ENERDAY

13th Conference on Energy Economics and Technology

Low-Carbon Energy System Transformation: Setting the Course for the Next Decade

Book of Abstracts

12th April 2019

Dresden

Contact

Linda Schwabe, TU Dresden, EE², enerday@ee2.biz, tel.: +49-(0)351-463-33297, www.ee2.biz

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Foreword

Dear participants of the 13th ENERDAY Conference on Energy Economics and Technology,

On behalf of the Chair of Energy Economics (EE2) at the Technische Universität Dresden and the Workgroup for Economic and Infrastructure Policy (WIP) at Berlin Institute of Technology (TU Berlin), it is our pleasure to welcome you to ENERDAY, the 13th Conference on Energy Economics and Technology, with this year's focus on *Low-Carbon Energy System Transformation: Setting the Course for the Next Decade*.

Europe has committed itself to ambitious climate policy targets. With the year 2020 right around the corner and new regulatory reforms set to take effect in the coming decade, it is an important point in time to make a critical assessment of the current challenges facing the low-carbon energy system transformation and to put forward policy insights and discuss potential course corrections. Against this background, this year´s ENERDAY conference is devoted to discussing the fundamental issues with regard to low-carbon transformation pathways:

- What energy policy measures and strategies need to be taken to put Europe on track to reach the policy goals set for 2030 and beyond?
- How well are climate policy instruments in the individual energy sectors working?
- How should the reforms made to the EU emission trading system (ETS) be assessed and what effect will they have on carbon prices?
- How can decarbonisation policies in non-ETS sectors, e.g. heating, transport, be effectively implemented?
- Are technological solutions sufficient or are drastic changes in consumption necessary?
- Will "Fridays for Future" be the starting point for incisive changes in consumption patterns?

The 13th Conference on Energy Economics and Technology ("ENERDAY") provides a platform for discussing the pressing issues surrounding energy systems, markets and policies, with a special focus on the next steps toward a "low-carbon energy system transformation". Empirical analysis, fundamental modelling approaches, best practice examples and evaluations of policy and market design are of particular interest. A special emphasis is placed on intensifying dialogue on techno-economic issues and perspectives. Thus, ENERDAY aims to provide a platform for strengthening the dialogue between those involved in economic and technical fields as well as serving to bridge the gap between practice and theory.

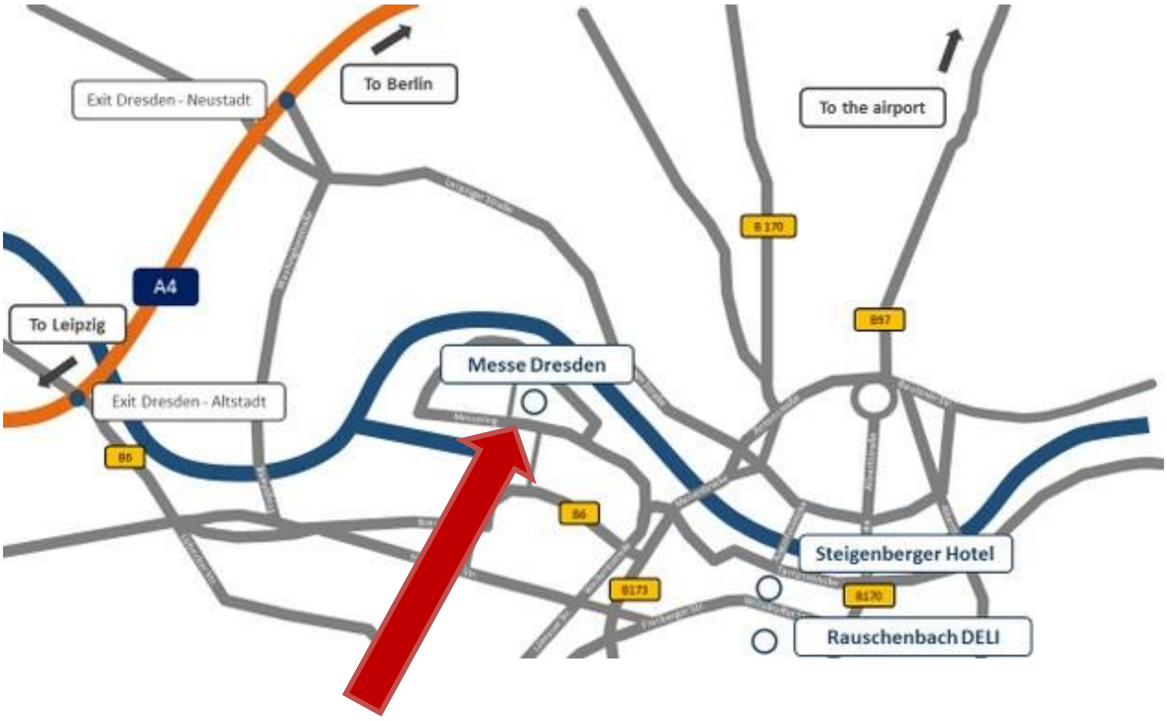
Scientific cooperation partners include DIW Berlin, the German Institute for Economic Research, and GEE, the German Chapter of the International Association of Energy Economics (IAEE). It is our pleasure to express our sincere gratitude to our premium supporters of this conference: 50Hertz Transmission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

