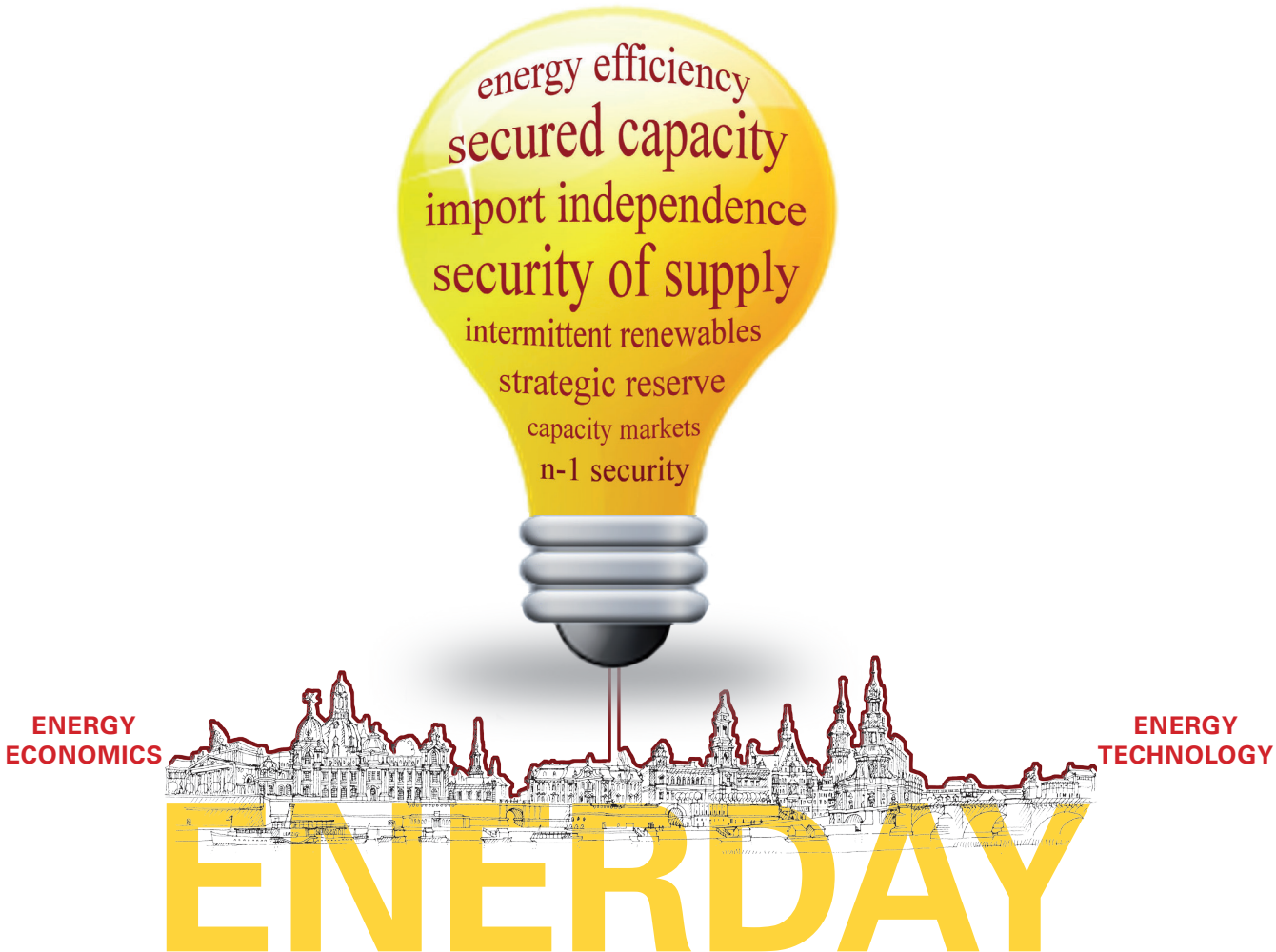
TECHNISCHE UNIVERSITÄT DRESDEN

DRESDEN concept

Faculty of Business and Economics, Chair of Energy Economics, Prof. Dr. Dominik Möst

10th Conference on Energy Economics and Technology

Sustainable Energy Security



17th April 2015, TU Dresden

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ENERDAY
10th Conference on Energy Economics and Technology
Sustainable Energy Security

Book of Abstracts

17th April 2015

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

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

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Foreword

Dear participants of the 10th Enerday, the 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 most cordially to the ENERDAY, the 10th Conference on Energy Economics and Technology, focusing this year on Sustainable Energy Security.

In the light of intensifying international tensions and the low-carbon transformation of the energy system, the issue of "sustainable energy security" is gaining attention. This includes both supply issues, resources and adequate capacity, demand issues, such as flexibility of demand and energy efficiency, as well as grid issues, such as system stability and service reliability. Especially the Ukrainian-Russian crisis stimulated a debate about a possible supply disruption of Russian gas exports, which would heavily challenge Europe's gas supply. One possibility to reduce import dependency is seen in Europe in the usage of renewable energy sources, but the fluctuating and uncertain character of most renewables also imposes challenges for a stable energy supply. Several questions with regard to sustainable energy security arise: what are the specific challenges in Germany and Europe? Which technologies are able to keep security of supply on the accustomed level? Which role do other policy objectives, such as climate protection, increase of energy efficiency, etc. play? Can the market provide adequate incentives or is more regulation required? Should the issue be addressed on the European, national or regional level?

The objective of this year's ENERDAY is to address challenges for energy markets, policies and energy systems with a special focus on sustainable energy security. Strategies for long-term as well as short-term security are of interest. Once again, we have an interesting program dealing with various challenges and aspects in the European energy markets. Thus, the ENERDAY shall provide a platform for intensifying the dialogue between economic and technical issues as well as between practice and theory.

Scientific cooperation partners are DIW Berlin, the German Institute for Economic Research, and GEE, the German Chapter of the International Association of Energy Economics (IAEE). It is a pleasant duty to express our sincere gratitude to the two supporters of this conference: 50Hertz Transmission GmbH one of the four German transmission grid operators, and the DREWAG, utility of Dresden.

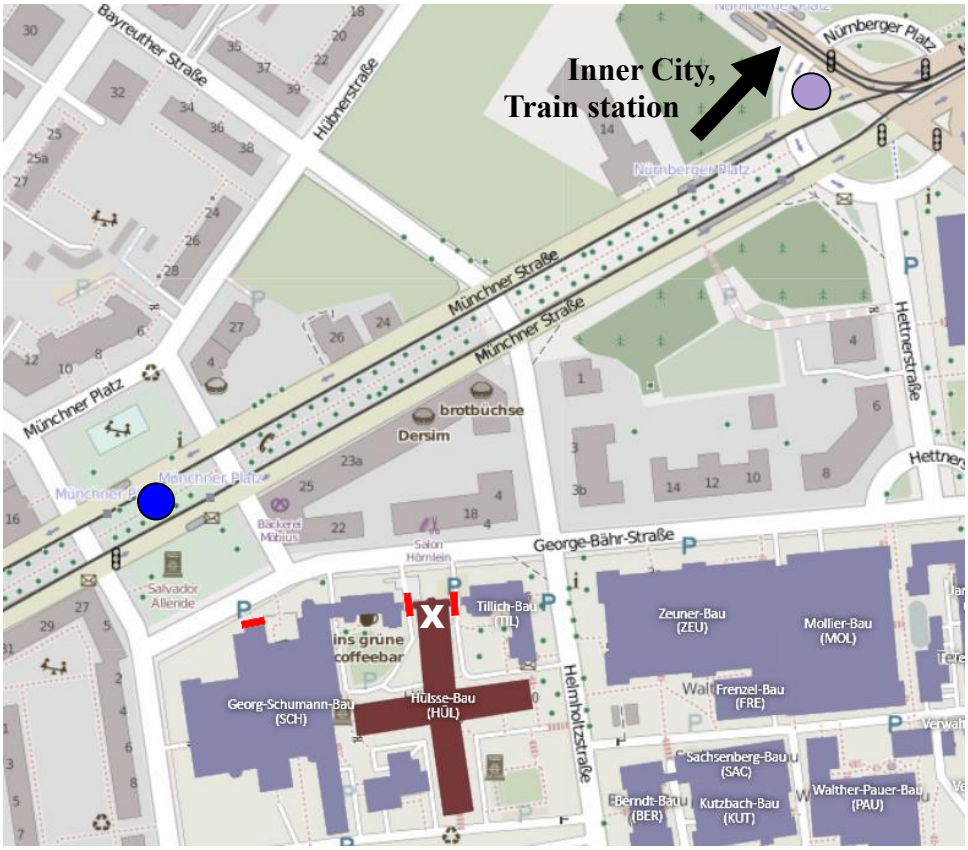
As the organizers of the conference, we were particularly delighted with the very good attendance in this year, which is reflected in the internationality of the participants and the amount of submitted contributions. We are pleased to be able to contribute to a fruitful exchange of scientific approaches and their practical application in energy economics. We would like to thank all the speakers for their contributions and the participants of the workshop.

We wish you a successful 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”.

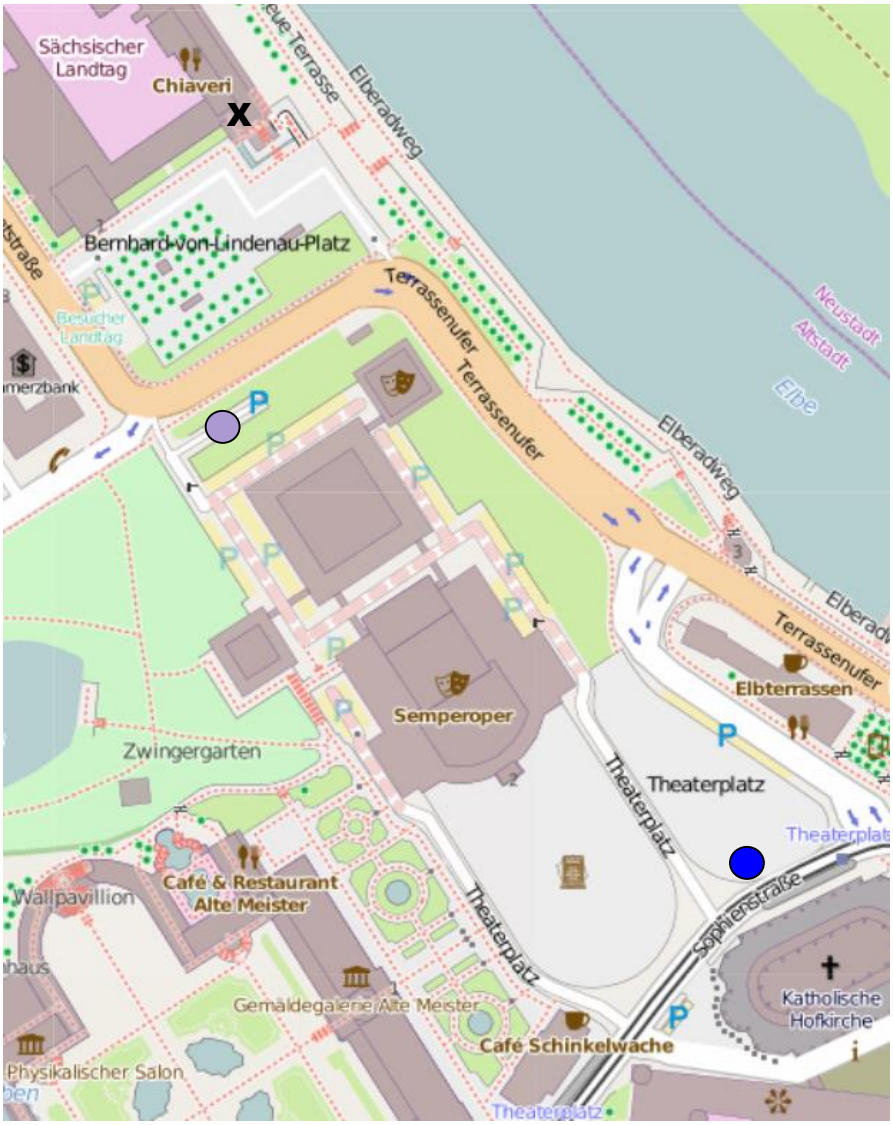
From the **West** take the bus No. 62 (direction: Weißig / Fernsehturm) up to “Nürnberger Platz”.

