3, D-01069 Dresden, David.Gunkel@tu-dresden.de*

**Keywords:** Transmission Grid Extensions, Germany, Energy System Transformation

Transmission grid extension constitutes a central aspect of the future energy system transition in Germany. This stems from the diverging occurrence of renewable energy feed-in and demand as well as future policy objectives geared toward a nuclear and carbon phase-out. After completing the phase-out of the nuclear energy program by the year 2022, the next most likely policy objective concerns a lignite phase-out. The existing layout of the German grid is not designed to accommodate these emerging challenges. Hence, the following paper addresses the impact of decommissioning lignite power plants on the most cost-efficient grid extensions by 2030. In order to analyze the optimal transmission grid design, enhanced methods for techno-economic analysis are required. The challenge of conducting an analysis of grid extensions involves the lumpy investment decisions and the non-linear character of certain constraints in a real-data environment. Adding new lines to the transmission grid introduces a degree of variability into approximate load flow calculations. To address this challenge, the following paper presents an application of the Benders Decomposition approach, dividing the problem into an extension and a dispatch problem combined with a Karush-Kuhn-Tucker-system. This combination allows for solving the problem in an efficient manner by utilizing the conditions derived in the sub-problem. Results show that lignite phase-out can significantly increase the amount of grid extensions necessary to sustain the energy system in Germany as well as the overall systems costs.

# Interaction Effects between different Types of Energy Generating Capacities – A Firm Level Study

Nora Schindler[1]

[1] *Vienna University of Economics and Business (WU), Research Institute for Regulatory Economics, Welthandelsplatz 1, Building D4, 1020 Vienna, Austria, nora.schindler@wu.ac.at*

**Keywords:** Investment Incentives, Integration of Renewables, Security of Supply, Missing Money, Capacity Markets

## Motivation

Energy markets in Europe have been restructured significantly in recent years. Among other factors the increased feed-in of renewables has led to a decrease of the number of hours that conventional fuel types such as gas, oil and coal are running. This in turn reduces the incentives to invest in those conventional fuel types of generating capacity. Nevertheless conventional fuel types are crucial to ensure the security of supply since they are needed to provide the amount of energy that is lacking as renewables cannot meet the whole demand and frequently intermit their energy supply.

According to Dixit and Pindyck (1994) and Bar-Ilan and Strange (1996) there exist different rationales for investment when the variance of the price increases. In order to assess whether there is a value associated with waiting or with the lost option and how an increase in the variance of the price and uncertainty influences investments in generating capacities, the number of hours running ($NOHR$) for each generating type as well as the variable cash-flows on a firm-level basis are generated using the merit-order curve and used as explanatory variables in a neoclassical investment model. The advantage here is that using a dataset which is available on a firm-level can yield interesting insights as to how firms are changing their technology mix to accommodate the changing energy landscape and what that means for the electricity generation mix. Another positive feature here is that the $NOHR$ yields a measure for uncertainty on a firm-level while the variance of the price at the spot exchanges corresponds to the uncertainty on the energy market as a whole.

## Methods

In order to answer the research question, we estimate a neoclassical investment equation including indicators of price levels and volatility for European energy utilities covering the period 2006–2014 and 14 European countries. The dataset enables a granular firm-level investigation of investments in actual generating capacity and the income each plant is generating is approximated using the merit order curve.

**Results**

Analysing the impact of lower spot market prices and price volatility on firms' investments in electricity generation capacity and the interaction between different types shows that investments in *renewable* capacities do in fact crowd out investments in *conventional* fuel sources and thus support the findings of the European Commission (2015).

In general, this study helps to add depth on the understanding of electricity investment incentives in a vastly changing environment.

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# Session 14.05 – 15.25
# DSO and Distributed Renewable Energy Sources

**Room: Dresden Memorial**
**Chair: Michael Zipf (TU Dresden)**

**DSO revenues from Local Balancing Cluster with active demand side**

Rafał Dzikowski (Lodz University of Technology)

**Reactive power provision from the distribution grid and its effects on redispatch cost**

Fabian Hinz (TU Dresden)

**Distributed Renewable Energy Sources with Demand Response Integration in Low Voltage Distribution Grid**

Jernej Zupančič (University of Ljubljana)

**Potential contribution of residential demand response to a fossil-free electricity system reserve**

Jonas Katz (Technical University of Denmark)

# DSO revenues from Local Balancing Cluster with active demand side

Rafal Dzikowski[1], Blazej Olek[2]

*[1] Lodz University of Technology, 18/22 Stefanowskiego Street, Lodz, Poland, 201442@edu.p.lodz.pl*
*[2] Lodz University of Technology, 18/22 Stefanowskiego Street, Lodz, Poland, blazej.olek@p.lodz.pl*

**Keywords:** balancing market, distribution systems, smart grids, Local Balancing Area, distribution code, Distribution System Operator

The presentation aims to assess the possible revenues and potential cost for DSO, related with development and operation of the Local Balancing Clusters (LBC) including Renewable Energy Sources (RES) and active loads (AL) participating local power balancing. The LBC can support a power system in the technical balancing of electrical energy, making a DSO an active contributor.

A LBC consists of active and passive generating units, RES, prosumers, energy storages and passive and active energy consumers (including Demand Side Response), which are all participants of the local balancing market held by a DSO. Thus members affects power demand and daily profile of energy exchange between distribution and transmission system. In order to ensure power system stability and supply reliability, local generation and demand management should be performed in cohesion with present balancing mechanisms used be Transmission System Operator (TSO). Due to local constraints and the large amount of active producers and consumers in distribution system, there is the need for local technical balancing (apart from trading balancing). In LBC, DSO as a system operator carries out power dispatch in distribution system, preparing daily operation schedules basing on forecasted demand and generation from passive producers/consumers and submitted balancing bids from active ones. Operating schedule includes daily demand profile and aggregated balancing bids, that DSO in behalf of active participants of local balancing market, submits to an upper Balancing Market held by a TSO.
The presentation delivers information about a LBC operation with focus on the role of controllable demand. Due to the importance of the economic aspect for prospective existing of LBCs, this presentation focuses on possible benefits for DSO and energy customers/producers/prosumers contributing in the LBC.