As the organizers of the conference, we have been delighted by the high level of interest shown by the research community, which is reflected in the internationality of the participants and the number of submitted abstracts. We hope you enjoy the high quality of the research presented. We would like to thank all speakers for their contributions and the participants of the workshop for their attendance.

We wish you an interesting and enriching conference and an enjoyable stay in Dresden and its surroundings,

Dominik Möst and Christian von Hirschhausen
& EE2 organizing committee

Conference Location



MESSE DRESDEN GmbH
Messering 6
01067 Dresden

By public transport:

from Dresden main station:

- Tram 10 (MESSE DRESDEN-bound)
- Exit for concerts and events: **"Messering, HALLE 1"**

from airport Dresden:

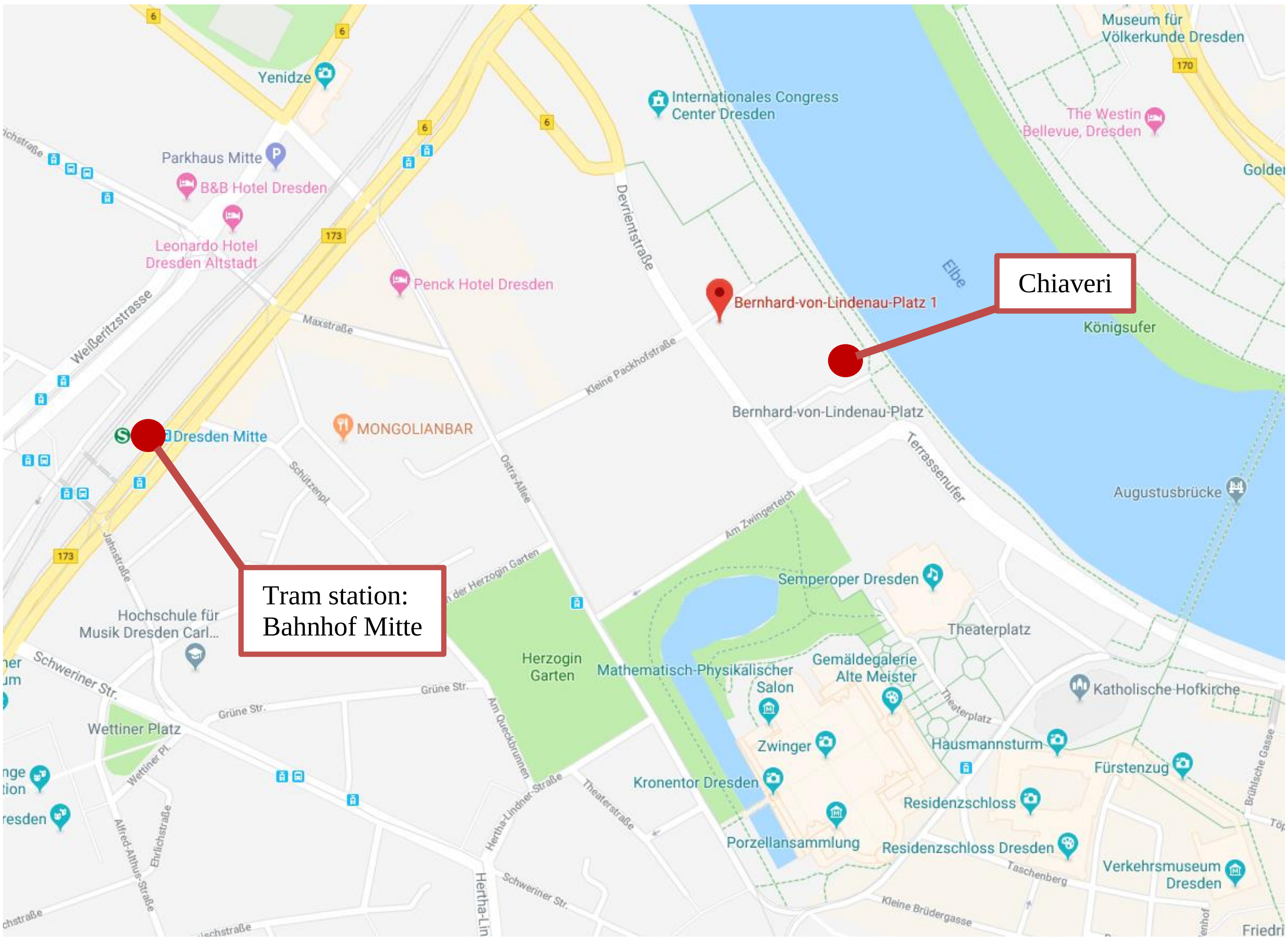
- S-Bahn S2 (Heidenau/Downtown-bound) to "Bahnhof Mitte" - rhythm: every 30 minutes
- From "Bahnhof Mitte": Tram 10 (MESSE DRESDEN-bound)
- Exit for concerts and events: **"Messering, HALLE 1"**