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

Conference Dinner

Friday, 17 April 2015, 7 pm

Chiaveri im Sächsischen Landtag, Bernhard-von-Lindenau-Platz 1, 01067 Dresden, Dresden
www.chiaveri.de



Tram station: Theaterplatz, Line 8

Basement garage Semperoper

X **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, 17th April 2015

Informal Get Together **Thursday, 16 April 2015, 7 pm**
Paul Rackwitz, Plauenscher Ring 33, 01187 Dresden

Conference Program on 17 April 2015, 8:15 am - 6 pm

8:15	Registration, Coffee & Tea		
8:45	**Opening Address** (Room: Faculty Assembly Hall) Prof. Dr. Udo Buscher, Dean of the Faculty of Business and Economics, TU Dresden Prof. Dr. Dominik Möst, TU Dresden, Chair of Energy Economics Prof. Dr. Christian von Hirschhausen, TU Berlin, Workgroup for Infrastructure Policy (WIP) and DIW Berlin		
9:15	**Keynote Speech** (Room: Faculty Assembly Hall, Chair: Prof. Dr. Christian von Hirschhausen) **Sustainable Energy Security: The hidden challenges** Prof. Dr. Karen Smith Stegen (Jacobs University Bremen)		
10:00	Coffee & Tea		
10:45 - 12:05	**Energy Security** (Room: Faculty Assembly Hall) Chair: Philipp Hauser	**Investment Planning** (Room: A03) Chair: Fabian Hinz	**Energy Policy** (Room: B37) Chair: Hannes Hobbie
10:45	**Energy security conceptions and renewable energy deployment in the EU** Javier Valdés (Ferrara and Parma Universities)	**Economic Viability of Grid Expansion, Energy Storage, and Demand Side Management: A Real Options and Welfare Analysis** Prof. Dr. Reinhard Madlener (RWTH Aachen University)	**Does Free Permit Allocation Cause Higher Emissions in the Electricity Sector? Firm-Level Evidence from a Natural Experiment** Dr. Aleksandar Zaklan (DIW Berlin)
11:05	**Long-term strategies to ensure a robust performance of the European electricity system** Paul Nahmmacher (Potsdam Institute for Climate Impact Research)	**Technology Investments for New Energy Systems: Regime, Market and Cost Uncertainties** Ernesto Garnier (RWTH Aachen University)	**The Economics of State Aid for Environment and Energy – New Developments in Response to Energy Security Challenges** Dr. Geza Sapi (European Commission)
11:25	**Sustainable security of electricity supply through coordinated national security of supply policies** Dr. Lyuba Ilieva (Frontier Economics)	**Optimum Investment Planning and Operation of Local Hybrid Energy Systems from the End-User Perspective** Andreas Fleischhacker (Vienna University of Technology)	**Designing business models for different market participants in a hybrid retail energy market** Daniel Schwabeneder (Vienna University of Technology)
11:45	**External oil supply risks under different scenarios in EU, US, Japan, China and India** Dr. Wina Crijns-Graus (Utrecht University)	**New balancing rule for the electricity market** Stephan Schiller (EnBW Energie Baden-Württemberg AG)	**Who can put the German Energie-wende into action? Characterizing arenas of change and implications for electricity infrastructure** Dr. Eva Schmid (Potsdam Institute for Climate Impact Research)
12:05	Lunch		
13:15	**Keynote Speech** (Room: Faculty Assembly Hall, Chair: Prof. Dr. Dominik Möst) **Maintaining System Security in the Face of German "Energiewende" (Perspective of a TSO)** Gert Schwarzbach (50Hertz Transmission GmbH)		
14:00	Short 5-Minute-Break		

14:05 - 15:25	**Transmission Grids** (Room: Faculty Assembly Hall) Chair: David Gunkel	**Balancing Markets** (Room: A03) Chair: Michael Zipf	**Role of Energy Demand** (Room: B37) Chair: Theresa Müller
14:05	**Cross-Country Electricity Trade, Renewable Energy and Transmission Infrastructure Policy** Dr. Jan Abrell (ETH Zürich)	**Impacts of Dynamic Probabilistic Reserve Sizing Techniques on Reserve Requirements and System Costs** Michael Bucksteeg (Universität Duisburg-Essen)	**Are current regionalisation approaches sufficient to decompose electricity demand? – A German case study** Anna-Lena Klingler (Fraunhofer ISI)
14:25	**Linking Europe - The Role of the Swiss Electricity Transmission Grid until 2050** Prof. Dr. Hannes Weigt (University Basel)	**Influence of the time discrete trade of electricity on the demand for secondary control reserve** Steffen Fattler (Forschungsstelle für Energie-wirtschaft e.V.)	**Spot price formation outside the typical merit-order of thermal power plants** Christoph Brunner (EnBW Energie Baden-Württemberg AG, TU Dresden)
14:45	**Probabilistic welfare analysis for system adequacy – analytical insights** Julia Bellenbaum (Universität Duisburg-Essen)	**Short-term power production planning under uncertain activation of control reserve** Michael Burkhardt (EnBW Energie Baden-Württemberg AG, TU Dresden)	**Shifting intra-day electricity consumption through monetary incentives and information feedback** Sylvain Weber (University of Neuchâtel)
15:05	**How Well Can a Regulator Oversee Electricity Transmission Planning? Limitations and Options for Improvement for the Case of Germany.** Alexander Weber (TU Berlin, WIP)	**Market design improvements in the German balancing power market – A fundamental model analysis** Diana Böttger (University of Leipzig)	**Renovation and Energy-related Household Behaviors in French Dwellings: a Focus on Thermal Comfort** Elena Stolyarova (EDF R&D)
15:25	Coffee & Tea		
16:15 - 17:35	**Electricity Prices Formation** (Room: Faculty Assembly Hall) Chair: Julia Michaelis	**Renewables and Market Design** (Room:A03) Chair: Daniel Schubert	**Energy System Analysis** (Room: B 37) Chair: Hannes Hobbie
16:15	**Studying forward premia in electricity markets: a correction** Prof. Dr. Silvester VanKoten (University of Economics, Prague)	**Cross-border Cooperations in European Energy Policy: Challenges in the Case of Intermittent RES-E** Daniel Weber (TU Berlin WIP)	**Supply Alternatives in the European Natural Gas Market – Analysing the contribution of LNG and Shale Gas** Philipp Hauser (TU Dresden)
16:35	**A simulation of continuous intraday markets for electricity** Alexander von Selasinsky (TU Dresden)	**Modelling electricity supply in Poland with integration of large-scale wind power and energy storage** Dr. Artur Wyrwa (AGH University of Science and Technology)	**The need for lithium – an upcoming problem for electric vehicles?** Daniel Schultz (Forschungszentrum Jülich)
16:55	**A parsimonious fundamental model for wholesale electricity markets - Analysis of the plunge in German futures prices** Thomas Kallabis (Universität Duisburg-Essen)	**Cross-Border Balancing Cooperation in the Alpine Region: Benefits and Challenges** Casimir Lorenz and Clemens Gerbaulet (TU Berlin, WIP)	**Is there an optimum scale for energy autarky?** Dr. Russel McKenna (Karlsruher Institut für Technologie)
17:15	**Two Price Zones for the German Electricity Market: Market Implications and Distributional Effects** Jens Weibezahn (TU Berlin, WIP)	**Analysis of design options for the German electricity market regarding security of supply** Dr. Dogan Keles (Karlsruhe Institute of Technology)	**The role of CHP in a highly renewable electricity system in Germany** Gerda Schubert (Fraunhofer ISI, TU Dresden)

Content

Session 10.45 – 12.05
Energy Security

Room: Faculty Assembly Hall
Chair: Philipp Hauser (TU Dresden)

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Javier Noel Valdés Lucas (Ferrara and Parma Universities)

Long-term strategies to ensure a robust performance of the European electricity system
Paul Nahmmacher (Potstdam Institute for Climate Impact Research, TU Berlin), Brigitte Knopf (Mercator Research Institute on Global Commons and Climate Change), Eva Schmid (TU Berlin), Michael Pahle (TU Berlin)

Sustainable security of electricity supply through coordinated national securirty of supply policies
Lyuba Ilieva, Jens Perner, Matthias Janssen (Frontier Economics)

External oil supply risks under different scenarios in EU, US, Japan, China and India
Wina Crijns-Graus, Mike van Moerkerk (Utrecht University)

Energy security conceptions and renewable energy deployment in the EU

Javier Noel Valdés Lucas (Ferrara and Parma Universities)

The development of the renewable energy sources (RES) as main energy sources in the future, responds to a combination of factors that can be classified by three dimensions: competition, energy security and environment. Nevertheless the energy security factors behind the support of RES have been poorly investigated (see, For Example Marques and Fourinhas, 2011 and 2012; Popp, 2011; Nesta et al. 2014; Aguirre and Ibinkule, 2014). Taking into account that energy security is a concept, not a policy, with strategic intent (Chester, 2010), this article aims to find new evidence on the relation between Energy Security conceptions and the development of RES in the EU. The working hypothesis is that different conceptions of energy security of European states explain the different paths in the deployment of RES. In order to test this hypothesis panel data of 21 EU members' energy sectors are employed to construct indicators for energy security used in EU's policy making. This paper contributes with three main findings to the literature on the drivers of RES. The introduction of a guide range of indicators of energy security not only seems to be relevant but also necessary in order to asses the real role of energy security in the elaboration of the energy policy. The second conclusion is that the variables related to energy security dimensions play a main role in the development of renewable energies at an european level. Finally, the results shows that the countries following a strategy of diversification of the energy sources present a higher commitment to RES deployment, and the more these countries diversify their energy sources, the higher the support of RES becomes. This result, is more in accordance with a modern approach to Energy Security and in accordance with the literature reviewed (s.e. Escribano et al., 2013; Correlje and Van der Linde, 2006).

Aguirre, M., and Ibikunke, G., (2014). Determinants of renewable energy growth: A global sample analysis, Energy Policy, Vol. 69, pp. 374–384.
Chester, L**.,** 2010. “Conceptualising Energy Security and Making Explicit its Polysemic Nature”, *Energy Policy*, Nº 38, (2), pp. 887–895.
Correlje, Aad & van der Linde, Coby, 2006. "Energy supply security and geopolitics: A European perspective," *Energy Policy*, Elsevier, vol. 34(5), pages 532-543, March.
Escribano,G. F., Marín-Quemada, J.M. and San Martín, E. 2013: “RES and Risk: renewable energy's contribution to energy security. A portfolio-based approach”, *Renewable & Sustainable Energy*, Elsevier Editorial System.
Marques, A. C., Fuinhas, J.A., 2012. “Are public policies towards renewable successful? Evidence from European countries”. *Renew. Energy* 44, pp.109–118.
Marques, A. C., Fuinhas, J.A., 2011. "Drivers promoting renewable energy: A dynamic panel approach," *Renewable and Sustainable Energy Reviews*, Elsevier, vol. 15(3), pages 1601-1608, April.
Popp, D., Hascic, I., Medhi, N., 2011.”Technology and the diffusion of renewable energy”. *Energy Economics,* Vol. 33, pp.648–662.
Nesta, Lionel & Vona, Francesco & Nicolli, Francesco, 2014."Environmental policies, competition and innovation in renewable energy," *Journal of Environmental Economics and Management*, Elsevier, vol. 67(3), pages 396-411

Long-term strategies to ensure a robust performance of the European electricity system

Paul Nahmmacher (Potstdam Institute for Climate Impact Research, TU Berlin), Brigitte Knopf (Mercator Research Institute on Global Commons and Climate Change), Eva Schmid (TU Berlin), Michael Pahle (TU Berlin)

Keywords: European Power System, Robust Decision Making, Long-term Optimization Modelling, Shocks

We combine optimization methods and the tools of robustness analysis for developing long-term strategies that ensure a robust performance of the European electricity system under shocks.
With the electricity system being constantly exposed to political, techno-economic and natural risks, it is crucial to ensure security of supply and minimum costs for a variety of possible futures – not only the ones that are perceived as the most likely. In this context, sudden short-term shocks that do not allow an adaption of the capacity stock are particularly challenging. If necessary incentives for investors to ensure security of supply are missing, policymakers may wish to implement additional policies to provide against such shocks. Common scenario analysis with investment optimization models is not sufficient for generating and analyzing adequate strategies. We therefore enhance the established energy scenario analysis by employing the framework of "Robust Decision Making" described by Lempert et al. (2006)[1]. Instead of stochastic approaches that require estimating the *probability* of the shocks beforehand, robust decision making starts from the perspective of *possibility*. This makes robustness the suitable concept for decisions under deep uncertainty, particularly in presence of low-frequency future uncertainties such as shocks. The criterion for selecting a robust strategy is not optimality but a good performance compared to other strategies across a wide range of plausible futures.
Combining optimization methods and robustness analysis in the long-term European electricity system model LIMES-EU[2] allows us to generate efficient long-term strategies for improving the robustness of the European electricity system under shocks; and thereby close an important gap in the literature. In this paper we focus on two kinds of shocks: (i) gas supply shocks and (ii) extreme weather events related to further climate change. We find that the installation of excess capacities as well as the deployment of renewable energy sources at levels higher than optimal in scenarios without the possibility of shocks significantly increase the overall robustness of the system.