# Reactive power provision from the distribution grid and its effects on redispatch cost

Fabian Hinz[1]

[1] *TU Dresden, Chair of Energy Economics, Münchner Platz 3, D-01069 Dresden, Fabian.hinz@tu-dresden.de*

**Keywords:** Reactive power, voltage stability, redispatch, distribution grid

For proper operation, electricity systems require ancillary services, which have historically been provided by large central power stations. In decentralizing energy systems, smaller generation units connected to the distribution grid have to assume more and more system responsibility. Therefore ancillary services should be provided to a larger extent from decentralized energy sources.

Voltage stability of electricity grids is ensured by the controlled feed-in of reactive power, which is provided either by generation units or by reactive power compensators. High-voltage transmission grids have a large requirement for reactive power in order to compensate their reactive power behavior. As reactive power can hardly be transported over large distances, local compensation is required. A controlled feed-in of reactive power to the distribution grids could not only increase system security, but also reduce operational cost for the system operators in terms of reduced losses and redispatch cost. Voltage-induced redispatch has to be conducted when voltage stability in a certain area cannot be guaranteed through the conventional power plants currently dispatched.

In order to monetarize these effects, a redispatch model, that does not only consider current-induced redispatch (overload of system equipment) but also voltage-induced redispatch, is developed. The approach is applied on the German transmission and 110kV distribution grid with a high spatial resolution containing load grid nodes, transmission lines, transformer stations, load centers, power plants and renewable energy sources. The load flows are reflected based on an enhancement of the DC-approximation approach, which allows to consider voltage stability in an iterative linear programming approach.

A conventional scenario, where reactive power is only provided by conventional power plants is compared to a scenario where reactive power can also be supplied by wind turbines connected to the distribution grid. The analysis shows that a substantial reduction of redispatch and curtailment cost can be achieved in the second scenario. As voltage stability is hardly addressed in techno-economic modelling frameworks, this novel and innovative work directly contributes to the system integration of renewable energies by evaluating reactive power the provision from an economic perspective.

# Distributed Renewable Energy Sources with Demand Response Integration in Low Voltage Distribution Grid

Jernej Zupancic[1], Tomi Medved[1], Blaz Prislan[1], Andreas Tuerk[2], Andrej F. Gubina[1]

[1] *University of Ljubljana, Faculty of Electrical Engineering, Ljubljana, Slovenia, jernej.zupancic@fe.uni-lj.si*
[2] *Joanneum Research, Graz, Austria, andreas.tuerk@joanneum.at*

**Keywords:** Distributed renewable energy sources, Demand Response, Aggregator agents, Scheduling Control, Distribution network

The share of distributed renewable energy sources (DRES) on low voltage (LV) grid, in particular the share of small-scale photovoltaic (PV) units, is increasing. Their behaviour is becoming an important factor in issues related to voltage levels, power quality and network stability. In the project INCREASE, which is part of FP7 program, new advanced control mechanisms of DRES were developed, enabling the distribution system operator (DSO) to better control voltage levels and the power quality of the network. One of the investigated measures was also optimal scheduling of demand response (DR) units in the LV network, using agent-based control of DR units. These units are scheduled by one or several aggregators, which additionally interact with the DSO in order to maintain secure and stable network status. The aggregators offer produced electricity and other products on electricity markets. The aggregation function is performed by a Scheduling control agent, which is responsible for scheduling the flexible part of DR unit's consumption, offering flexible energy products of aggregated DR units. SCA plans the DR unit schedule based on multiple inputs: electricity market prices, forecast of network consumption, DRES production along with network topology and power quality regulations.

The Aggregator can choose between two optimization functions: the economic and the energy-based. With the economic schedule, the scheduling control agent is maximising the profits from flexible energy products offered on the market. With the energy-based optimization, the DR units are scheduled to minimise the power flows throughout the system and improve the amount of energy injected by the PV units.

In this paper, we compare the outcomes of both optimizations. Through the scenario approach, the analysis is carried out using a realistic LV network model with the increasing PV and DR penetration levels. Business economic results involving various actors are compared for each of the optimization types. Environmental impacts, such as avoided emissions of air pollutants and emission related costs, were also taken into consideration and are presented as well. The results serve as recommendations for the policy makers and the retailers considering setting up the aggregator group.

[1] INCREASE Project, "Report on common definition of Ancillary Services in the Transmission system and in the Distribution system", Deliverable D5.1, October 2015
[2] INCREASE Project, "Optimal coordinating strategies to harmonise multi services/objectives" Deliverable D3.4, October 2015

# Potential contribution of residential demand response to a fossil-free electricity system reserve

Jonas Katz[1], Olexandr Balyk[1]

[1] *Technical University of Denmark, Department of Management Engineering, Produktionstorvet 426, 2800 Kgs. Lyngby, Denmark, jokat@dtu.dk*

**Keywords:** Residential demand response, System reserves, Partial equilibrium model

The flexibility potential of the demand side has gained some attention from policy makers recently in countries developing large shares of variable renewable electricity generation. Both TSOs and regulators frequently mention the potential contribution of demand response to reliability in a system relying on renewable energies. Technically, it would certainly be a suitable option to solve a part of the problem with intermittent production.

Most often demand response is a resource restricted to a short time intervals. An evaluation of its contribution must therefore be sufficiently detailed on the time scale. Many analyses focus on the hourly scale, and many times the economic potential found is limited. Flexibility of the demand side may, however, be better suited for short-term response. Thus, to grasp the full potential one should include contributions within the hour. Such flexibility will then be available as a reserve to the power system.

A few studies investigate the impact of demand response on the reserve requirement. We want to contribute to these findings with a study of residential demand response in Denmark using a partial-equilibrium model of the electricity system (Balmorel). To support a more complete grasp of the system value of demand flexibility, we study the potential impact of residential demand response on the costs of system reserves in a fossil-free electricity supply.

In this study we first estimate a marginal reserve requirement based on the characteristics of wind forecasting errors. We then use a generic model of residential demand response to estimate potential savings in the costs of reserves due to active load shifts in the spot market and due to direct contributions of demand to reserve capacity.