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

Gala Dinner

Friday, 12 April 2019, 6:30 pm

Chiaveri, Bernhard-von-Lindenau-Platz 1, 01067 Dresden, Germany



By public transport:

From Dresden main station:

- Dresden Hauptbahnhof
  Distance: 2.1 km
- Local public transport: Tram N° 10 (direction Messe Dresden to "**Bahnhof Mitte**" (3 stations).

From Dresden Messe (Conference Location):

- Tram N° 10 to direction Striesen to "**Bahnhof Mitte**" (6 stations).

More information:
http://www.chiaveri.de/

Conference program on Friday, 12th April 2019

Pre-Conference-Dinner Informal Get Together	**Thursday, 11 April 2019, 6 pm**	Restaurant Campus, Hübnerstraße 13, 01069 Dresden
Conference	**Friday, 12 April 2019, 8:30 am**	Messe Dresden, Via Mobile 7 (see Venue Info)

8:30	Registration, Coffee & Tea
9:00	**Opening Address** (Room: Hamburg Conference Hall) Prof. Dr. Dominik Möst, TU Dresden Prof. Dr. Christian von Hirschhausen, TU Berlin
9:30	**Keynote Speech** (Room: Hamburg Conference Hall, Chair: Prof. Dr. Christian von Hirschhausen) **The Energy Transformation in Europe and Beyond – The Big Picture and Some Details** Prof. Dr. Manfred Hafner, Johns Hopkins University SAIS-Europe, SciencesPo PSIA, Fondazione Eni Enrico Mattei