[1] Lempert et al. (2006): A General, Analytic Method for Generating Robust Strategies and Narrative Scenarios. In: Management Science, Vol. 52, No. 4, pp. 514-528.
[2] Nahmmacher et al. (2014): Documentation of LIMES-EU - A long-term electricity system model for Europe. https://www.pik-potsdam.de/members/paulnah/limes-eu-documentation-2014.pdf

Sustainable security of electricity supply through coordinated national security of supply policies

Lyuba Ilieva, Jens Perner, Matthias Janssen (Frontier Economics)

Currently, security of electricity supply is to a large extent national responsibility. Member states develop energy policies on security of supply (SoS) which are not co-ordinated with neighbouring countries. Therefore, there is a substantial risk that policy decisions are based on misleading or contradictory assumptions on potential contribution to SoS from foreign countries. This may lead either to risks for SoS or to inefficient high costs for ensuring SoS.

The development of an internal electricity market in the EU creates opportunities for more sustainable security of electricity supply but requires substantial co-ordination to avoid deficiencies and distortions. However, potential benefits can be achieved and risks, such as free-riding, avoided only if member states adopt an EU perspective when developing their energy policies and increase their coordination. The following areas require more coordination:

how member states assess the security of the supply of their electricity system;

how they design their internal electricity markets, including instruments adopted to ensure the long-term security of electricity supply; and how system operators take technical actions in case of endangered security of the system.

Our analysis shows that the current European framework on electricity SoS and national energy policies do not reflect the need for international co-ordination outlined above. The current approaches to analyse SoS, a number of market design rules as well as technical rules to run the system in scarcity events are not designed to reflect critical system situations in an internationally co-ordinated manner. Therefore, when developing their energy policies, national member states and EU regulators should increasingly coordinate themselves and take a regional or even EU perspective in order to avoid deficiencies and distortions.

External oil supply risks under different scenarios in EU, US, Japan, China and India

Wina Crijns-Graus, Mike van Moerkerk (Utrecht University)

Keywords: External oil supply risks, scenarios, peak oil, import diversification

Energy has been stated to be '*the oxygen of the economy and the lifeblood of growth*' (World Economic Forum, 2012). The inflow of energy for countries where domestic production is unable to meet demand is essential to keep their economies going and growing. Oil is typically considered to be the most critical fossil fuel as an important input for the petro-chemical and transportation sector as well as the limited and geographically less spread reserves.

In this research external oil supply risks are assessed for the period up to 2035 by taking into account different climate and oil-supply projections for the EU, United States, China, Japan and India (being the five largest importers of oil in the world).

It is found that the extent of implementation of climate policies has a large effect on external oil supply risks. When comparing the countries, China faces the lowest risks in terms of oil import diversification in all scenarios, except in a 2 degrees scenario, in which the United States becomes oil-independent. China, India and the US's trends converge over the projection period as China is facing increasing oil import diversification risks due to an increasing dependency factor over time. In all scenarios, Japan has the lowest oil import diversification. When potential exports of supplier countries are taken into account Japan faces lower external oil supply risks, by relying on suppliers (mainly OPEC) with high R/P ratios and large shares in total world oil trade. The US faces higher risks, as it relies on exporters with low R/P ratios (e.g. Ecuador and Mexico) for their imports. For the EU, all figures are highly influenced by Russia, accounting for 32% of total imports, and to a lesser extent Norway (11%), which increases the risks significantly. The main risk for China is that their oil imports are mainly from countries with low R/P ratios. And India predominantly imports oil resources from countries with a higher country risk level, being heavily reliant on imports from Iran and Iraq.

The constructed scenarios, and the oil-supply risk indices derived, present a picture of highly increased risks for the five largest oil-importing nations, when more stringent climate policies are prevented from being implemented (or implemented too slowly).

Session 10.45 – 12.05
Investment Planning

Room: A 03
Chair: Fabian Hinz (TU Dresden)

Economic Viability of Grid Expansion, Energy Storage, and Demand Side Management: A Real Options and Welfare Analysis
Reinhard Madlener, Henning Krings (RWTH Aachen University)

Technology Investments for New Energy Systems: Regime, Market and Cost Uncertainties
Ernesto Garnier, Reinhard Madlener (RWTH Aachen)

Optimum Investment Planning and Operation of Local Hybrid Energy Systems from the End-User Perspective
Andreas Fleischhacker, Daniel Schwabeneder, Georg Lettner, Hans Auer (Vienna University of Technology)

New balancing rule for the electricity market
Stephan Schiller, Holger Wiechmann (EnBW Energie Baden-Württemberg AG)

Economic viability of grid expansion, energy storage, and demand side management: A real options and welfare analysis

Reinhard Madlener, Henning Krings (RWTH Aachen University)

Keywords: Real options analysis, Demand side management, Electric grid, Energy storage, Welfare analysis

In this paper we model the economic viability of alternative investment opportunities in grid expansion, energy storage systems, and demand-side management (DSM). We examine the viability and relative attractiveness of investing in one of these three alternatives by using real options analysis (ROA). Special attention is put on the modularity and the lumpiness of the investment, and on the time limitations for exercising the respective options. Another decisive factor analyzed is energy supply security, for which we propose a novel approach for quantification. Finally, taking positive externalities of the investments into account, the relevance of the measures for supply security is discussed by means of a welfare analysis. Obviously, the high complexity of all mentioned investment opportunities requires a high grade of abstraction for any model specification that attempts to encompass the different investment opportunities simultaneously. Using data from several sources, the model results are presented for two test cases per investment option. The test case results show the high volatility of the energy market conditions caused by heavily fluctuating resources and electricity prices. Still, for the data used all investment opportunities examined generate a profit under the given boundary conditions. The demand side management investment allows for the highest profit but also shows a very wide range of simulation outcomes. The energy storage system investment has a strictly higher value than the grid expansion investment if its modularity is taken into account. In the cost benefit analysis, however, this advantage changes wanes to the impact of the supply security improvement provided by the grid expansion. Even though the test cases are investigated only to demonstrate the models' functionality, they showcase nicely the value of managerial flexibility and security of supply. A better choice of parameter value, especially considering the DSM investment, might allow for an even better comparison of the different investment alternatives taken into consideration.

Technology Investments for New Energy Systems: Regime, Market and Cost Uncertainties

Ernesto Garnier, Reinhard Madlener (RWTH Aachen)

Keywords: Technology Investments; Regulatory Risk; New Energy Systems; Compound Real Options

This research investigates the impact of different barriers to technology investments within new energy systems. We define new energy systems as distinct from previous energy systems along four lines: (1) substitution of conventional with renewable power generation; (2) substitution of centralized, large-scale generation assets with distributed, small- scale generation and storage assets; (3) increasingly responsive and better-informed customers that actively engage in power system dynamics; and (4) a digital network of multidirectional power and information flows rather than a grid of unidirectional power flows.

As the transition towards new energy systems relies on significant investments in technology and business models, potential investment barriers deserve particular attention. Among the most debated ones are low profits in power markets and investment cost uncertainty. Among the more subtle and subjective ones are threats to utility incumbency and (mis-) perceptions of first-mover effects. And, perhaps most notably, regulatory uncertainty.

We seek to explore whether these potential barriers could provide an explanation for the diverse – and often insufficient – investment levels across markets and investor types, with respect to some technologies and business models that are central to new energy systems.

In an exemplary, investor-specific approach, we evaluate the opportunity to build a technological platform that can operate various distributed energy resources (DER) as a virtual power plant (VPP). The value of DER operations and hence of the platform is considered to be contingent on stochastically behaving power market prices and subsidies. Regulation is defined as a given regime, a change of which implies a disruption to price and subsidy parameters. The work leverages compound real options (RO) methodology, incorporating both the underlying uncertainties and the flexibility of the investor. The optimal investment strategy is identified in terms of both investment thresholds and timing. Ultimately, in a discussion, we compare our findings to the actual investment behavior observed to derive policy and investor implications.

While our research is currently still in progress, some preliminary conclusions are already worth mentioning. First, the presence of the risks mentioned earlier, particularly regulatory risk, add to the value of flexibility arising from postponed investment. Second, platforms that enable multiple business models reduce risk exposure and thus facilitate investments. Further, we find indications that the weak position of incumbents in new energy systems may well be caused by the underestimation of first-mover advantages.

Optimum Investment Planning and Operation of Local Hybrid Energy Systems from the End-User Perspective

Andreas Fleischhacker, Daniel Schwabeneder, Georg Lettner, Hans Auer (Vienna University of Technology)

Keywords: energy infrastructure, private investments, decentralized generation

The key question of planning energy infrastructure is which kind of technology provides the most advantages in terms of economic, environmental and security of supply issues. Based on this question, energy supply companies and local/regional governments have to consider alternative solutions across traditional supply and demand sectors and make plans for the total integrated energy infrastructure (Bakken et al. 2007).

So far, energy infrastructure e.g. electricity, natural gas and heat grids are planned and operated usually independent from each other. This is not least due to the implementation of unbundling rules in competitive energy markets, where market participants maximize their individual benefits and profits. Therefore, synergies as long as they are compatible with the implemented regulations and market rules, are envisaged in this paper. Furthermore, private investments in energy infrastructure are usually neglected. For this reason this paper's analysis focuses on the framework development and evaluation of an optimal energy system from the end-user's perspective.

This work develops an optimization model to minimize the energy system's total costs. The method uses a steady-state power flow model and considers all costs of the predefined technologies (investment, fuel, operation and maintenance costs). It is based on the multi-grid approach and the modelling of energy hubs according to (Schulze 2010; Kienzle 2011; Geidl 2007).
An energy hub is characterized by production capacity, energy consumption and storage capacity. Different energy hubs are connected by grids. The predefined energy sources are grid connected energy sources (e.g. electrical, natural gas and heat grid) as well as stationary energy sources (e.g. solar radiation or biomass). The proposed model is formulated as a mixed-integer linear optimization problem which minimizes the net-present-value (NPV) of predefined technology options (e.g. district heating, heat pump or µCHPs).

The results of the investigated cases indicate a high affinity for decentralized investments. Due to high electricity costs for households in Germany own consumption of electricity turns out to be highly profitable. Considering the heat supply of small scale customers, connecting to the natural gas grid (under the assumption of low connection costs) is the most economical solution followed by district heating.

Because of non-linear economies of scale, large energy customers have much more possibilities to generate electricity locally in an economic way, for example with µCHPs. Economies of scope are only verifiable for large costumers while they have no relevant impact for small costumers . The cost-optimum solution appears to be strongly dependent of future price scenarios, because fuel costs represent the major share of total costs.

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New balancing rule for the electricity market – A comparative evaluation of a newly proposed meter readings approach.

Stephan Schiller, Holger Wiechmann (EnBW Energie Baden-Württemberg AG)

Keywords: balancing rule, smart meter, standard load profile (SLP)

The German "Energiewende" (energy transition) is shifting the added value within the energy sector towards a distributed generation and an intelligent energy world. Therefore it is necessary to provide customers greater incentive to consume the electricity in times of a surplus and accompanied low prices. According to the currently applicable balancing principles for small customers like households and commerce, which are based on standard load profiles (SLP), suppliers are not able to display differences in the customer's load behavior in their balancing. As a result there is no incentive at all for electricity providers to influence the demand of their customers and to achieve any benefits in the procurement.

This article proposes a new mass market-capable balancing approach on the basis of anonymized meter readings and compares it with the current SLP-method. This concept aims to generate a profile out of measured load profiles, which exhibits a sufficient accuracy in order to predict the entire customer consumption. To prove the quality of this new balancing approach, 1.000 two-rate domestic customers were analyzed on a quarter-hour basis in the year 2013. For ensuring the validity of the reference profile in comparison to the population, different random samples were drawn. Afterwards the respective totalized time series were formed and scaled on the basis of the annual energy amount. For an additional validation of this concept, the total population was also changed randomly. Differences between the scaled reference profile and the respective entire population were evaluated by means of various statistical figures.

In comparison with the SLP-method, there were noticeable alterations in the daily energy amount, despite filtering all bridging days, long weekends and monthly influences. Overall, the deviation of the random sampling showed a high similarity in their course. The differences decreased, the more the reference profiles were correlating with the annual energy distribution of the population. Accordingly the difference amount within the balancing group of a network operator was reduced.

The results also showed that even a randomly selected 15% subset of a population can display the load behavior with a sufficient accuracy (mean absolute percentage error < 12%). Moreover, a subset of 10%, which has an approximate distribution of the annual energy consumption of the population, also provides better results than the standard load profile. Furthermore, even at sample sizes with only 50 customers, the proposed meter readings approach reflected sufficiently precise the load behavior of the 1.000 household customers (5% sample size). From these results the assumption can be deduced that small subsets of larger populations can already create load profiles, which are sufficiently accurate for the balancing of energy amounts. Thus, it was shown that this balancing approach on the basis of meter readings can improve the existing standard load profiles.