# Session 16.00 – 17.20
# Pricing, Incentives and Demand Response

**Room: Faculty Assembly Hall**
**Chair: Fabian Hinz (TU Dresden)**

**Analysis of Incentive-based Demand Response Mechanism**

Dr. Robert Basmadjian (University of Passau)

**Demand Response Potential of End-users Facing Real Time Pricing**

Dr. Yiqun Ma (University of Groningen)

**Real-time Electricity Pricing with Hetero-geneous Consumers and Variable Renewable Energy Supply: Welfare and Distributional Effects**

Christian Gambardella (Potsdam Institute for Climate Impact Research)

**Investment Incentives for flexible Demand Options under different Market Designs**

Mirjam Ambrosius (University of Erlangen- Nürnberg)

# Analysis of Incentive-based Demand Response Mechanism

Robert Basmadjian[1], Florian Niedermeier[2], Herman De Meer[3]

[1] *University or Passau, Innstrasse 43, Passau, Germany, robert.basmadjian@uni-passau.de*
[2] *University or Passau, Innstrasse 43, Passau, Germany, florian.niedermeier@uni-passau.de*
[3] *University or Passau, Innstrasse 43, Passau, Germany, demeer@uni-passau.de*

**Keywords:** Demand Response, Data Centers, Cost-benefit analysis

It has been shown that data centers are excellent candidates to participate in Demand Response (DR) mechanisms due to their inherent flexibility (e.g. workload shifting, cooling set points alteration) on one hand, and on the other because of their significant energy demand. In this paper, we perform a cost-benefit analysis for the purpose of assessing the viability of DR mechanism to the use case of data centers. To this end, we consider a real ecosystem consisting of Stadtwerke Passau[2] (SWP) as the Energy Supplier (ES) and Innowerk-IT[3] as the Data Center (DC) having its own IT customers (ITC).

SWP has internal power generation sources such as renewables and fossil-based generators. However, due to lack of sufficiency, it also has a contract with other bigger ESs in Germany to feed power to the grid of SWP. This contract states the maximum power demand of SWP which is currently fixed to 60 MW. During power shortage situations (e.g. peak power demand), in addition to the activation of internal fossil generators, SWP buys more power from those external ESs if needed. On one hand, the activation of fossil generators is not ecologically friendly, and on the other buying additional power from external ES is extremely costly. For instance, exceeding 1 KW above the limit of 60 MW causes SWP to pay about 60€ even if this happened for 1 second. Regarding Innowerk-IT, it has also a power contract with SWP stating the costs which consist of night and day tariffs for the consumed energy together with the highest power demand cost.

We show in this paper that by introducing incentives with sort of fair penalty and reward schemes to the DR mechanisms, it is possible to achieve a win-win situation to all the parties (e.g. ES, DC, and ITC) of the ecosystem. The obtained results confirm the suitability of DCs in participating to DR mechanisms.

[2] www.stadtwerke-passau.de
[3] http://www.innowerk-it.de/

# Demand Response Potential of End-users Facing Real Time Pricing

Yiqun Ma

*Faculty of Economics and Business, University of Groningen, Nettelbosje 2, 9747 AE Groningen, The Netherlands, yiqun.ma@rug.nl*

**Keywords**: Price-based Demand Response, Demand Response Potential

A central problem in the electricity market is to balance demand and supply, and to ensure reliability, due to increasing supply of intermittent renewable energy sources. One possible option for maintaining this balance is demand response (DR). DR, including price-based and incentive-based options, attempts to alter the timing (load shifting) and the total consumption level of electricity (load shedding). Recent studies on the estimation of DR potential focus on the load reduction over a long time horizon, such as the annual potential of DR. However, assessment of the potential of price-based DR in the real time market is sparse so far, which is useful to examine the effects of DR policies. In this study, we present a price-based DR model under technical restrictions to examine the hourly potential of DR for balancing electricity in the short run.

This study aims to identify the hourly potential of price-based DR in industrial, tertiary and residential sectors in a number of European countries (Germany, Netherlands, United Kingdom, Denmark, Norway, Sweden and Finland). Due to technical restrictions and consumer preferences, the DR is not available at any time. The estimation of hourly potential of price-based DR depends on parameters and assumptions regarding load profiles, as well as the used specific model. Firstly, we construct shiftable load profiles, considering main technical restrictions, such as the time availability of DR (time for load shifting and shedding of a day), technical constraints (installed capacity, utilization rate and revision rate) and the impact of outdoor temperature (heating degree hours and cooling degree hours). Secondly, to estimate the potential of price-based DR, the hourly own and cross elasticities are determined by own calculation and existing literature. These elasticities are necessary for understanding the relationship between electricity prices, load shedding and load shifting.

Results from the proposed model with Dutch data over 2014 show that the maximum hourly potentials of price-based DR in industrial, tertiary and residential sectors can be around 0.01%—7.5% of total loads. Notably, the potential of DR is highest in winter at night and lowest in summer at night.

These results have some policy implications of price-based DR for balancing electricity demand and supply. Instead of increasing investment in generation capacity, the estimated hourly potential of DR shows that DR can provide a relatively small source to balance electricity demand and supply. Besides that, with more volatile hourly prices, DR can reduce the costs of end-users.

# Real-time Electricity Pricing with Heterogeneous Consumers and Variable Renewable Energy Supply: Welfare and Distributional Effects

Christian Gambardella[1], Michael Pahle[1]

[1] *Potsdam Institute for Climate Impact Research (PIK), P.O. Box 601203, 14412 Potsdam, Germany, Phone: + (49)-331-288-2423, email: chgamba@pik-potsdam.de*

**Keywords:** Electricity Demand Response, Variable Renewables Integration, Real-time Pricing, Partial Equilibrium Modelling, Heterogeneous Agents Modelling

Incentivizing consumers to consume less electricity, when it is relatively expensive and more, when it is relatively cheap via real-time retail pricing (RTP) can augment allocative efficiency in real electricity markets (Borenstein and Holland 2005). While this is not common practice yet, introducing RTP on a large scale in systems with high penetration rates of variable renewable energy sources (vRES) is regarded as one of the most efficient options to accommodate increasingly volatile energy supply (Mills and Wiser 2014; Connect Energy 2015; Gambardella et al. forthcoming). However, consumers reveal very *heterogeneous consumption patterns* (covariation with price) and *consumption volumes* (customer size) such that many may actually perceive to lose from less cross-subsidized consumption, if switching from being flat to being real-time priced and, thus, may not adopt RTP even if it was highly efficient.

This work analyzes this tension between the social acceptance barriers of RTP, such as the redistribution of consumption costs (Borenstein 2007a), and its potential social benefits in a market with intermittent supply from vRES like wind and solar power. Therefore, applying a partial long-run equilibrium model of a perfectly competitive electricity market, we compare both the redistribution of consumption costs and the gross welfare gains from increasing the portion of RTP among heterogeneous consumers and the share of vRES supply. A given share of consumers is modelled to be able to react to real-time prices while the rest faces a flat price, assuming an iso-elastic demand function (Borenstein and Holland 2005). Heterogeneous consumption patterns are constructed for residential, industrial as well as trades and services (T&S) customers by computing specific consumption time series from standard load profiles as used by German TSOs, which are scaled to fit German hourly load data.