10:15 **Coffee & Tea**

10:45 - 11:45	**Low-Carbon Energy System Transformation I/III** Room: Hamburg Hall Chair: Constantin Dierstein	**Gas Markets** Room: Rotterdam Hall Chair: Philipp Hauser	**Local energy markets** Room: St. Petersburg Hall Chair: Thomas Walther	**Economics of consumer behavior** Room: Florenz Hall Chair: Samarth Kumar
10:45	**Ways to a low-emission energy system - repercussions of a German coal phase-out** Michael Wiesmeth, Universität Stuttgart	**Implementing new capacity booking regimes for gas transmission networks – How will gas storages be affected?** Dominic Lencz, ewi Energy Research & Scenarios	**On the Stability of Energy Communities with limited generation capacities** Andreas Fleischhacker, TU Wien	**Digital labels as the next step for informed consumer decisions - experiences from an EU field trial** Dr. Uta Burghard, Fraunhofer-Institut für System- und Innovations-forschung ISI
11:05	**Short-term effectiveness of electrolytic hydrogen production for energy system decarbonisation** Kai Klöckner, RWTH Aachen University	**Drivers and barriers of future gas demand - A meta analysis** Hendrik Scharf, TU Dresden	**Pricing mechanisms and market designs in peer-to-peer electricity trading: fostering energy access and self-sufficiency** Jens Weibezahn, TU Berlin	**Households' Dynamic Investment Choice in Energy Efficient Technology** Sebastian Mertesacker, University of Cologne
11:25	**Scenarios for decarbonizing an integrated energy system** Leonard Göke, TU Berlin	**Gas Flows and Gas Prices in Europe: What is the Impact of Nord Stream 2** Dr. Maik Günther, Stadtwerke München GmbH	**Techno-economic evaluation of combined micro power and heat generation assets: Implications for the multi-tenant building market in Germany** Prof. Dr. Reinhard Madlener, RWTH Aachen University	**Photovoltaic self-consumption after the support period: Will it pay off in a cross-sector perspective?** Jonas Klamka, University of Siegen

11:45 **Short 5-Minute-Break**

11:50 - 12:50	**Low-Carbon Energy System Transformation II/III** Room: Hamburg Hall Chair: Matthew Schmidt	**Energy transition on a local level** Room: Rotterdam Hall Chair: Jens Maiwald	**Flexibility in energy systems** Room: St. Petersburg Hall Chair: Steffi Schreiber	**Alternative fuels for transportation** Room: Florenz Hall Chair: Hendrik Scharf
11:50	**Decarbonization of the European energy system with strong sector couplings** Prof. Dr. Martin Greiner, Aarhus University	**A Generic Evaluation Process for Power-to-X Business Cases in an Urban Setting** Stefan Scharl, RWTH Aachen University	**How to Estimate the Balancing Capability of Hydropower? – A Proposed Method that Reveals Insights in Factors Affecting Flexibility** Dr. Richard Scharff, Vattenfall	**LNG from renewable sources as an alternative fuel for maritime shipping?** Prof. Dr. Andreas Seeliger, Hochschule Niederrhein
12:10	**Analyzing Potential Stranded Assets – A Challenge for the European Low-Carbon Transition?** Konstantin Löffler, TU Berlin	**The transition of the energy system towards (almost) complete decarbonization from an utility perspective** Dr. Holger Wiechmann, Energie Baden-Württemberg AG	**The impact of sector coupling options on electricity systems – An evaluation of different flexibility options** Mario Kendziorski, TU Berlin	**Application-side merit-order-curves for synthetic fuels in the german energy system** Tobias Hübner, Forschungsgesellschaft für Energiewirtschaft mbH
12:30	**Modelling of the European Union's Long-Term Strategy towards a carbon-neutral energy system** Alessia De Vita, National Technical University of Athens	**Sustainability assessment of the energy transition: Insights from Saxon municipalities, Germany** Kendisha Soekardjo Hintz TU Dresden	**Find your way around the various flexibility mechanisms under the European burden-sharing** Marc Vielle, École Polytechnique Fédérale de Lausanne	**Economic comparison of electric fuels produced at excellent sites for renewable energies: A Scenario for 2035** Philipp Runge, Friedrich-Alexander-Universität Erlangen-Nürnberg
12:50	**Lunch**			
13:50 - 14:50	**Market design** Room: Hamburg Hall Chair: Constantin Dierstein	**Carbon mitigation and EU ETS** Room: Rotterdam Hall Chair: Carl-Philipp Anke	**Modelling and Simulation of Energy Markets** Room: St. Petersburg Hall Chair: Dirk Hladik	**Renewable energies** Room: Florenz Hall Chair: Matthew Schmidt
13:50	**Strategic reserve for Switzerland: Is it needed and (how) would it work?** Prof. Dr. Hannes Weigt, University of Basel	**The amendment of the EU ETS: decomposition of effects and dynamic efficiency** Theresa Wildgrube, ewi Energy Research & Scenarios	**Is the more complex model always the better one? Evidence from the assessment of security of electricity supply** Lars Nolting, RWTH Aachen University	**Paradoxa, anomalies and limits – the collective dynamics of energy systems** Prof. Dr. Marc Timme, TU Dresden - cfaed
14:10	**Incentive-based Subsidy and Tax for Efficient Generation Investment**	**CO2 mitigation costs of smart space heating systems for private households in Germany**	**Reliability constrained generation expansion planning: Case study for different system sizes and characteristic renewable profiles**	**The impact of multi-year weather variability on the security of supply in highly renewable power systems: a case study for Germany**