Session 10.45 – 12.05
Energy Policy

Room: B37
Chair: Hannes Hobbie (TU Dresden)

Does Free Permit Allocation Cause Higher Emissions in the Electricity Sector? Firm-Level Evidence from a Natural Experiment
Aleksandar Zaklan (DIW Berlin)

The Economics of State Aid for Environment and Energy – New Developments in Response to Energy Security Challenges
Geza Sapi (European Commission DG COMP), Kai Struckmann (White & Case LLP Brussels)

Designing business models for different market participants in a hybrid retail energy market
Daniel Schwabeneder, Andreas Fleischhacker, Georg Lettner, Hans Auer (Vienna University of Technology)

Who can put the German Energiewende into action? Characterizing arenas of change and implications for electricity infrastructure
Eva Schmid (Potsdam Institute for Climate Impact Research), Brigitte Knopf (Potsdam Institute for Climate Impact Research, Mercator Research Institute on Global Commons and Climate Change), Anna Pechan (Carl von Ossietzky Universität Oldenburg)

Does Free Permit Allocation Cause Higher Emissions in the Electricity Sector? Firm-Level Evidence from a Natural Experiment

Aleksandar Zaklan (DIW Berlin)

Keywords: EU ETS, free permit allocation; emissions; difference-in-differences, causal analysis

A number of overlapping energy and climate related policies has been in force in Europe in the past decade, one of which is the European Union's Emissions Trading System (EU ETS). There has long been an interest in both the policy and research communities to disentangle the respective contributions of each policy to emission reduction. Doing so is an important contribution towards evaluating the effectiveness and efficiency of each policy, as well as interactions between them. In this paper I exploit exogenous variation induced by a natural experiment to evaluate whether abolishing free allocation in favor of full auctioning of allowances for electricity producers had a causal impact on average emissions. Specifically, I use the fact that while free allocation has expired for electricity producers in the EU-15 countries free allocation continues in eight of the EU's new member states. This situation creates valid treatment and control groups. Accordingly, I implement a difference-in-differences research design based on firm-level and plant-level data from the European electricity generation sector, as covered by the EU ETS. Preliminary results indicate that moving from mostly free permit allocation to full auctioning had a significant causal effect on emissions, lowering them by more than 10%. This result indicates that the EU ETS has an impact on emissions at the firm level, in addition to the other prevailing policies, such as support for power generation from renewable sources and efficiency measures. Another conclusion is that the question of free allocation should be viewed as more than a purely distributional issue.

The Economics of State Aid for Environment and Energy – New Developments in Response to Energy Security Challenges

Geza Sapi (European Commission DG COMP), Kai Struckmann (White & Case LLP Brussels)

Keywords: State aid, Energy and Environment, Nuclear generation, European Union

State aid for environment and energy has undoubtedly been one of the most turbulent economic policy areas of the European Union in the recent years. In April 2014 the European Commission published its Energy and Environmental State Aid Guidelines (EEAG), outlining the Commission's view of the compatibility of government support measures with EU state aid rules. These Guidelines have brought novelties on several fronts that were subject to a heated public debate across Europe. First, the EEAG introduced a new method for exempting energy intensive firms from various electricity surcharge payments. Second, the EEAG also included detailed rules for the support of renewable energy, including a gradual move away from feed-in-tariffs towards a system of electricity market premia and a general move towards competitive tendering of subsidies. Third, the EEAG included provisions for the state aid conformity of capacity mechanisms, a form of electricity market intervention that is gaining terrain across Europe. Finally, heated debate surrounded several recent state aid decisions of the Commission that are likely to shape Europe's energy policy in the next decades, including the Commission's approval of the UK's support scheme to build a nuclear power plant at Hinkley Point C.

The aim of this article is to review the main economic rationale of the Commission behind its recent state aid policy measures in the energy and environmental domain. We provide a detailed review of the main state aid policy novelties in the energy sector, outline the Commission's economic rationale for state aid for renewable support, for its view on state aid in the form of exemptions from renewable support payments and capacity mechanisms, and the economic arguments underlying its state aid decision in the UK nuclear case.

Designing business models for different market participants in a hybrid retail energy market

Daniel Schwabeneder, Andreas Fleischhacker, Georg Lettner, Hans Auer (Vienna University of Technology)

Keywords: hybrid energy networks, business models, retail tariff types

The increasing global energy demand and the further development of European energy markets will raise new challenges and business opportunities for different market participants in the energy supply chain across the different energy domains electricity, heat and gas. In general, different energy services (e.g. heating, cooling, lighting, etc.) demanded by customers can be met by different energy domains. Thus, electricity, heat and gas supply companies are competing for customers' load profiles. Considering certain coupling technologies (e.g. CHP, heat pumps, etc.), the different distribution grids can be interpreted as one hybrid energy network.

The work presented in this paper is part of the European FP7 project "OPtimising Hybrid Energy grids for smart citieS (OrPHEuS)". This project aims to develop hybrid energy network control strategies and corresponding business models to achieve better efficiency and smarter operation enabling a cooperative coexistence of different energy domains. For the economic validation a formal framework is set up describing the objectives, practices and interdependencies of the various market players, namely distribution system operators (DSO), supply companies and consumers.

In detail, the analytical contribution of this paper is the development of mutually consistent optimization models for each market participant from a hybrid energy networks' point-of-view considering the existing market rules but also anticipating possible future structural changes in the energy market design. The models are formulated as linear programs (LP) and mixed integer programs (MIP). They are implemented in MATLAB using the YALMIP toolbox and solved by the Gurobi Optimizer. Some interesting aspects of the objectives of the various market participants are indicated in the following:

i. To describe the consumers' objectives, several LPs are presented. Starting from a cost function for standard customers (without self-generation) several models are developed by gradually adding new terms and constraints according to additionally installed technologies (e.g. PV systems, heat pumps, energy storages, etc.) in order to describe the characteristics of "prosumers" (with self-generation).
ii. The supply company models are also formulated as LPs or MIPs if long-term investments are considered. Special focus is laid on the difference between single- and multi-domain operation.
iii. The model describing the DSOs' objectives focuses on the asset management of the existing grid and possible further network extension. It is formulated as a MIP and aims to optimize (re-)investment timing in the grid from an economic point of view subject to the constraints set in a grid regulation process.

At present, the models are still being developed. Therefore, final results on the evaluation of different business models are not available yet. However, preliminary results are presented, showing the functioning of customer models and the influence of different tariff types on the (residual) loads of residential customers/"prosumers". These findings suggest that tariff design can have a significant impact on the residual loads of "prosumers" with self-generation and energy storages if their devices are controlled automatically in a cost-minimizing way.

Who can put the German Energiewende into action? Characterizing arenas of change and implications for electricity infrastructure

Eva Schmid (Potsdam Institute for Climate Impact Research), Brigitte Knopf (Potsdam Institute for Climate Impact Research, Mercator Research Institute on Global Commons and Climate Change), Anna Pechan (Carl von Ossietzky Universität Oldenburg)

Keywords: Actor landscape, strategic action fields, energy system transformation, mitigation

Germany's energy system is in a state of transition known as the *Energiewende*, targeting a competitive low-carbon economy until 2050. Existing mitigation scenarios for Germany describe technological transitions that are driven primarily by exogenous assumptions; little reference is made to the questions of why and how this change comes about and which actors and institutions are decisive in this process. We contribute to filling this gap.

In order to advance the understanding of the infrastructure requirements in the German Energiewende this paper pursues a comprehensive literature review to characterize different arenas of change in the electricity system. We do so by specifying key actors, their motives and activities and infer implications for the electricity infrastructure of the future. We define arenas of change as real or virtual fields of interaction on a shared issue, in which actors purposefully or not pursue actions that collectively lead to macroscopic change processes, thereby adapting the technological, economic and legal status quo.

A synthesizing discussion illustrates that the question of how to transform the German electricity infrastructures is ultimately a question of values that need to be resolved in public debate. However, a long latency period in grid-based infrastructure development posits limits on the kind of Energiewende that can be realized in the decade to follow.

By focusing on actors in potentially conflicting arenas of change as structuring units of analysis we explicitly take into account the sociological dimension of technology development. In due course this line of research targets to develop more comprehensive Energiewende futures: Qualitative infrastructure scenarios that can serve as a point of reference for both quantitative modeling exercises and the public discourse. As a first step this paper delivers a structured overview of the actor landscape in the German Energiewende that is of value to other modelling as well as non-modelling energy transition researchers.

Session 14.05 – 15.25
Transmission Grids

Room: Faculty Assembly Hall
Chair: David Gunkel (TU Dresden)

Cross-Country Electricity Trade, Renewable Energy and Transmission Infrastructure Policy
Jan Abrell, Sebastian Rausch (ETH Zürich)

Linking Europe – The Role of the Swiss Electricity Transmission Grid until 2050
Hannes Weigt, Ingmar Schlecht (University of Basel)

Probabilistic welfare analysis for system adequacy – analytical insights
Julia Bellenbaum, Christoph Weber (University of Duisburg-Essen)

How Well Can a Regulator Oversee Electricity Transmission Planning? Limitations and Options for Improvement for the Case of Germany.
Alexander Weber (Technische Universität Berlin, WIP)

Cross-Country Electricity Trade, Renewable Energy and Transmission Infrastructure Policy

Jan Abrell, Sebastian Rausch (ETH Zürich)

Keywords: Cross-country Electricity Trade, Infrastructure Policy, Renewable Energy, Carbon Dioxide Emissions, General Equilibrium Modeling

We examine the impacts of increased European cross-country electricity trade induced by transmission infrastructure policy (TIP) in a model that integrates the electricity sector in an economy-wide general equilibrium framework. Besides capturing the empirically relevant determinants for cross-country electricity trade, the model features a high temporal resolution to represent two-way trade in a homogeneous good (electricity) and endogenous transport costs that depend on the utilization of available transmission infrastructure. We find that proposed European TIP breaks even with investment costs after 4-10 years but fails to exploit substantial welfare gains from further energy market integration. Gains from TIP significantly increase with the level of intermittent renewable energy (RE) production. TIP generally makes the majority of European countries better off but can create negative welfare impacts, emanating from economy-wide interactions, for countries with initially low electricity prices or ”wheeling” countries. Carbon dioxide emissions impacts from TIP are not unambiguous. At low or intermediate levels of wind and solar production, consistent with current and year-2020 EU targets, TIP induces a substitution towards coal-fired electricity and increases emissions. If RE production is sufficiently high, TIP has the potential to yield sizeable emissions reductions at the aggregate (European) level but will also profoundly change regional emissions patterns.

Linking Europe – The Role of the Swiss Electricity Transmission Grid until 2050

Hannes Weigt, Ingmar Schlecht (University of Basel)

Keywords: Switzerland, energy transition, network extension, investment delay

The aim of this paper is to evaluate the role of the Swiss electricity transmission system and the planned network extensions in the context of Central European electricity market developments and thereby the Swiss and European energy transitions. In addition, we conduct a sensitivity analysis of delayed grid investments for Swiss and European network projects, respectively. By deriving a quantification of potential costs and system stability impacts due to delayed network investments, we can identify whether the currently observed lag in many energy investments poses a threat to achieving the envisioned energy transitions.

Probabilistic welfare analysis for system adequacy – analytical insights

Julia Bellenbaum, Christoph Weber (University of Duisburg-Essen)

Keywords: Value of transmission capacity, system adequacy, reliability, social welfare analysis, optimal transmission expansion

To achieve the objective of a European Single Market for Electricity, an integration of infrastructure is required. Similarly, the growing share of renewable contribution to generation raises the need for infrastructure expansion and backup capacity where the latter may partially be replaced by transmission capacity.

Within a probabilistic approach to system adequacy, first generation adequacy is investigated and then augmented to a joint consideration of generation and transmission adequacy. This paper is meant to derive the value of transmission capacity as a component of system adequacy. Three components are identified to contribute to this value. First, the possibility of transmission increases system reliability, thereby replacing backup capacity. Second, more efficient use of resources or respectively (existing) generation capacity adds to the value of transmission capacity. The third component is a consequence of diversifying the demand structure usually resulting from the interconnection of two systems.

Complementing Cepeda et al. (2009), who numerically investigate the impact of transmission capacity on generation adequacy, this paper is meant to provide analytical insights. The analytical model is based on constrained social welfare maximisation. A benevolent central social planner is faced with a two-stage decision problem in which the first stage refers to investing into generation and transmission capacity while the second concerns operating the system. Optimal generation and transmission capacities are derived by solving the constrained maximisation problem. An illustrating numerical application is parameterised to system sizes of the German and Dutch electricity markets. Furthermore, sensitivity analyses for system sizes, the choice of unit sizes and the probability of failure are conducted.