Our preliminary results are twofold*; first*, the redistribution of consumption costs from introducing RTP across consumer segments could indeed become of little concern with higher vRES shares because consumption then co-varies less with price, implying a comparatively low amount of cross-subsidized consumption. *Secondly*, relatively large amounts of gross welfare gains from RTP could be left on the table if RTP was mainly enforced on large, industrial consumers. Since residential and T&S customers have rather volatile consumption patterns, putting many of these consumers on RTP entails comparatively large allocative gains, particularly in a vRES dominated market.

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# Investment Incentives for Flexible Demand Options Under Different Market Designs

Mirjam Ambrosius[1,5], Veronika Grimm[2,5], Christian Sölch[3,5], Gregor Zöttl[4,5]

[1] *University of Erlangen- Nürnberg, Lange Gasse 20, 90403 Nürnberg, Germany, mirjam.ambrosius@fau.de*
[2] *University of Erlangen- Nürnberg, Lange Gasse 20, 90403 Nürnberg, Germany, veronika.grimm@fau.de*
[3] *University of Erlangen- Nürnberg, Lange Gasse 20, 90403 Nürnberg, Germany, christian.soelch@fau.de*
[4] *University of Erlangen- Nürnberg, Lange Gasse 20, 90403 Nürnberg, Germany, gregor.zoettl@fau.de*
[5] *Energie-Campus Nürnberg, Fürther Str. 250, 904429 Nürnberg, Germany*

**Keywords:** Electricity Markets, Flexible Demand, Network Expansion, Generation Expansion, Investment Incentives, Congestion Management, Computational Equilibrium Models, Multilevel Programming

Due to the growing share of renewable energy, the German energy market is changing from a demand-side driven market to a supply-side driven system. A transition to a flexible energy demand could be a profitable approach in order to make use of price fluctuations. This does not only apply for the frequently discussed demand side management for private households but also for industrial energy consumers. However, if flexible production is carried out by large scale consumers, flexible production units might mitigate price fluctuations. This will in turn lead to a reduction of profitability of the flexible production approach for other stakeholders.
The paper at hand analyses investment incentives for flexible manufacturing facilities under different market designs. We propose a multi-stage equilibrium model which incorporates generation capacity investment, network expansion and redispatch, and include extensions regarding a flexible production approach. The model allows to investigate incentives for flexible production as well as locational choices and the impact of flexible energy demand on the energy market as a whole.
In particular, we explore the profitability of flexible production units for different shares of flexible energy consumers in the electricity market. Furthermore, we examine at which point flexible production units will have a considerable influence on energy price development and the extent to which price fluctuations will be mitigated by flexible demand. In order to explore the effect of different market designs on the incentives for flexible demand options, we compare a nodal pricing system with a single price zone for the stated issues.
To illustrate our results, we include a case study with data for the German electricity market for the year 2035 which further supports our theoretical findings. First computational results reveal that flexible production units might be very profitable. However, a large scale flexibility of energy demand does have a smoothing impact on the energy price curve and therefore slightly reduces profits for flexible production approaches. Our results also illustrate the influence of different market designs on the establishment of flexible production units. In general, more flexible production units will be built in a nodal pricing system than in a single market zone. Regarding locational aspects, an accumulation of flexible production units in regions with high renewable energy generation, e.g. northern Germany, is observed. Another important finding is the fact that in solutions with more flexible production, less transmission line expansions are needed in order to satisfy the energy demand throughout Germany.

# Session 16.00 – 17.20
# Electric Vehicles and Demand Response

**Room: A 03**
**Chair: David Gunkel (TU Dresden)**

**Demand response technologies as optimal storage options in 2030**

Benedikt Eberl (Forschungsgesellschaft für Energiewirtschaft mbH)

**Future load shift potentials of electric vehicles in different charging infrastructure scenarios**

Tobias Boßmann (Fraunhofer Institute for Systems and Innovation Research ISI)

**Reserve provision by electric vehicles in Germany: model-based analyses for 2035**

Wolf-Peter Schill (DIW Berlin)

**Uncertainties in Optimized Scheduling of Electric Vehicle Charging**

Zongfei Wang (Karlsruhe Institute of Technology; Helmholtz Research School on Energy Scenarios)

# Demand response technologies as optimal storage options in 2030

Benedikt Eberl[1], Felix Böing[2], Anna Gruber[3], Alexander Murmann[4], Christoph Pellinger[5], Serafin von Roon[6]

*[1,3,6] FfE GmbH, Am Blütenanger 71, 80995 München, Germany, beberl@ffe.de*
*[2,4,5] FfE e.V., Am Blütenanger 71, 80995 München, Germany, cpellinger@ffe.de*

**Keywords:** Functional storage, MOS 2030, systemic optimization, stakeholder optimization

The project Merit-Order of Storages (MOS) 2030 discusses the needs of additional storage technologies for the year 2030 from different angles. Not only the systemic point of view is regarded and discussed, but also the potential earnings of different technologies considering fees and taxes for storing energy.

A linear optimization model is deployed to simulate the implementation and usage of different elements of the power system for the year 2030. In the same step, the model optimizes the installation of additional flexibility options such as conventional technologies as well as functional storage systems as demand side management for example. To outline the difference between a systemic point of view and a stakeholder element focused perspective, three different approaches of additional installation and usage of flexibility options are discussed.

In a first step, the systemic optimum of the enhancement and operation of flexibility options is calculated regarding the overall economic costs. The second run describes the usage of the in step 1 defined elements under the context of taxes and fees the different units have to take into account. A third and last run computes anew the additional installation and usage of storage technologies, this time against the background of fees and taxes.

The different simulation runs show that the installed technologies, their capacities and their usage (cf. Figure 3) diverge for a systemic point of view and a stakeholder optimum. While already built storage systems like pump-storage-systems are used less frequently when fees and taxes increase, functional storage options as DSM in industrial processes and cross-sectional technologies as well as flexible usage of domestic and public heat generation become more and more attractive. Additionally, DSM in industry is the major option for all three optimization runs as its potential is fully developed for the systemic optimization as well as the stakeholder optimal solution.