	Lamia Varawala, KTH Royal Institute of Technology	Dr. Dominik Schäuble, Institute for Advanced Sustainability Studies	Markus Groissböck, University of Innsbruck	Fridolin Pflugmann, TU München
14:30	**Low-carbon energy system transformation: the role of markets** Mike Bostan, European Federation of Energy Traders	**Carbon avoided costs for the low-carbon technologies in Russia and EU** Andrey Khorshev, Russian Academy of Sciences	**Modelling of imports and exports for the German electricity system** Timona Ghosh, TU Berlin	**Interaction of sector coupling technologies with further flexibility options in energy systems with different PV-Wind shares** Christoph Zöphel, TU Dresden
14:50	**Short 10-Minute-Break**			
15:00	**Keynote Speech** (Room: Hamburg Conference Hall, Chair: Prof. Dr. Dominik Möst) **Impulses for a new heat market design** Florian Weiser, MVV Energie AG			
15:45	**Coffee & Tea**			
16:15 - 17:15	**Modelling of the heating sector** Room: Hamburg Hall Chair: Philipp Hauser	**Low-Carbon Energy System Transformation III/III** Room: Rotterdam Hall Chair: Christoph Zöphel	**Modelling Aspects of Energy Markets** Room: St. Petersburg Hall Chair: David Schönheit	**Transition of the transport sector** Room: Florenz Hall Chair: Michael Burkhardt
16:15	**Bottom-up modelling of heating investment using clustered time series data** Berit Hanna Czock, ewi Energy Research & Scenarios	**Survey and classification of business models for the energy transformation** Johannes Giehl, TU Berlin	**Impact of Different Generation Shift Key Strategies on the Flow-based Market Coupling Domain in Germany** Richard Weinhold, TU Berlin	**Charging infrastructure business models and policies for electric vehicles in Karnataka** Prof. Dr. A.M. Nagaraj, Dayananda Sagar College of Engineering
16:35	**Nearly Zero Energy Cities: Scalability of energy self-consumption from buildings to large urban areas** Manuel Villa, FUNSEAM	**Cost and Metal Savings through a Second-Life for Electric Vehicle Batteries** Anika Regett, Forschungsstelle für Energiewirtschaft e.V.	**Acceleration strategies of the Generation Expansion Problem by Bender Decomposition** Matthias Zech, TU Dresden	**The effect of digitalization on the energy consumption of the EU passenger transport** Dr. Michel Noussan, Fondazione Eni Enrico Mattei
16:55	**Active retrofitting for multi-apartment buildings: use case analysis with a special focus on photovoltaics and different heating systems** Bernadette Fina, TU Wien	**Pathways for Germany's energy transition towards 2050** Frederik Seehaus, TU Berlin	**Forecasting negative market prices at power exchanges using transformation approaches** Benjamin Aust, TU Bergakademie Freiberg	**Decarbonizing Public Transport: Implementing the Transition to Zero Emissions** Elisa Claus, KCW GmbH

17:15 **Closing Words in the Foyer of the Via Mobile 7, Messe Dresden**

Gala Dinner
Official Closing Event

Friday, 12 April 2019, ~6:30 pm

Restaurant CHIAVERI Bernhard-von-Lindenau-Platz 1
01067 Dresden

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Keynote 9.15– 10.00

Room: Hamburg Conference Hall

The Energy Transformation in Europe and Beyond – The Big Picture and Some Details

Prof. Dr. Manfred Hafner[1]

[1] *Johns Hopkins University SAIS-Europe, Sciences Po PSIA, Fondazione Eni Enrico Mattei*

In his key-note speach Prof. Hafner will highlight the need to decarbonize the global energy system over the next decades and will thus focus on the challenges and opportunities associated to this process. He will address the the issue from a sectoral perspective as well as from a global vs regional dimension, developed versus developing countries, with a focus on Europe but also examples from other world regions including Subsaharan Africa. Different decarbonization scenarios exist, we don‘t have the one silver bullet, so we need to promote all available options and we need more technological innovation. In his speach he will address the technological, economic and societal challenges, launching some provocative discussion questions and providing some food for thoughts to convert challenges into opportunities in order to set the scene for further discussions during the Enerday 2019 Conference.