The analytical solution reveals the relation of installed capacity to maximum load. The expectation that this ratio decreases with increasing system size as well as decreasing probability of failure is confirmed. Moreover, under the assumption of unrestricted transmission capacity between the two countries considered, the optimal extent of overall generation capacity is lower than for the separated countries, yet the marginal benefits of interconnection are decreasing with the size of the participating countries.

Cepeda, M. et al. (2009) Generation adequacy and transmission interconnection in regional electricity markets, Energy Policy 37(12), pp. 5612-5622.

How Well Can a Regulator Oversee Electricity Transmission Planning? Limitations and Options for Improvement for the Case of Germany.

Alexander Weber (Technische Universität Berlin, WIP)

Keywords: electricity transmission planning, transmission investment, regulation, public participation

In light of massive transmission expansion requirements in Germany, transmission planning governance has been reformed in 2011. As a result, the regulator is required to technically check and approve the TSOs‘ plans. However, it has not yet been investigated, how effectively a “third-party” planner is able to scrutinize transmission plans of TSOs: In contrast to any other party, TSOs do have unique year-long experience in transmission planning and from system control. The large investments foreseen call for due regulatory oversight to avoid inefficient investment (both in terms of structure and volume). Besides this, as highlighted by the recent and heated debate, further questions are (i) how well transmission planning is in line with policy objectives and generation deployment and (ii) whether societal control is sufficient.

To approach the problem, we conduct a detailed analysis of the technical planning process, identifying relevant knowledge/experience and interdependencies of decisions. This allows us to understand how expensive the build-up of required expertise is and what trade-offs this implies with respect to observability of transmission planning and coordination. Further we take into account regulatory practice and consider the political debate. Theoretically, the analysis is guided by (new) institutional economics and political economics.

We find that transmission planning can in general be monitored by a third party, at justifiable cost; however, scrutiny of shorter-term measures (such as protection equipment, capacitor banks, etc.) will remain limited as interdependencies with operational experience are substantial. Still, current regulatory practice could be massively improved by benchmarking TSOs’ plans against alternative plans instead of conducting sensitivity checks on line-per-line basis. As gains from coordination (especially with generation investment) are significant, and, at the same time distributional consequences of transmission projects (as illustrated by strong local resistance) are severe, this makes a case for stable political consensus to avoid short-termism and high cost of reversal. Further, increased transparency on planning data could allow for a more intense knowledge build-up at the regulator by increased interchange with (non-TSO) planning experts. As a result, the 2011 reform seems to be sensible from an overall perspective, still, some improvements, most prominently, an increased depth of regulatory scrutiny, could be made at limited cost.

This abstract is a shortened and heavily adapted version of a forthcoming research report of the project “E-Plan” (authored by Thorsten Beckers, Alexander Weber and Ann-Katrin Lenz), funded under contract number 0325323A by the German Federal Ministry for Economic Affairs and Energy.

Session 14.05 – 15.25
Balancing Markets

Room: A 03
Chair: Michael Zipf (TU Dresden)

Impacts of Dynamic Probabilistic Reserve Sizing Techniques on Reserve Requirements and System Costs
Michael Bucksteeg, Lenja Niesen, Christoph Weber (University Duisburg-Essen)

Influence of the time discrete trade of electricity on the demand for secondary control reserve
Steffen Fattler, Christoph Pellinger (Forschungsstelle für Energiewirtschaft e. V.)

Short-term power production planning under uncertain activation of control reserve
Michael Burkhardt (EnBW Energie Baden-Württemberg AG, TU Dresden)

Market design improvements in the German balancing power market – A fundamental model analysis
Diana Böttger, Thomas Bruckner (University of Leipzig)

Impacts of Dynamic Probabilistic Reserve Sizing Techniques on Reserve Requirements and System Costs

Michael Bucksteeg, Lenja Niesen, Christoph Weber (University Duisburg-Essen)

Keywords: probabilistic reserve sizing, renewable energy sources, forecast error, convolution, power system modeling

The Integration of RES (Renewable Energy Sources) leads to an increasing variability and uncertainty in electrical power systems. As electricity can virtually not be stored, demand and generation have to be in balance at all times. Due to the unpredictability of RES generation, an efficient provision of reserve capacity and thus adequate reserve sizing techniques are becoming essential elements in power system operation. In the past numerous studies on the impact of RES on reserve requirements have been performed wherefrom a variety of reserve sizing methods have emerged ranging from deterministic to probabilistic with the latter featuring both static and dynamic approaches [1], [2].

We propose a new dynamic reserve sizing approach similar to that of Bruninx and Delarue [2]. The dynamic model is compared to a static model which represents the status quo of most power system operators. The static sizing of reserves is based on a probabilistic approach. Thereby, yearly unconditional distributions of load, wind and solar forecast errors and plant outages are convolved. The resulting joint probability density function allows us to determine static reserves given a predefined reliability level [1].

While the static model ignores the high dependency of the forecast errors on the forecast, in the dynamic model we focus on the joint distribution of the forecast error ϵ and the forecast p*. Based on conditional probability distributions of load, wind and solar forecast errors and plant unavailabilities a joint probability density function is convolved and hourly reserves are computed.

The benefits of this improved dynamic reserve sizing are then demonstrated by a case study. Thereby, the potential for reserve and cost reduction is analyzed from a system perspective using the JMM (Joint Market Model). The JMM is a detailed unit-commitment model depicting the European electricity market. Its objective function minimizes variable generation costs. The model includes restrictions for the electricity market, the transmission grid, the reserve power market and also the heat market [3].

Since the static model does not distinguish between different time segments of the day it overestimates reserve requirements especially during off-peak times without solar generation and low demand variations. In contrast, the improved dynamic approach estimates reserve requirements more accurately and leads to significant cost savings.

[1] H. Holttinen, M. Milligan, E. Ela, N. Menemenlis, J. Dobschinski, B. Rawn, R. J. Bessa, D. Flynn, E. Gomez Lazaro and N. Detlefsen, "Methodologies to Determine Operating Reserves due to Increased Wind Power," in Proc. 2013 IEEE Power and Energy Society General Meeting, pp. 1-10.
[2] K. Bruninx and E. Delarue, "A Statistical Description of the Error on Wind Power Forecasts for Probabilistic Reserve Sizing," IEEE Trans. Sustain. Energy, vol. 5, no. 3, pp. 995-1002, July 2014.
[3] A. Tuohy, P. Meibom, E. Denny and M. O'Malley, "Unit Commitment for Systems With Significant Wind Penetration," IEEE Trans. Power Syst., vol. 24, no. 2, pp. 592-601, May 2009.

Influence of the time discrete trade of electricity on the demand for secondary control reserve

Steffen Fattler, Christoph Pellinger (Forschungsstelle für Energiewirtschaft e. V.)

Keywords: SCR-demand, Germany, influence of market scheme

Electricity trade in Europe is currently almost entirely based on 1-h-schedules. Recently, the trading of 15-minute-discrete blocks was introduced to the EEXs intraday trading platform. This form of trade results in a cascaded generation-load-curve. In combination with a continuous physical demand-load-curve, this creates a characteristic over- and undersupply of the electric power system. The resulting frequency deviations have already been analyzed and their cause linked to the step-wise power schedules in the dissertation of Tobias Weißbach [1]. The purpose of this study is to prove that this schedule based electricity trade, besides its impact on the grids frequency and the primary control reserve, creates a characteristic system inherent demand for secondary control reserve (SCR).

The conducted research is based on a 4-sek.-discrete time series of the demand for SCR, which is published by the German TSO 50 Hertz, and an equivalent data for the net frequency. At a first step, both time series have been analyzed qualitatively. As depicted in Figure 1, there appears to be a strong coherence between the frequency deviations during every hour change and the demand for SCR. Furthermore, it is shown that this effect is particularly pronounced during times of a high load ramp, especially in the mornings and the afternoons, resulting in a characteristic pattern in the curve of SCR-demand.

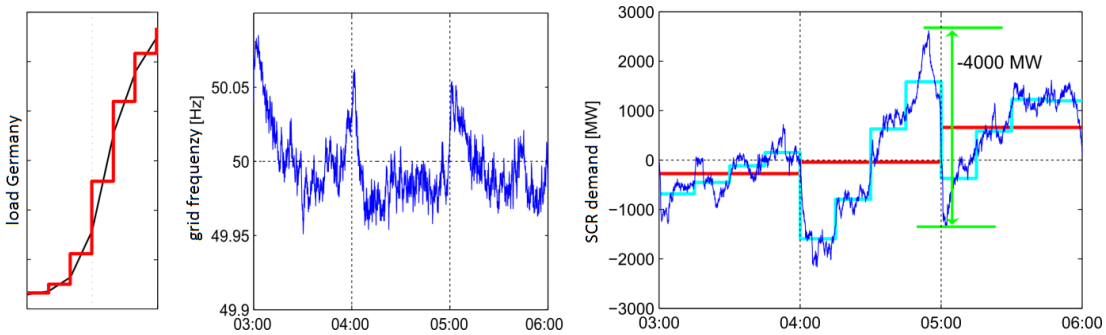

Figure 1: *Load, grid-frequency and SRC-demand in times of high load ramp [2]*

In a next step, the average course of SCR-demand during the characteristic hours between 04:00 and 07:00, 09:00 and 11:00, and 21:00 and 24:00 has been calculated as shown in Figure 2. In times of inclining load (between 04:00 and 07:00) the demand for SCR falls drastically after the change of the hour and rises steadily towards the end of the hour. However, in times of declining load (between 21:00 and 24:00), an opposite behavior of the curve can be identified. In times of a normally constant system load no such behavior can be observed.

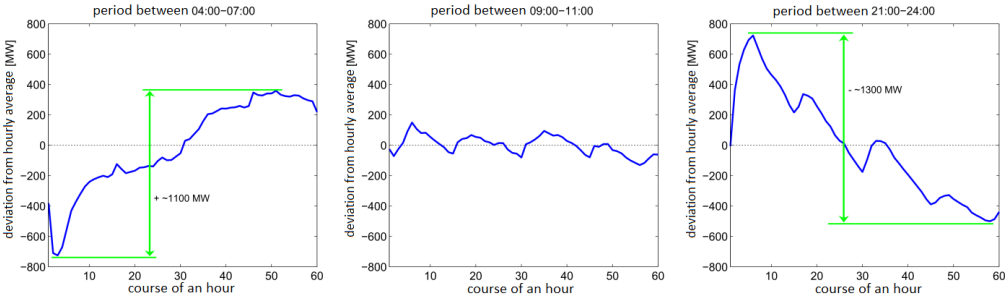

Figure 2: *Average course of SCR-demand for characteristic hours [2]*

The typical SCR-demand curve in times of inclining or declining system load can be approximated by a sawtooth pattern. At a last step, a Fourier-transformation of the timeline is performed. By comparing the resulting frequency spectrum of the SCR-demand timeline with the one of a sawtooth pattern, the coherence between the 1-hour-schedule in electricity trading and the demand for SCR is verified.

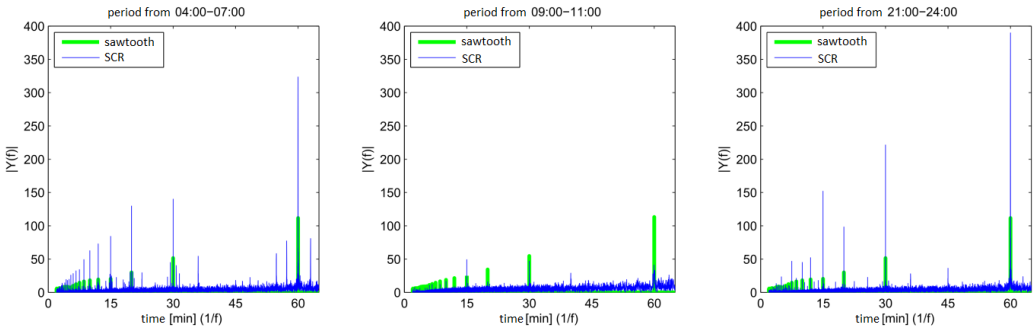

Figure 3: *Frequency spectrum of sawtooth pattern and characteristic hours [2]*

Through a comprehensive empirical analysis of the SCR demand timeline, the coherence between the 1-hour-shedule based trading of electricity and a characteristic demand for SCR is verified. Finally, an algorithm is implemented to calculate the amount of the required secondary balancing energy to compensate the influence of the schedule based trading of electricity. It can be shown that the effect declines in magnitude about 60 % in the considered time frame (01/2012 – 06/2014) .Through an economical quantification, costs of about 3,9. Mio. € per month could be associated to the described effect, which are equivalent to about 2 % of the total costs of activated SRC.