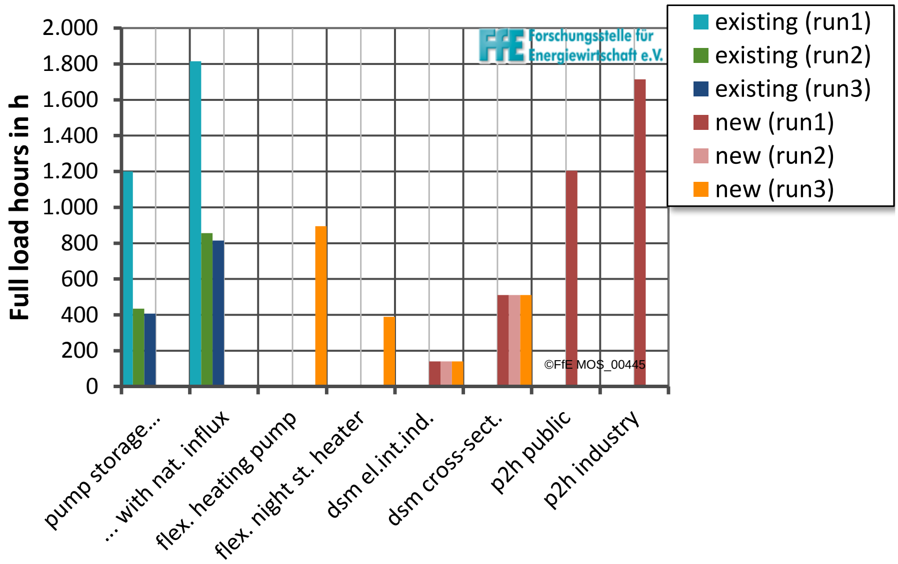


*Figure 3: Full load hours of existing and newly installed storage technologies*

The overall conclusion is that the actual regulation framework doesn´t lead to a cost effective implementation and operation of flexibility options in the future energy system.

# FUTURE LOAD SHIFT POTENTIALS OF ELECTRIC VEHICLES IN DIFFERENT CHARGING INFRASTRUCTURE SCENARIOS

Tobias Boßmann[1], Till Gnann[2], Julia Michaelis[3]

*[1] Fraunhofer Institute for Systems and Innovation Research ISI, Breslauer Str. 48, 76139 Karlsruhe, Germany, +49 721 6809-257, tobias.bossmann@isi.fraunhofer.de, www.isi.fraunhofer.de*
*[2] For affiliation see above, +49 721 6809-460, till.gnann@isi.fraunhofer.de*
*[3] For affiliation see above, +49 721 6809-463, julia.michaelis@isi.fraunhofer.de*

**Keywords:** electric mobility, charging infrastructure, demand response, simulation models

## Motivation

Electric vehicles can be a means to reduce greenhouse gas emissions, but in a significant number, they risk to cause additional load peaks. While most studies focus on domestic charging facilities or include additional charging at work of private passenger cars, this paper also considers commercial plug-in electric vehicles (PEVs) and the use of public charging stations. The aim of this paper is to assess the extent to which additional charging facilities contribute to PEV market penetration in Germany and avoid new peaks in the residual load[4].

## Methods

For this purpose, we combine two existing models: The agent-based simulation model ALADIN (ALternative Automobiles Diffusion and INfrastructure) simulates the driving of conventional vehicles with PEVs. It allows to determine their ability to substitute conventional vehicles and, thus, to derive the PEV market diffusion and uncontrolled charging behavior (Gnann 2015). The resulting charging profiles and number of PEVs serve as an input for the eLOAD (energy LOad curve ADjustment) model. eLOAD is used to determine the least-cost scheduling of PEV-charging depending on an hourly price signal. It thereby simulates the potential contribution of demand response to residual load smoothing (Boßmann 2015). In this modeling exercise, we aim to assess the impact of additional charging infrastructures (in public and at work) on the contribution of electric vehicles to residual load smoothing and the integration of renewable energy sources.

## Results and discussion

In a scenario with only domestic charging, 4.6 million PEVs diffuse into the German vehicle stock, while results in scenarios with additional charging options at work or at work and in public are about 15% higher (5.3 million). This can be explained by the additional charging options for private PEVs at work. Public charging points do not increase the number of PEVs, even when these charging points are largely subsidized.

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[4] The residual load equals the system load minus the generation of fluctuating renewable energies.

In the scenario with widespread charging infrastructure (at home, at work and in public), uncontrolled charging of electric vehicles would raise electric load by more than 2 GW, in particular at current peak hours (around 10am and 7pm, see Figure 4). Considering demand response, charging in summer is primarily shifted into midday hours. In the winter season, it is partially shifted into night time hours, especially at days with low solar generation. With respect to the overall impact on the residual load, electric vehicles can facilitate peak shaving by about 2 GW or 3.2%. The surplus of renewable electricity can be reduced by 1.1 TWh or 19%.

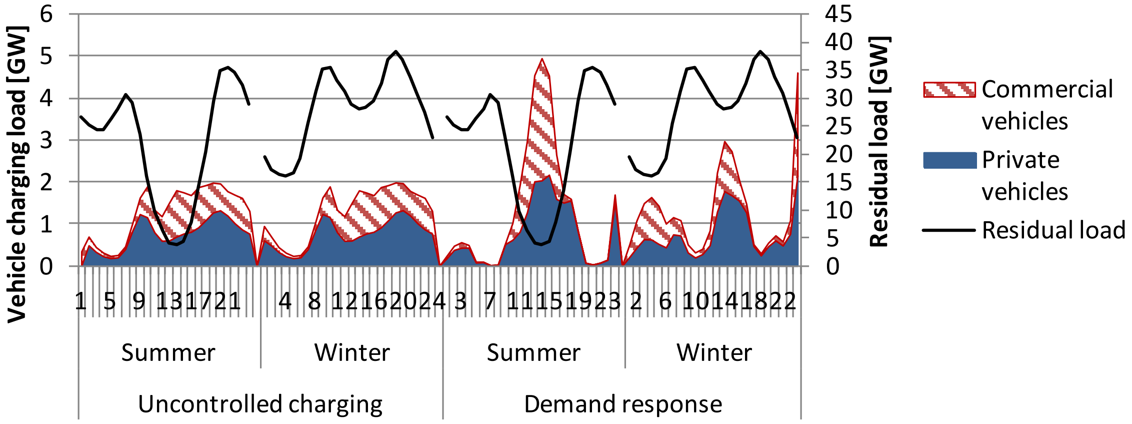


*Figure 4: Average vehicle charging and residual load in 2030 with charging options at home, at work and in public*

In comparison to simulations with more limited infrastructure (charging only at home or at home and at work) we come to the conclusion that widespread charging infrastructure does not only enhance the diffusion of private electric vehicles but also facilitates peak shaving and renewables integration.