Session 10:45 – 11:45
Low-Carbon Energy System Transformation I/III

Room: Hamburg Hall
Chair: Constantin Dierstein (TU Dresden)

Ways to a low-emission energy system - repercussions of a German coal phase-out

Dipl.-Ing. Michael Wiesmeth, PD. Dr. Markus Blesl, Universität Stuttgart

Short-term effectiveness of electrolytic hydrogen production for energy system decarbonisation

Kai Klöckner, RWTH Aachen University

Scenarios for decarbonizing an integrated energy system

Leonard Göke, TU Berlin

Ways to a low-emission energy system - repercussions of a German coal phase-out

Dipl.-Ing. Michael Wiesmeth[1], PD. Dr. Markus Blesl [2]

[1] System-analytical methods and Heat Market Group (SAM), Institute of Energy Economics and Rational Energy Use, University of Stuttgart, Germany, mw@ier.uni-stuttgart.de
[2] System-analytical methods and Heat Market Group (SAM), Institute of Energy Economics and Rational Energy Use, University of Stuttgart, Germany, mb@ier.uni-stuttgart.de

Keywords: Energy System Transformation, Energy and Climate Policy, Coal Phase-Out, EU ETS, Energiewende

Motivation

Under the influence of global climate change, Germany is undertaking considerable efforts to protect the climate with the implementation of the energy transition (Energiewende). In light of the Paris Agreement and limiting global warming to below 2°C, Germany is seriously considering phasing out power generation from hard coal and lignite. In its final report the Commission on "Growth, Structural Change and Employment" also pointed out a specific path towards phasing out the use of coal. For us, this raises the question of the repercussions of ambitious climate protection policies in the German transformation sector.

Methods

For the comparative assessment of climate policy and coal phase-out repercussions we conduct a scenario-based energy system analysis. The Pan-European TIMES Energy System Model (TIMES-PanEU) is an energy system model comprising 31 regions, which includes all EU28 countries as well as Switzerland and Norway. The modeling period extends from 2010 to 2050 with 5-year time step. As an energy system model, TIMES-PanEU represents all sectors, concerning energy supply and demand, such as the raw materials supply sector, public and industrial electricity and heat generation, industry, trade, services, households, and transport. The objective function of the model is the minimization of the total discounted system costs for the time horizon 2010 to 2050. This model enables us to determine the economically optimal energy supply structure with a specified useful energy or energy service requirement with simultaneous consideration of energy and environmental policy specifications.

Results

Our reference case is represented by a scenario with the specifications of the climate protection plan of the German Federal Government. On this basis, a total emission reduction of 90% compared to 1990 will be achieved by 2050, through sector-specific greenhouse gas reduction targets,. In comparison, we evaluate scenarios with a specific, measure-based implementation of climate protection in the transformation sector. The measures considered range from a slow and rapid phase-out of coal to a phase-out in accordance with the Commission's guidelines and the setting of a country-specific minimum CO2 price. Optionally, we combine these scenarios with increased quotas for renewable energies as well as a certificate decommissioning in the ETS system to compensate for the emerging waterbed effect.

We analyze the multiple repercussions in the energy system with regard to system cost changes, electricity prices, electricity import and export patterns, certificate prices in the EU-ETS system, greenhouse gas emissions of the transformation sector as well as the repercussions of the respective climate protection policy on the level and composition of the resulting final energy consumption by sector.