[1] Weißbach, Tobias: Verbesserung des Kraftwerks- und Netzregelverhaltens bezüglich handelsseitiger Fahrplanänderungen: Stuttgart, 2009
[2] Data published on the website of 50Hertz Transmission GmbH: „http://www.50hertz.com/de/Maerkte/Regelenergie/Regelenergie-Downloadbereich", downloaded on 27.10.2014

Short-term power production planning under uncertain activation of control reserve

Michael Burkhardt (EnBW Energie Baden-Württemberg AG, TU Dresden)

Keywords: stochastic optimization, control reserve, value of stochastic solution, unit commitment

Short term power production planning is done by energy companies to determine a profit maximizing operation schedule meeting several operational boundaries. The production plan is mainly influenced by market prices and electricity demand as well as the intermittent renewable energy production. Control reserve is used by transmission system operators to balance generation and demand to ensure a reliable and secure electricity transmission network. For hydro power plants providing control reserve, it is important to take into account the activation of control reserve during the planning period. This is because of the limited amount of energy being stored in the water reservoirs. The previous mentioned factors are uncertain during the planning process. In practice the uncertainty is approximated with its expected value and the optimization problem is formulated as a deterministic model.

This presentation aims to consider uncertainty for the short-term operational planning period. It provides a mixed integer multi-stage stochastic problem formulation to consider the uncertainty in control reserve activation and intraday market prices during the short-term power production planning process. The model uses scenario trees as approximations of the activated control energy and the intraday market prices. The model solution is than compared with a deterministic model which does not consider uncertainty. A sensitivity analysis is used to evaluate the dependency on the input data.

Results are presented based on a model parameterization of a single pumped storage hydro power plant. The stochastic solution generates additional profit comparing the stochastic with the deterministic solution. The sensitivity analysis illustrates that the additional value depends on the amount of provided control reserve.

Market design improvements in the German balancing power market – A fundamental model analysis

Diana Böttger, Thomas Bruckner (University of Leipzig)

Keywords: balancing power market, capacity price, market design, primary reserve, fundamental model

The expansion of weather-dependent renewable energy sources increases the challenge to balance supply and consumption at any point in time which is necessary for a secure operation of power grids. Balancing power markets are designed to provide sufficient capacity to compensate for unavoidable forecasting errors in production or consumption in the short term. These small markets showed high price volatility in the past. The market design of the balancing power market has become more flexible in the last years. But still there might be potential to improve the current market design to facilitate the integration of renewable energy sources, such as the introduction of more flexible products.

We introduce a fundamental model for the German balancing power market. A database of the German power plant fleet serves as input data and includes all techno-economic parameters of thermal and pumped hydro storage power plants. Offers for reserve capacity from power plant operators include the possibility to pool several power plants. The current market design is reflected in the model, particularly the bidding periods of one week for primary and secondary reserve as well as four hour blocks for tertiary reserve. Capacity prices are determined by the comparison of (expected) revenues from the day-ahead spot market with and without capacity reservation. Strategic behaviour of bidders is neglected.

The ability of the fundamental model to reproduce historical capacity prices is evaluated for the years 2012-2014 with a focus on primary reserve. Depending on the specific spot prices, average capacity prices for primary reserve vary noticeably from week to week whereas historical prices were more or less on one level. Therefore, it seems that current bids of power plant operators include the risk of unfavourable spot prices. With a shorter lead time, capacity prices for primary reserve could be much lower especially if the product length would be shorter than one week.

Session 14.05 – 15.25
Role of Energy Demand

Room: B37
Chair: Theresa Müller (TU Dresden)

Are current regionalisation approaches sufficient to decompose electricity demand? – A German case study
Rainer Elsland, Anna-Lena Klingler, Patrick Degner, Yannick Oswald, Martin Wietschel (Fraunhofer Institute for Systems and Innovation Research)

Spot price formation outside the typical merit-order of thermal power plants
Christoph Brunner (EnBW Energie Baden-Württemberg AG, TU Dresden)

Shifting intra-day electricity consumption through monetary incentives and information feedback
Sylvain Weber, Diana Pacheco, Stefano Puddu (University of Neuchâtel)

Renovation and Energy-related Household Behaviors in French Dwellings: a Focus on Thermal Comfort
Elena Stolyarova (MINES ParisTech, EDF R&D), Hélène Le Cadre (MINES ParisTech), Dominique Osso (MINES ParisTech)

Are current regionalisation approaches sufficient to decompose electricity demand? – A German case study

Rainer Elsland, Anna-Lena Klingler, Patrick Degner, Yannick Oswald, Martin Wietschel (Fraunhofer Institute for Systems and Innovation Research)

Keywords: Electricity demand, geographic allocation, regional demand, structural change, simulation

Developing strategies to deal with the challenges of the energy transition requires a detailed understanding of electricity demand with a high regional resolution. In this context, frequently discussed research questions include the need for regional power grids or power plant capacities and regional flexibility potentials. From a methodological point of view, some concepts have been developed in recent years to map national electricity demand on a district, municipality or even grid node level. In principle, these approaches distribute national electricity demand based on relatively simplified indicators (e.g. electricity demand per gross domestic product), but neglect its structural composition in terms of sectoral and technological heterogeneity.

This study aims to contribute to this research field by developing a new approach to distribute national electricity demand on a municipality level distinguished by demand-side sector and technology.

The methodological foundation for the concept to be developed is the annual electricity demand model of the energy demand model FORECAST[1]. FORECAST captures the industry, tertiary, residential, agriculture and transport sectors. While all sectors follow a similar bottom-up methodology, the particularities of each sector like technology structure, heterogeneity of actors and data availability are also considered. The newly developed concept builds upon the input data (drivers) and output data (energy demand by energy carrier) of FORECAST. To consistently map electricity demand with detailed technological structure at a high regional resolution, distribution keys are derived based on demand theory and taking into account sectoral heterogeneity and structural change over time.

To benchmark the developed concept, a scenario analysis is conducted that compares the results to the findings of existing approaches based on simplified indicators for Germany until 2035. The analysis reveals that a missing level of granularity in terms of the structural composition of electricity demand can lead to systematically different conclusions. Among others, the results are discussed in the following clusters: centrality (from very central to very peripheral), region (urban vs. rural) and density (agglomeration vs. sparsely populated).

[1]FORECAST is a modelling platform that captures the final energy demand of the EU 28+3 (3: Norway, Switzerland, Turkey) by country up to 2050 (http://www.forecast-model.eu/).

Spot price formation outside the typical merit-order of thermal power plants

Christoph Brunner (EnBW Energie Baden-Württemberg AG, TU Dresden)

Keywords: Demand shift, electricity market, flexibility, spot price modelling, substitution

The continuous expansion of electricity generation from intermittent renewable energy sources (RES) has already changed the structure of electricity spot prices in Germany considerably. The economics of all power stations, storage systems and flexible loads are highly depend on the development on these spot prices in the future, since they affect their market-based operation. The common method to describe the spot price impact of RES is to shift the residual load along the merit-order curve of thermal power plants. But, this procedure is questionable if conventional power stations are turned off and electricity demand is entirely covered by RES with negligible short-term costs, e.g. wind and photovoltaic power. The object of this presentation is to contribute to the discussion of how spot price formation can take place outside the typical merit-order of thermal power plants.

To predict the alteration of spot prices in high RES situations, it is essential to understand the interaction of intermittent RES and thermal generation in combination with additional storage technologies and flexible demand. Therefore, the impact of the latter mentioned flexibility measures is analysed by adding them exogenously to a fundamental price model that minimises overall electricity generation costs for a given demand in hourly time resolution. To examine the spot price effect of different flexibility types separately and combined three scenarios are analysed. One scenario that considers substitution of primary energy demand, a second scenario that focuses on storage-like technologies and the third scenario finally estimates the combined effect of the two previous ones.

The results demonstrate the general feasibility to assess the spot price effects of substitutive demand and additional storage capacities during times with RES surpluses. Especially the outcomes of the competition scenario confirm that spot markets in general are likely to maintain their synchronisation function in the future, even if extreme high shares of fluctuating RES are anticipated. Nevertheless, the results from different sensitivities also indicate further challenges that need to be dealt with when examining the development of future electricity spot prices.

Shifting intra-day electricity consumption through monetary incentives and information feedback

Sylvain Weber, Diana Pacheco, Stefano Puddu (University of Neuchâtel)

Solar energy production takes place at times when demand for electricity is not necessarily high. This mismatch might be reduced in several ways: electricity might be transported and consumed elsewhere, it might be stored for later consumption, or households could be encouraged to align their consumption with solar energy production. While the first two solutions imply high installation costs, the latter might prove relatively inexpensive and easy to implement.

In this paper, we assess the impacts of two experiments based on smart meters, in which we encourage households to shift their consumption towards the period of the day (11am-3pm) in which the production of solar energy is the largest. The relevance of such a study is enhanced in the context of the energy transition, as renewable energies are bound to gain importance in the energy mix.

The first experiment consists in providing households with detailed information feedback about the evolution of their electricity consumption and the fraction they consume between 11am and 3pm. They have also been provided with information about the consumption of similar households. No other motivation is given to these households. The second experiment consists in a competition, in which households are ranked according to their proportion of electricity consumed between 11am-3pm and its evolution. Participating households are aware of the rules of the competition, but minimal information about their electricity consumption is provided.

Our results show that monetary incentives have sizeable impacts on the proportion of electricity consumed during the period 11am-3pm. This proportion increased by about 2.9 percentage points in treated households, which is considerable given its average level of 20%. Households achieved this outcome by reducing their consumption (mostly) in the evening. Information feedback, however, has no statistical impact on the proportion. Nevertheless, we observe that households exposed to this treatment globally decrease their consumption, which seems to indicate that households undertake actions to decrease consumption but neglect more complex information.

We draw two main policy implications from our results. First, monetary incentives matter. Time-of-use tariffs can thus be expected to be an effective demand-side management tool. Second, even though our information letters did not lead to the intended shift of electricity consumption, results show that this type of tool may be used to achieve substantial electricity conservation. This finding suggests an inexpensive improvement of the current payment system, in which electricity bills are provided every two months and computed on expected consumption.

Renovation and Energy-related Household Behaviors in French Dwellings: a Focus on Thermal Comfort

Elena Stolyarova (MINES ParisTech, EDF R&D), Hélène Le Cadre (MINES ParisTech), Dominique Osso (MINES ParisTech)

Keywords: Thermal Comfort, Heating Systems, Energy Efficiency Retrofits, Household Behavior, Choice Experiment

The thermal comfort in winter is ensured by the capacity of space heating to maintain the desired indoor temperature. This temperature is chosen by household, subject to two limits. On the one hand, the indoor temperature must be high enough to prevent adverse effects on human health due to increase in the risk of diseases. On the other hand, it would be preferable to limit the level of indoor temperature in order to reduce energy consumption for environmental and economic reasons. Given the importance of thermal comfort, it may play a major role in the decision to undertake or not the retrofits works. The discomfort encourages the household to improve thermal characteristics of dwelling and to install more efficient equipment. In this study we propose first the formulation of household utility function from energy retrofits which takes into account the thermal comfort. After that, we estimate Multinomial and Mixed Logits to understand the household behavior the role of thermal comfort in the household's energy decisions.

In January 2015 a sample of 2000 respondents is collected by internet from a panel of 600,000 French Households. The survey consists of two parts (revealed preferences data and two choice experiments) and contains questions about socio-economic and demographic information, dwelling conditions, energy attitudes, space heating system and thermal comfort. In the first choice experiment, the respondent must take a choice between three offers of space heating systems in order to replace the old system which is broken down. The offers are characterized by the following attributes: investment cost, expected energy-savings potential, energy used, type of space heating system, guarantee period, control system to manage set temperature, financial grant and bank loan. In the second choice experiment, we propose to improve energy efficiency of respondent's dwelling. The respondent must choose between three offers: install new space heating system, insulate walls and roof, to do both. The offers' attributes are the same as in the first choice experiment.

Session 16.15 – 17.35
Electricity Prices Formation

Room: Faculty Assembly Hall
Chair: Julia Michaelis (Fraunhofer ISI, TU Dresden)

Studying forward premia in electricity markets: a correction

Silvester van Koten (University of Economics, Prague)

Strategic bidding in Intraday markets

Alexander von Selasinsky (Chair of Energy Economics, Dresden)

A parsimonious fundamental model for wholesale electricity markets – Analysis of the plunge in German futures prices

Thomas Kallabis, Christian Pape, Christoph Weber (University of Duisburg-Essen)

Two Price Zones for the German Electricity Market: Market Implications and Distributional Effects

Jens Weibezahn (Technische Universität Berlin, WIP), Jonas Egerer (DIW Berlin), Hauke Hermann (Oeko Institut e. V.)