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# Reserve provision by electric vehicles in Germany: model-based analyses for 2035

Wolf-Peter Schill[1, *], Moritz Niemeyer[1], Alexander Zerrahn[1], Jochen Diekmann[1]

[1] *Deutsches Institut für Wirtschaftsforschung (DIW Berlin), Department of Energy, Transportation, Environment, Mohrenstraße 58, 10117 Berlin.*
[*] *Corresponding author: wschill@diw.de*

The German government has set ambitious goals for both the expansion of electromobility and renewable energy supply. According to its *Energiewende* policy, electricity supply from fluctuating renewables is supposed to further increase considerably. This will tend to require an greater provision of balancing reserves. At the same time, supply from conventional dispatchable plants, which used to provide the bulk of reserves, will decrease. Against this background, this article analyzes the scope for an assumed fleet of 4.4 million electric vehicles to supply balancing reserves in 2035. Examining two different future power plant parks, it explores the potentials of reserve provision with and without vehicle-to-grid interactions of electric vehicles. Results from an improved open-source power system simulation model show that the assumed vehicle fleet can efficiently provide a substantial share of reserve requirements, also in case the vehicle-to-grid option is restricted. Arbitrage on wholesale markets, on the other hand, is negligible under basic assumptions. Likewise, total system cost savings are minor when compared to a pure cost-optimal loading of vehicle batteries. Under alternative assumptions on the future power plant park as well as on wear and tear costs of batteries when feeding into the grid, however, wholesale arbitrage, reserve provision and system cost reductions can be substantial.

# Uncertainties in Optimized Scheduling of Electric Vehicle Charging

Zongfei Wang[1,2*], Patrick Jochem[1], Wolf Fichtner[1]

*[1] Institute for Industrial Production (IIP), Chair of Energy Economics, Karlsruhe Institute of Technology (KIT), Hertzstrasse 16, Building 06.33, Karlsruhe, Germany*
*[2] Helmholtz Research School on Energy Scenarios*
*[*] Corresponding author: zongfei.wang@partner.kit.edu*

**Keywords:** Electric Vehicles, Inhomogeneous Markov Chain, Mixed-integer Linear Programming, Optimal Charging, Monte Carlo Analysis

With increasing market penetration of electric vehicles (EV), capacity bottlenecks in distribution grids seem unavoidable for uncontrolled EV charging. One key issue concerning the integration of EV to the grid is how to optimally schedule their charging behavior. The objective of this paper is to find a way to solve this problem while considering the uncertainties in EV arrival time, battery state of charge upon arrival and leaving time. Driving behaviors of EV users are first described in an inhomogeneous Markov process. We use real EV usage data from a field test with about 30 EV with three recorded EV states (driving, charging and only parking) for 6 months. With this data, EV driving patterns are simulated and uncertainties in EV's availability for charging can be considered. This EV driving data from the Markov process is than used in a mixed-integer linear programming (MILP) model to optimize the EV charging schedules. Battery and inverter characteristics such as minimum charging power and non-linear charging pattern are taken into consideration. The optimization is conducted from a distribution grid operator's perspective which considers besides grid constraints (i.e. maximum loads) also dynamic electricity tariffs. Due to the uncertainty of the arrival and leaving time as well as the required energy demand, our approach will not lead to a global optimum. Therefore, the global optimum is given for a perfect foresight scenario as a benchmark. Both results and the underlying reasons for differences are discussed comprehensively.

Finally, a Monte Carlo analysis is applied by randomly generating driving patterns from the Markov process so that the average and the confidence bound of charging curves can be seen. Again, the main implications of this analysis are presented and discussed. Additionally, different ways of modeling battery degradation and battery cost may be presented.

# Session 16.00 – 17.20
# Renewable Integration

**Room: B37**
**Chair: Christoph Brunner**

**Innovative market integration of renewable electricity**

Sebastian Bothor (TransnetBW GmbH)

**Optimal trade-offs between Energy Efficiency improvements and additional Renewable Energy supply: A review of international experiences**

Mattia Baldini (TU Denmark)

**Electricity storage and flexibility requirements on the road to decarbonization in European electricity**

Clemens Gerbaulet (TU Berlin)

**Is a multiplicative RES surcharge a good instrument to leverage DSM?**

Lyuba Ilieva (Frontier Economics Ltd.)

# Innovative market integration of renewable electricity

Andreas Semmig[1], Dr. Philipp Guthke[1], Jürgen Wolpert[1], Sebastian Bothor[1]

[1] *TransnetBW GmbH, Pariser Platz Osloer Str. 15-17, 70173 Stuttgart, Germany, a.semmig@transnetbw.de*

**Keywords:** Market integration of renewable energy, incentive regulation, algorithm based marketing, Transmission System Operator

Increasing the energy efficiency is one of the main goals of the German Energiewende. TSO's contribute to this goal by innovative market integration of renewable energy and thereby giving transparent price signals to the market. As a consequence the information of the availability of renewable generation capacities in comparison to the demand and therefore the actual need for flexibility is directly and transparently transported to the market.

Under these considerations, the aim of this paper is twofold: First, we reflect the current situation and the development of the integration of renewable energy from a TSO perspective. The increase of renewable generation capacity is described in relation to changes in market products, the role of market participants, and the driving forces behind the developments. As an example, the introduction of more flexible products on the stock markets as well as in the balancing markets is reviewed and set in connection to the increasing need for flexibility.

Second, we describe the legal aspects and the technical details of different market integrations of renewable energy. We review and compare the commercialization by TSO's (ÜNB-Vermarktung) with the commercialization by third parties (Marktprämienmodell) as regulated in the EEG. We particularly emphasize the developments made by TransnetBW to trade energy on the day-ahead and intraday market. In addition, we present our experiences in the operation of innovative energy forecasts and trading algorithms, which are motivated by reducing balancing energy and costs under uncertain circumstances. The development of the cost efficiency of the integration mechanisms by TSO's and third parties is investigated. We conclude with our perspective on further developments of the market integration of renewable energy.