Short-term effectiveness of electrolytic hydrogen production for energy system decarbonisation

Kai Klöckner*, Peter Letmathe

**Corresponding author*
RWTH Aachen UniversitySchool of Business and Economics
Chair of Management Accounting
Templergraben 64D-52062 AachenTel.: +49 241 8096167, kloeckner@controlling.rwth-aachen.de

Germany's decarbonisation targets for 2030 will be missed widely even when accounting for increasing amounts of electricity from renewable energy sources (RES), more efficient CHP-HP concepts as well as for evolving smart charging infrastructures. Our study targets this potential failure and demonstrates how electrolytic hydrogen production affects the effectiveness of decarbonisation strategies for the German energy system in the upcoming decade. Decarbonisation scenario pathways for the period from 2020 to 2030 are modelled based on declared plans of federal authorities and alternative proposalsof environmental associations. Across all scenarios, decarbonisation is characterised by decreasing capacities of coal-fired power plants and increasing amounts of electricity from intermittent RES while at the same time considering the consequentially required flexibility technologies. In particular, the increasing usage of electrolysers to both absorb excess electricity and produce hydrogen as a substitute for fossil fuels is considered as an enabler of flexibility and decarbonisation. Using the EnergyPLAN model, annual and hourly performance indicators are calculated in order to evaluate the effectiveness of decarbonisation measures in seven distinct pathway scenarios that vary with regard to the paces of the coal phase-out and the roll-out of water electrolysis technologies. The results strongly support the alternative coal phase-out plans investigated. Disadvantages of substantially upgrading the electrolyser capacity are negligible. Arguments that the configuration of the energy system permits to make sense of electrolytic hydrogen production in the short-term are found to be non-persuasive. Even though there are initially additional fossil-fuelled combustion processes required to supply the electricity for water electrolysis in order to meet fixed hydrogen demands, the effectiveness of emissions reduction is highest when the hydrogen usage potential is fully exploited.

Scenarios for decarbonizing an integrated energy system

Leonard Göke[1]

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

Keywords: power system modelling, energy system modelling, decarbonization, energy sector integration

Motivation

While in the power sector transition from fossil fuels to renewables is progressing, in the heat and mobility sector it still is in its initial stage. Decarbonizing these sectors is challenging: Since the sustainable potential of biomass is limited, there are few renewable energy sources available to use directly. Consequently, decarbonization in the heat and mobility sector implies to increasingly rely on renewable electricity as an energy carrier. This can be achieved by either converting electricity into synthetic fuels or direct use of electricity in electric cars or heat pumps. However, both ways result in major sectoral interdependencies and, thus, the integration of the energy system. Against this background, we analyze conceivable development of the European energy system until 2050.

Methods

Based on storylines sketching global and European political and economic developments, quantitative scenarios regarding the demand for energy services, climate protection efforts and the social acceptance of technologies are derived. These assumptions serve as input data for determining investment in energy technologies for each scenario. Therefore, two different models are combined to allow for an accurate representation of interdependencies between the power, heat and mobility sector. Both models compute cost minimum pathways for transformation of the energy system until 2050 in 5 year steps. The scope of the first model includes the entire energy system and, as a result, has to neglect certain details, especially in the power sector, which, as explained above, is expected to play a key role. However, these details are taken into account by the second models which sole focus is the power sector. Accordingly, outputs of the first model like power demand stemming from the heat and mobility sector or the remaining biomass potential are used as inputs for the subsequent optimization of the power sector. Lastly, investment in the power sector determined by the first model is compared to final results of the second to ensure plausibility.

Results

Only preliminary results so far.

Session 10:45 – 11:45

Gas Markets

Room: Rotterdam Hall
Chair: Philipp Hauser

Implementing new capacity booking regimes for gas transmission networks – How will gas storages be affected?

Dominic Lencz, ewi Energy Research & Scenarios

Drivers and barriers of future gas demand - A meta analysis

Hendrik Scharf, TU Dresden

Gas Flows and Gas Prices in Europe: What is the Impact of Nord Stream 2

Maik Günther, Stadtwerke München GmbH

Implementing new capacity booking regimes for gas transmission networks – How will gas storages be affected?