Studying forward premia in electricity markets: a correction

Silvester van Koten (University of Economics, Prague)

Keywords: Forward Premia, Electricity Markets, Energy Economics, Mean Power Demand, Financial Markets

Forward premia have been hypothesized to be increasing in mean power demand on the basis of a theoretical risk premium model by Bessembinder and Lemmon (2002). This hypothesis is not correct in that it does not follow from their theoretical model. Figure 3 in Bessembinder and Lemmon (2002) contains an important error. A revised hypothesis states that the equilibrium forward premium initially increases, then decreases, in mean power demand.

Strategic bidding in Intraday markets

Alexander von Selasinsky (TU Dresden)

Continuous intraday markets for electricity are an important instrument for balancing forecast errors of the feed-in from renewables because they allow to trade electricity close to real-time. The work to be presented proposes a simulation approach to capture the markets' characteristics of strategic behaviour and the opportunity to trade multiple times. This allows to give insights into the costs of balancing forecast errors in the German intraday market.

A parsimonious fundamental model for wholesale electricity markets - Analysis of the plunge in German futures prices

Thomas Kallabis, Christian Pape, Christoph Weber (University of Duisburg-Essen)

Keywords: Fundamental model, electricity prices, futures market

The German electricity market has seen a plunge in wholesale prices in recent years. From 2008 until 2013, base prices dropped by more than 40%, leading to burdens for affected actors and policy makers. This paper investigates driving factors of the price decrease. We determine the fundamental component of electricity base future prices for the front-year contracts 2008-2013. By using a simplified stack model we are able to quantify the impact of specific fundamental factors. The price difference between the fundamentally expected and the actual futures prices can then be attributed to e. g. risk aversion, potential speculation or policy uncertainty. Policy uncertainty particularly refers to the nuclear phase-out and deviations between the expected and actual renewable energy feed-in caused by the renewable support scheme in Germany.

Our methodology is based on a parsimonious stack model, where the electricity supply curve is approximated by piece-wise linear functions for the main technologies. By intersecting the supply with expected residual demand, we determine the fundamental power price, which in turn delivers the expected base price by averaging the expected hourly prices over the futures contract's delivery period. The approximation of generation technologies as linear segments allows analytical derivation of sensitivities. Additionally the limited input data and low computational burdens make it feasible for repeated applications with frequent information updates and Monte-Carlo simulation analyses.

It turns out that the parsimonious model captures a large amount of the variations in electricity futures prices, indicating that electricity prices are mainly driven by fundamental factors. We quantify which of the factors fuel prices, renewable feed-in, conventional generation capacities and demand contributed most to the observed price slide. Our investigation points out that misjudgments regarding renewable capacity additions are not the single crucial reason for the plunge in wholesale electricity prices.

Two Price Zones for the German Electricity Market: Market Implications and Distributional Effects

Jens Weibezahn (Technische Universität Berlin, WIP), Jonas Egerer (DIW Berlin), Hauke Hermann (Oeko Institut e. V.)

Keywords: German electricity market, congestion management, bidding zone configuration, distributional effects

We discuss the implications of two price zones, i.e. one northern and southern bidding area, on the German electricity market. In the northern zone, continuous capacity additions with low variable costs cause large regional supply surpluses in the market dispatch while conventional capacity decreases in the southern zone. As the spatial imbalance of supply and load is increasing, the current single bidding area results more often in technically infeasible market results requiring curative congestion management. Additional bidding zones would enable better market integration of scarce transmission capacities in a system exposed to structural regional imbalances. Using a line sharp electricity sector model, this paper analyzes the system implications and the distributional effects of two bidding zones in the German electricity system in 2012 and 2015, respectively. Results show a decrease in cross-zonal re-dispatch levels, in particular in 2015. However, overall network congestion and re-dispatch levels increase in 2015 and also remain high for both bidding zones. Results are very sensitive to additional line investments illustrating the challenge to define stable price zones in a dynamic setting. With two bidding areas, prices in the model results increase in the southern zone and decrease in the northern zone. The average price deviation grows from 0.4 EUR/MWh in 2012 to 1.7 EUR/MWh in 2015 with absolute values being significantly higher in hours with price differences. Stakeholders within zones are exposed to the price deviations to a different extent. Distributional effects are surprisingly small compared to the wholesale price or different network charges.

Session 16.15 – 17.35
Renewables and Market Design

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

Cross-border Cooperations in European Energy Policy: Challenges in the Case of Intermittent RES-E
Albert Hoffrichter, Alexander Weber, Daniel Weber (TU Berlin, Workgroup for Economic and Infrastructure Policy)

Modelling electricity supply in Poland with integration of largescale wind power and energy storage
Artur Wyrwa (AGH University of Science and Technology

Cross-Border Balancing Cooperation in the Alpine Region: Benefits and Challenges
Casimir Lorenz and Clemens Gerbaulet (TU Berlin, Workgroup for Economic and Infrastructure Policy)

Analysis of design options for the German electricity market regarding security of supply
Dogan Keles, Andreas Bublitz, Wolf Fichtner (Karlsruhe Institute of Technology)

Cross-border Cooperations in European Energy Policy: Challenges in the Case of Intermittent RES-E

Albert Hoffrichter, Alexander Weber, Daniel Weber (TU Berlin, Workgroup for Economic and Infrastructure Policy)

Keywords: intermittent RES, cooperation mechanisms, transaction costs, distributional effects, new institutional economics

For several years, the European Commission has been promoting cross-border cooperations on the development of new RES-E capacities. Consistently, numerous studies find that a coordinated expansion of intermittent RES-E in Europe can substantially decrease generation costs. However, just two European states (Sweden and Norway) entered into cooperation and only few member states are planning to do so (e.g. Germany or the Netherlands).

In order to provide explanations for the hesitation of the EU member states, we analyze the major effects of cross-border cooperations from a national perspective. To do so, a qualitative model consisting of three interconnected states, where transmission capacity varies from scenario to scenario, is used. In each scenario, we examine whether a bilateral RES-E-cooperation has positive effects on the achievement of a previously defined set of national objectives. The analysis is mainly based on new institutional economics (especially the transaction cost theory and the related theory of incomplete contracts) and welfare economics.

Our results indicate that cross-border RES-E-cooperations may cause a considerable increase in transaction costs that counteracts the benefits resulting from potentially lower production costs. Various sources can lead to a rise in transactions costs: First, cross-border investments in RES-E induce distributional effects. The larger these effects, the more will states tend to invest resources in order to influence their direction. Second, uncertainties regarding the development of the technical system, the institutional framework, and the actions of other states complicate the determination of resulting distributional effects. Thus, cooperation contracts will be costly and largely incomplete. In some cases, cross-border cooperations even have negative impacts on the achievement of environmental objectives.

We also discuss several approaches to reduce transaction costs and address these challenges. As most of these measures are difficult to implement, many potential cross-border cooperations may not be beneficial in the short term. However, due to a growing scarcity of favorable locations, the (production) cost-saving potential of cross-border coordination can increase in parallel to the share of renewable electricity in the system. In the future, this (among other effects) may enhance the profitability of regional cooperations between states with similar objectives and a relationship of trust.

Modelling electricity supply in Poland with integration of large-scale wind power and energy storage

Artur Wyrwa (AGH University of Science and Technology)

Keywords: energy system, large-scale wind power, energy storage, modelling

Increasing share of electricity generation from intermittent renewables, such as wind, results in fluctuation of electricity which is fed into the electric grid. Consequently, the volatility of the residual load curve increases unless additional storage capacities are built to compensate for these fluctuations. The paper presents the results of the modelling of Polish electricity supply with integration of large-scale wind power and use of energy storage. The main analytical tool used in this study was the TIMES-PL model, which belongs to the family of energy-economic models generated with the use of the TIMES platform. Producers are represented by electricity generation technologies while consumers by electricity demand. The Reference Energy System covered subsystem of primary energy supply and electricity generation technologies needed to satisfy the demand. The modelling horizon covered the period from 2011 to 2050. The temporal resolution covering five-year periods was used. Each representative modelling year was further split into 224 time slices in order to improve the temporal characteristics of demand and supply sides. Three Massive-Wind (MASS-W) scenarios were elaborated, which assumed significant increase in wind capacity additions along the entire modelling horizon enabling almost full exploitation of available economical wind potential by 2050. In all these scenarios coal fired and nuclear power plants were defined as base-load plants, meaning that the production output from these plants could not vary much between timeslices. It was assumed that wind plants are interconnected with uncongested transmission capacity (the so called “copperplate” transmission system) and that grid interconnectors are too weak to allow for substantial inter-regional electricity exchange. The first, MASS-W-STORE scenario assumed, that every kWh produced by wind power plants is utilised whereas the new investments in flexible back-up gas plants were neglegible. The aim of this scenario was to determine the storage capacity that was necessary to allow full feeding into the grid of electricity generated in wind plants. On the contrary, the MASS-W-GAS assumed, that the surplus production from wind plants could be curtailed and the electric storage was limited only to the existing hydro pumped-storage plants. The aim of this scenario was to determine back-up gas capacity additions, which were necessary to cover the demand in time periods with insufficient wind. The MASS-W-MIX assumed combination of expansion of back-up gas power plants and electricity storage systems. For each of the MASS-W scenarios a number of simulation runs were performed for the set of wind speed distributions data generated by the Meteo preprocessor of the Polyphemus model. The results of this sensitivity analysis made it possible to determine the necessary gas/storage capacities for the most extreme cases. Each of the scenario provided fully described quantitative results in the 4E dimensions i.e. Energy (energy flows), Engineering (technology mix), Environment (emissions of CO2) and Economy (electricity generation costs). The results of the study can support preparation of the power supply expansion plan with integration of large-scale wind power and use of energy storage.

Cross-Border Balancing Cooperation in the Alpine Region: Benefits and Challenges

Casimir Lorenz and Clemens Gerbaulet (TU Berlin, Workgroup for Economic and Infrastructure Policy)

The European electricity system is currently subject to significant changes, not only with respect to developments in generation and networks but also concerning the arrangements for operating the system. These are to a large extent laid out in Network Codes endorsed by regulators, network operators and the European Commission; their objective is to create an "Internal Energy Market". As both the electricity system and the proposed rules to re-design existing balancing arrangements such as the Network Code Electricity Balancing are highly complex we perform a quantitative analysis of the region consisting of Switzerland, Austria, and Germany to assess the possible benefits and challenges of increased cooperation on the balancing markets.

We use a detailed power plant dispatch and unit commitment model for Austria, Switzerland, and Germany with a block-sharp representation of power plants, interconnection between the countries' grids, scheduled power withdrawals and localized imbalances leading to the need to activate balancing energy. This includes ramping, must-run, heat generation, and startup restrictions that significantly influence the opportunity cost of balancing provision.

We model the entire year of 2013 in weekly blocks, based on the results of a simplified version of the model for the entire year, to be able to represent influence of seasonality for hydro power plants and storages. We examine the potential of overall system cost savings by allowing for increased cross-border exchange of balancing services, also taking into account implications for the dispatch at the day-ahead time-frame. We consider joint balancing capacity procurement for all three countries. Further, we estimate the cost-minimizing level of network capacity to be used exclusively for cross-border balancing services.

Our results allow us to estimate the relative impacts of the proposed arrangements in terms of system costs, but at the same time the models results underestimate the actual costs observed in 2013 especially for Austria and Switzerland. Our results indicate that benefits are the largest for full cooperation. Furthermore the reservation of balancing capacity shifts towards specific countries. Therefore the benefits do not need to be distributed evenly between the countries. Hence compensation mechanisms will become necessary to give incentives for all countries to join such cooperation. Furthermore the optimal level of network capacity reserved for cross-border balancing varies significantly depending on spot market conditions.