# Trade-offs between Energy Efficiency improvements and additional Renewable Energy supply: A review of international experiences

Mattia Baldini[1], Henrik Klinge Jacobsen[2]

[1] *Technical University of Denmark (DTU), Anker Engelunds Vej 1, Lyngby, Denmark, mbal@dtu.dk*
[2] *Technical University of Denmark (DTU), Anker Engelunds Vej 1, Lyngby, Denmark, jhja@dtu.dk*

**Keywords:** Renewable Energy, Energy savings, Trade-off, Synergy, Sustainable energy policy

Energy is a commodity used worldwide, representing a vital input for social and economic development. Due to continuous growth, energy demand has increased. Solutions have been proposed in order to satisfy the increase in demand, often implying the increase of capacity of the power mix. Meanwhile, current issues concerning climate change and fossil fuels depletion has moved attention towards cleaner ways to produce energy. This trend facilitated the breakthrough of renewable technologies. Since then, support policies have promoted the large deployment of renewables, without considering enough improvements made in the energy saving field. Indeed, less attention has been paid to implement energy efficiency measures in energy systems modeling, which has resulted in scenarios where expedients for a wise use of energy (e.g. energy savings and renewables' share) are unbalanced and cost-savings opportunities are missed. The aim of this paper is to review and evaluate international experiences on finding the optimal trade-off between efficiency improvements and additional renewable energy supply. A critical review of each technique, focusing on purposes, methodology and outcomes, is provided along with a review of models adopted for the analyses. The models are categorized and presented according to their main characteristics (e.g. bottom-up/top-down model, regional/national analysis, partial/general equilibrium, static/dynamic model).

The results of this paper provide, to the decision-makers, informations useful for identify a suitable analysis for investigate on the optimal trade-off between renewables and energy efficiency measures in energy-systems under different objectives.

# Electricity storage and flexibility requirements on the road to decarbonization in European electricity

Clemens Gerbaulet[1, 2], Casimir Lorenz[1, 2]

[1] *TU Berlin, Strasse des 17. Juni 135, 10623 Berlin, Germany, cfg@wip.tu-berlin.de*
[2] *DIW Berlin, Mohrenstr. 58, 10117 Berlin Germany.*

**Keywords:** Decarbonization, Storage, Flexibility requirement, Europe, Electricity sector modeling

On the path to decarbonization in Europe it is likely that the ambitious climate targets (80-95% reduction of green-house gas emissions by 2050) can only be reached when a significant share of electricity production comes from variable renewables such as wind and solar power.

In this paper we focus on the development of flexibility options using a detailed representation of storage technologies as well as demand flexibility options in an electricity sector investment model for Europe *DynELMOD*, which models the expansion of generation capacity as well as grid expansion for all European countries starting in 2015 until 2050. Given a set of boundary conditions such as yearly $CO_2$ emission budgets, technological parameters and technological availability and cost assumptions the model determines the cost-minimal generation portfolio, cross-border transmission expansion as well as the underlying generation and storage dispatch. We extend the model with a detailed storage technology representation including multiple technologies with varying technical characteristics and associated cost parameters representing short-, mid-, and long-term storage options such as Li-Ion batteries, pumped hydro storage as well as power to gas.

Preliminary results show that fewer storage capacities than anticipated are built by the model. The amount and regional distribution of the storage capacities is less sensitive to variations in investment cost than expected. The main driver of flexibility need is the level of renewable deployment in conjunction with availability of interconnection between countries as increased interconnection can provide a cost-effective alternative to installation of short- and mid-term flexibility options such as batteries or pumped hydro storage.

The spatial distribution and demand for storage is less influenced by the investment cost but mostly by the amount of wind and solar power as well as interconnection capacity between countries.

# Is a multiplicative RES surcharge a good instrument to leverage DSM?

Lyuba Ilieva, Jens Perner, Michael Zähringer

*Frontier Economics Ltd.*

**Keywords**: dynamic RES surcharge, EEG levy, demand response, auto-generators

Currently, small and medium-sized business consumers are often served by electricity tariffs which do not vary over time and do not reflect any scarcity or surplus of supply at the wholesale market. This does not create any incentives for such consumers to flex their demand in response to supply changes even if their costs for demand response were low.

The RES surcharge in Germany ("EEG-levy") is currently paid as a fixed component of the final energy tariff. We evaluate an existing proposal by Ecofys/RAP for a dynamic EEG-levy designed such that the level of the levy is linked multiplicatively to an hourly wholesale price. We investigate how such levy would affect demand side response in particular and the electricity sector overall.

The effectiveness of such an instrument depends on the extent to which electricity retailers pass-on variations of the EEG-levy to consumers. Assuming that retailers pass-on the full variation of the EEG levy, we find that:

- A multiplicative EEG-levy can create substantial additional incentives to develop and to employ load shift potentials with low variable costs, especially in the trade, commerce and service sector;
- The effective additional potential provided (compared to a static EEG levy), however, will be constrained by fixed costs for investment and maintenance of load management;
- Efficiency gains from additional demand response can occur mainly in low-price hours when a zero EEG-levy would improve the dispatch of auto-generators and decrease hurdles for sector coupling;
- Inefficiencies can occur due to distorted competition between different flexibility options especially in hours with higher prices; and
- Price risks for market participants (i.e. suppliers and consumers) and the refinancing of EEG-expenditures increase.

In total, we assess that the inefficiencies and additional risks which arise with a multiplicative RES levy proposed by Ecofys/RAP are unlikely to outweigh the efficiencies.