Analysis of design options for the German electricity market regarding security of supply

Dogan Keles, Andreas Bublitz, Wolf Fichtner (Karlsruhe Institute of Technology)

Keywords: market design, capacity market, energy-only-market, electricity prices, security of supply

The implementation of a capacity market or a strategic reserve in the electricity sector is currently discussed in Germany. The performance of the current Energy-Only-Market (EOM) in providing sufficient investment incentives to ensure a long-term supply adequacy is evaluated very differently by the relevant market players such as the generation companies and the regulator. This is due to the fact that the increasing feed-in of electricity based on volatile renewable energies reduces the number of operating hours of conventional power plants and thus power plant operators in the EOM can generate fewer revenues. However, flexible conventional power plants are still needed, especially when peak load times meet low wind and photovoltaic power production. As the revenue situation of the conventional capacities is becoming worse at the moment, the question is raised whether the marginal cost-based EOM provides enough incentives for investments in new power plant capacity or a capacity mechanism should be introduced as a new market segment for the product “secured power” or “production capacity”.
In this contribution, the scope is to assess the performance and cost efficiency of different market design options (EOM, market with strategic reserve or capacity market) and to give decision makers new insights to the discussion based on quantitative results. The analyses are carried out applying the agent-based simulation model PowerACE that simulates the German wholesale electricity market.
This study analyzes and evaluates those capacity mechanisms which are described in different design proposals and which are currently under consideration for Germany. These are the EOM, the EOM expanded with a strategic reserve, the central capacity market and the decentralized one. The evaluation of the selected capacity mechanisms is carried out by using the agent-based simulation model PowerACE that consists out of the four modules: markets, electricity supply, electricity demand and regulator (see Genoese, 2010). The model displays all the power plants in the German electricity market. Essential input parameters are the development of electricity demand, prices of carbon dioxide and fuels, imports and exports of electricity and the expansion of renewable energies. Investments occur in the model based on calculation of profitability of the simulated power plant utilization of predetermined conventional technology options. Decision basis of the investment planning agents are the income generated from the hourly prices in the spot and forward market and any additional revenues from the related capacity mechanism. An important model extension is the implementation of an auction for strategic reserves and/or capacity markets. The resulting market designs are then analyzed under various parameter settings taking the investment behavior of the agents, the development of generation capacity, electricity prices, carbon dioxide emissions and costs into account. Furthermore, it is possible to examine whether it comes to undersupply of demand in a certain market design options and under different parameterizations or not.

Simulation results for the EOM and for an energy market design with different capacity remuneration systems are briefly summarized and compared in the following. Until 2030, all mechanisms are able to provide enough incentives to guarantee security of supply at all times. The capacity level in the central and decentralized capacity market is always the highest, mainly due to additional gas turbines that would not be profitable in an Energy-Only-Market. From 2030, the implementation of a capacity market seems favorable. An EOM, even with an additional strategic reserve of 5 GW, is under the given assumptions unable to guarantee security of supply at all times. This is related to the increasingly volatile cash flows of, especially but not only, peak capacity investments. In some years, these investments may be extremely profitable but only small changes, e.g. different renewable feed-ins, can completely alter their profitability.

Naturally, a higher level of security of supply comes with increased costs. If a capacity market is introduced, the cumulated cash flows to the supply companies increase by an amount of about 20-30 billion Euro from 2015-2030. However, after 2030, scarcity prices and loss-of-load prices diminish the costs advantages on an Energy-Only-Market. In years of scarcity, a capacity market then comes with lower costs compared to an Energy-only-market or an Energy-only-market with a strategic reserve.

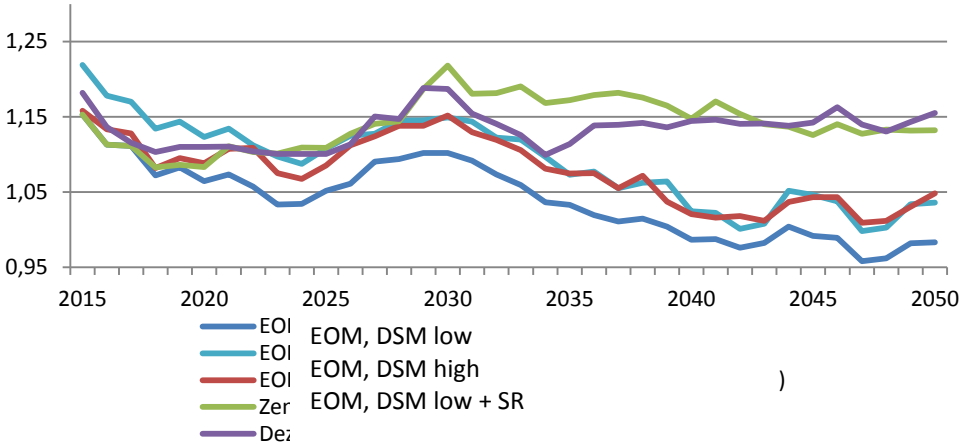

Figure 1: Development of security of supply for different regulatory market scenarios.

In this study, the German electricity market and the impact of different capacity remuneration systems on the system's security of supply have been analyzed. In a next step, the European perspective could be taken into account, for example, which influence does the French capacity market have on the German market? To further understand the security of supply in situations of high demand and low renewable feed-in, grid restrictions could be regarded as well.

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Session 16.15 – 17.35
Energy System Analysis

Room: B37
Chair: Hannes Hobbie (TU Dresden)

Supply Alternatives in the European Natural Gas Market – Analysing the contribution of LNG and Shale Gas
Philipp Hauser, Dominik Möst (Technische Universität Dresden)

The need for lithium - an upcoming problem for electric vehicles?
Daniel Schulz (Forschungszentrum Jülich)

Is there an optimum scale for energy autarky?
Dr. Russel MCKenna (Karlsruher Institut für Technologie)

The role of CHP in a highly renewable electricity system in Germany
Gerda Schubert (Fraunhofer ISI, TU Dresden)

Supply Alternatives in the European Natural Gas Market – Analysing the contribution of LNG and Shale Gas

Philipp Hauser, Dominik Möst (Technische Universität Dresden)

Keywords: natural gas, European diversification strategy, LNG imports, shale gas

During the current Ukraine crisis compounded questions about the European dependence of Russian natural gas became more important again. Generally, there are two main possibilities to diversify Europeans gas supply and therewith to increase security of supply: The first option is the diversification of the supply structure due to an expansion of LNG import capacities. A second opportunity is the exploiting of new natural gas resources as shale gas. Thus, domestic European production of natural gas would increase. The objective of this analysis is to assess the impact of LNG imports and of shale gas exploitation on Europeans dependency from main gas suppliers. Therefore we introduce a new Gas Market Model (GaMaMod) that represents the European natural gas market within a bottom-up approach. In order to analyse the European gas supply we look to two main scenarios for the year 2025 with regard to an extension of LNG import capacities and an increased exploitation of European shale gas. Modifying the basic conditions within the scenarios (e.g. high natural gas demand versus low natural gas demand etc.) we present the main impacts on the European natural gas market. Thereby we focus our analysis on the impact of these options on the diversification of the imported gas as well as the economic consequences of these different diversification strategies Our results show that LNG and shale gas has an effect on the diversification of gas supply, but the effect is quite limited and main European gas suppliers, especially Russia, will remain in their dominant role of a strong European gas supplier.

The need for lithium – an upcoming problem for electric vehicles?

Daniel Schultz, Wilhelm Kuckshinrichs (Forschungszentrum Jülich)

Keywords: Electric Vehicles, Energy Storages, Lithium, Resource Criticality, Recycling

In the context of the transition of the energy and mobility system, storage technologies currently attract high attention. As a promising technology, lithium ion battery systems could be used for zero-emission mobility and for purposes surrounding the integration of renewable energy sources into the grid. But if these applications experience a large-scale penetration, manifold natural resources will be required. This work has the aim to identify future demand paths for the essential resource lithium and to clarify whether temporary or even permanent critical situations on the lithium world market are to expect. For this, a simulation model was built, mapping the future market penetration of relevant applications of lithium batteries. By combining with particular material requirements, and adding non-battery demand, the annual total lithium demand can be modelled. Results show that especially when the electric mobility kicks in, an enormous rise of demand for lithium has to be expected, accompanied by considerably additional demand generated by stationary energy storage purposes.

With the pending demand rise in mind, the supply side was carefully analysed. Due to ongoing technical progress and the recycling option, a situation of permanent scarcity is unlikely. Adopting the flow perspective, a different situation emerges: Presently, Chilean and Australian extraction dominates, but expansion prospects are limited. The installation of major extraction capacities at a huge, nearly untouched Bolivian brine deposit will require much capital and know-how from outside, but the current nationalistic economic policy has the potential to discourage foreign investments. As a result, a temporary physical scarcity on the lithium market within the next decades could be passed through the supply chain and trigger a risk for the broad penetration of battery applications like electric vehicles.

Is there an optimum scale for energy autarky?

Russell McKenna, Erik Merkel, Tobias Jäger, Wolf Fichtner (Karlsruhe Institute of Technology)

Keywords: Energy autarky, storage, community energy, optimization, multi-generation

Previous studies have aimed at optimizing the sizing of PV and battery storage systems whilst minimizing overall costs (e.g. Weniger et al. 2013), but these have mainly focused on electricity supply. On the other hand, there have been several efforts aiming at a more holistic energetic autarky for larger energy systems such as municipalities and/or villages (cf. Jenssen et al. 2014, Schmidt et al. 2012). Attempts to formalize these approaches and develop a general framework for energy autarky are mainly qualitative in nature (cf. Müller et al. 2011; Rae & Bradley 2012). In addition, whilst there are some general quantitative frameworks for assessing the level of autarky on the dwelling level, such as for net zero energy buildings (Sartori et al. 2012), which develop indicators to assess the degree of integration of a building into the surrounding (electricity) network, there is a lack of research into the scale effects on energy autarky. This contribution investigates the scale effects on attempts at achieving energetic autarky by extending an existing capacity and dispatch optimization model for m-CHP systems from Merkel et al. (2014). The focus thereby lies on electricity-generating technologies as opposed to heat pumps and/or solar thermal because, due to the high transportability of electricity, they are most relevant to the decision regarding self-supply or feed-in. Stylized demand classes are defined through a combination of scale (number of buildings) and demand types (households, services, industry); thus the optimal sizing and dispatch of heat and electricity systems is determined and generalized conclusions can be drawn about the scale effects on attempts to achieve energy autarky. The results should indicate whether there is an optimal scale at which energy autarky could be sensible for domestic buildings.

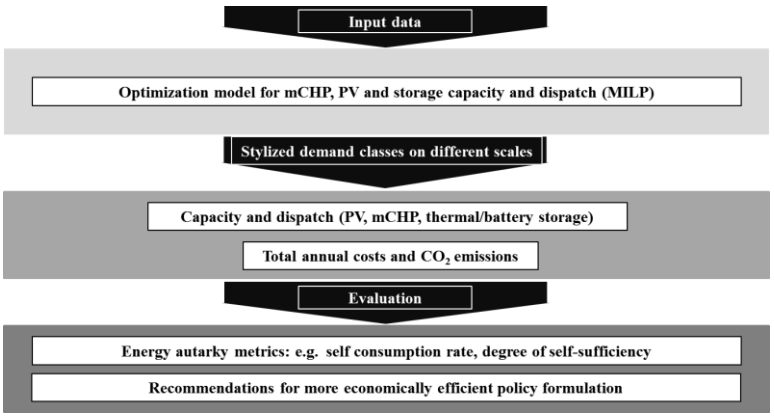

Figure 2 – Schematic overview of the employed methodology from Merkel et al. (2014)

Jenssen, T., König, A., Eltrop, L. (2014): "Bioenergy villages in Germany: Bringing a low carbon energy supply for rural areas into practice", Renewable Energy, 61, 74-80
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The role of CHP in a highly renewable electricity system in Germany

Gerda Schubert, Benjamin Pfluger (Fraunhofer ISI, TU Dresden)

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In Germany we see a remarkable change in the electricity system. The increasing electricity production from fluctuating renewable sources such as wind and photovoltaic causes a need for more flexibility. At the same time Germany aims at a decarbonisation not only of the power system but of the heating market as well [1]. The combination of these challenges leads to certain frictions, but it also offers new opportunities for synergies.

Combined heat and power production (CHP) is a well established option to provide heat and power with a high overall efficiency and thus comparatively low CO_2 emissions. However, rising shares of fluctuating renewable electricity on the electricity market compete with electricity produced in CHP plants already today. This competition will intensify within the next decades. At the same time heat storages can increase flexibility of CHP plants and power-to-heat technologies can help to integrate renewable electricity from the electricity market into the heat market, for example into district heating grids.

To evaluate the potential of CHP in an electricity system with high shares of renewables, an integrated assessment of the heating and electricity market is necessary, including seasonal and daily patterns of renewable electricity production and heat demand. The assessment in this paper is based on a least-cost optimization assuming perfect foresight and an hourly resolution (8.760 hours per year) for the years 2020, 2030, 2040 and 2050 with PowerACE-Europe [2]. Interactions between renewable electricity and CHP can be assessed, as the capacity development of renewables is integrated in the optimization based on a detailed potential calculation for photovoltaic and wind energy [3]. Different scenarios for the German electricity market up to the year 2050 are analyzed.

The results show that economically optimized CHP shares are high in the medium term, but decrease with increasing renewable shares on the electricity market. Heat storages, however, play a major role to increase the flexibility of heat grid operation. Under the modeling framework used in this analysis, assuming perfect foresight and not accounting for the reserve market or grid restrictions within Germany, power-to-heat technologies evolve only in systems with high renewable shares and show low utilization hours. In an integrated European scenario, utilization hours of power-to-heat technologies are significantly higher.

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