# Session 16.00 – 17.20
# Gas

**Room: Dresden Memorial**
**Chair: Philipp Hauser (TU Dresden)**

**Shaking Dutch Grounds Won't Shatter the European Gas Market**

Prof. Dr. Franziska Holz (DIW Berlin; Hertie School of Governance)

**The Economics of Natural Gas Storage in Europe**

Dr. Andreas Schröder (Uniper Global Commodities SE / E.ON)

**Options for diversifying the European Union's natural gas market**

Simon Schulte (University of Cologne)

**Strategic Behavior in Global LNG Markets: Outlook for the Asia-Pacific Region**

Philipp Feister (TU Dresden)

# Shaking Dutch Grounds Won't Shatter the European Gas Market

Franziska Holz[1,2], Hanna Brauers[1] , Philipp M. Richter[3], Thorsten Roobeek[2]

[1] *DIW Berlin, Mohrenstr. 58, 10117 Berlin, Germany, fholz@diw.de, hbrauers@diw.de*
[2] *Hertie School of Governance, Friedrichstr. 180, 10117 Berlin, Germany, holz@hertie-school.org*
[3] *TU Dresden, Faculty of Business and Economics, Helmholtzstraße 10, 01069 Dresden, Germany, Philipp_Moritz.Richter@tu-dresden.de*

**Keywords:** natural gas, supply security, Europe, equilibrium modeling

The Netherlands have been a pivotal supplier in Western European natural gas markets in the last decades. Recent analyses show that the Netherlands would play an important role in replacing Russian supplies in Germany and France in case of Russian export disruption (Richter & Holz, 2015). However, the Netherlands have suffered from regular earthquakes in recent years that are related to the natural gas production in the major Groningen field. Natural gas production rates – that are politically mandated in the Netherlands – have consequently been substantially reduced, with an estimated annual production 30% below the 2013 level. We implement a realistically low production path for the next decades in the Global Gas Model and analyze the geopolitical impacts. We find that the diversification of the European natural gas imports allows spreading the replacement of Dutch gas over many alternative sources, with diverse pipeline and LNG supplies. There will be hardly any price or demand reduction effect. Even if Russia fails to supply Europe, the additional impact of the lower Dutch production is moderate. Again, alternative suppliers from various sources are able to replace the Dutch volumes. Hence, the European consumers need not to worry about the declining Dutch natural gas production and their security of supplies.

# The Economics of Natural Gas Storage in Europe

Alexandre Haikel[1], Dr. Andreas Schröder[1]

[1] *Uniper Global Commodities SE / E.ON, Phone +49 15157004319, E-mail: andreas.schroeder@uniper.energy*

**Keywords:** Natural Gas, Storage, Seasonality

This contribution deals with the economics for natural gas storage operations in the EU. It opens by defining flexibility supply & demand in natural gas markets. We draw a picture of current healthy supply in flexibility terms for the EU gas market and correspondingly an environment of low seasonal price spreads. Departing from the current market situation, we identify fundamental drivers for the economic outlook of storage operation. Although indigenous EU production is declining, LNG imports, storage availability and pipeline imports are major determinants in covering swing requirements in the current market. On the demand-side of flexibility, we observe a potential for rising seasonal swing of natural gas demand inside the EU in large parts due to seasonal variability of gas demand in the power sector. We identify - as further drivers for summer-winter spreads - coal-to-gas switching price ranges of the power sector as well as producer behaviour of several gas market agents. Results of our analysis include a qualitative discussion on the rationale behind the supply, demand and arbitraging of LNG, which determine seasonality and thus price spreads in the gas market. Adding to our economic analysis, we take a look at the regulatory and political developments surrounding gas storage operations. The commercial framework is flanked by the intentions of the European Commission on the remuneration of security of supply via LNG imports and storage.

# Options for diversifying the European Union's natural gas market

Simon Schulte[1] and Florian Weiser[1]

[1] *Institute of Energy Economics, University of Cologne, Vogelsanger Strasse 321a, 50827 Cologne, Germany.*
*E-mail: simon.schulte@ewi.research-scenarios.de*

**Keywords:** European natural gas market, diversification, oligopolistic market behavior, mixed complementarity programming

The European natural gas market is characterized by a strong import dependency of highly concentrated and oligopolistic acting suppliers. Due to the future declining indigenous European production, this trend is likely to strengthen over the next decades. To address the issue we analyzed different options to diversify the future European Union's (EU) natural gas import. Therefore, we implemented different political interventions to the EU's market. These are beside maximum supply restrictions to dominant market players as the Russian federation, also minimum import shares of liquefied natural gas (LNG) from overseas and via pipeline from the southern gas corridor.

In a first step, we analyzed the effects of such import restrictions in an oligopolistic market in general. Therefore, we implemented the constraints analytically to a simple Cournot duopoly and examined the effects on the market prices. In a second step, we implemented the restrictions in a more complex market model for the global natural gas market. The model we applied is the COLUMBUS model that was developed by Hecking and Panke (2012). The COLUMBUS model is a mixed complementarity model of the global natural gas market. Due to its mixed complementarity character, the model is able to cover the market behavior of the main natural gas market players. Hence, we could transfer our theoretically findings of the Cournot duopoly into the more complex natural gas market.

Our first results show that the maximum import constraint work like an exporter's capacity constraint. Compared to that, the minimum import level lead to a decrease of the European wholesale prices. This effect is comparable to a fixed feed-in tariff of renewables in the German power sector. The minimum import level forces new players into the market. Therefore, some other players are pushed out of the market. However, someone has to pay for the feed-in tariff.

Our results are preliminary and we have to apply further robustness checks to validate these.

**References**

Hecking, H., & Panke, T. (2012). COLUMBUS – A global gas market model. Working Paper. EWI. University of Cologne. Cologne.

# Strategic Behavior in Global LNG Markets: Outlook for the Asia-Pacific Region

Philipp Feister[1]

[1] *Vattenfall Energy Trading / Technische Universität Dresden, philippfeister@gmx.de*

**Keywords:** Natural gas, LNG, Asia-Pacific, Mixed Complementarity Problem, LNG transportation, long-term contracts, take-or-pay

LNG increasingly gains importance as trade transportation links connect markets and transmit both physical commodity volumes and price signals. With the Asia-Pacific region as the largest sink for LNG, becoming the worlds' largest concentrated gas consuming region, global gas markets are increasingly affected by its market development. In this study, LNG trade of Asia-Pacific importers with exporters from Asia and from outside Asia is analysed based on a market model formulated as a Mixed Complementarity Problem (MCP). The model focus lies on expected trade flows being affected by enduring inflexibilities from long-term contracts with take-or-pay obligations and oil-price indexation. In this regard, interdependencies with an emerging short-term LNG market for seasonal balancing reveal a continuous shift away from long-term contracts towards more flexible supply. Moreover, the model covers LNG transportation represented by a linear programming approach in order to minimize transport costs, taking LNG shipping capacities into consideration. The scenario analysis investigates the possible exertion of market power by suppliers (while generally other market participants are assumed to be price-takers) and effects of external factors on the model outcome, e.g. the oil-price development and the restart of Japanese nuclear power generation.