Eren Cam[1], Dominic Lencz[1*] and Simon Schulte[1]

[1] *Institute of Energy Economics at the University of Cologne, Germany,*
** dominic.lencz@ewi.uni-koeln.de*

Keywords: Gas networks, entry-exit tariffs, BEATE, Storage utilization

Motivation

When transporting gas between market areas traders take into account the capacities they already booked. When supplying gas, those capacity costs are sunk and hence using those capacities results in zero marginal costs. If a trader likes to book additional capacities, she can choose between products with different runtimes. With the introduction of BEATE (BK9-14-608) in 2016 capacity regulated tariffs at interconnectors with German market areas differ regarding their runtime. Since then tariffs for daily and intraday capacities are 40 percent higher than for yearly ones. Those increased costs for short-term capacity bookings increase incentives to transport gas steadily and use storages for short term variations. With the introduction of BEATE 2.0 in 2020 tariffs for intraday capacities are likely to be increased even further such that they are twice as expensive as yearly ones. So far, a quantitative economic assessment analyzing the effect on pipeline and storage utilization is absent in the literature. The objective of our work is to investigate the effect of ex-ante capacity bookings and runtime dependent intra-yearly capacity schemes as introduced by BEATE in Germany on German storage utilization.

Methods

To answer those questions the European infrastructure and dispatch model TIGER is extended and applied. In a first step, restrictions to model runtime-dependent capacity prices like in BEATE are integrated in the model. In a second step, the effected yearly, quarterly, monthly and daily capacity bookings are retrieved from the ENTSOG transparency platform and added to the model. By conducting a scenario analysis the effect of ex-ante bookings as well as the current and proposed runtime-dependent entry-exit scheme are analyzed.

Results

We are currently implementing the ex-ante bookings and the intra-yearly capacity scheme into the TIGER model and hence there are no results so far. However, on the ENERDAY first results would be presented.

Drivers and barriers of future gas demand - A meta analysis

Fabian Arnold[1], Dominic Lencz[1], Hendrik Scharf[2*], Simon Schulte[1]

[1] Energiewirtschaftliches Institut an der Universität zu Köln gGmbH (EWI), Germany
[2] Technische Universität Dresden, Faculty of Business and Economics, Chair of Energy Economics, Germany
[*]hendrik.scharf@tu-dresden.de

Keywords: Natural gas, energy transition, meta-analysis, gas as a bridge

Motivation

In energy transition, the future role of natural gas is a central issue. On the one hand, natural gas is the fossil fuel with lowest CO_2-intensity, on the other hand, energy supply with natural gas is often more costly than utilizing other conventional alternatives, especially in the power sector. In turn, German nuclear and coal phase-outs plus EU ETS may strengthen the role of natural gas. In this paper, we present the results of different studies which determine long-term future natural gas consumption on diverse scenarios, referring to Germany, EU-28 and/or Europe, and draw conclusions regarding the potential of natural gas as a bridge in the context of energy transition. Subsequently, we perform a deeper analysis of the drivers and barriers of natural gas consumption.

Methods

In this literature review, we showcase, bring together and interpret possible future developments of natural gas consumption and analyze the role of natural gas when it comes to reducing GHG emissions. In order to identify drivers and barriers, we undertake a deeper analysis of literature to figure out which implications are conducive to and which are inhibiting natural gas consumption.

Results

Studies show various future developments of natural gas consumption depending on the considered area, scenario type and other assumptions. Most Germany-related target scenarios show a peak in 2020 and a drop afterwards. The EU and Europe related target scenario draws a similar picture, showing this peak for 2025. While from a German perspective in the long term, natural gas usage may also stay more or less stable according to scenarios which do not consider carbon emission goals, from a European perspective, there are also some scenarios which determine a strongly increasing trend until 2040. Further results would be available on the Enerday.

Gas Flows and Gas Prices in Europe: What is the Impact of Nord Stream 2

Maik Günther[1], Volker Nissen[2]

[1] Stadtwerke München GmbH, Emmy-Noether-Str. 2, 86920 Munich, Germany, guenther.maik@swm.de

[2] TU Ilmenau, Department of Service Information Systems Engineering, Ehrenbergstraße 29 98693 Ilmenau, Germany, volker.nissen@tu-ilmenau.de

Natural gas plays an important role in Europe. It is a bridging technology for the transition of the electricity system and has also a significant potential to reduce CO_2 emission in the mobility and heating sectors. Nevertheless, Europe is strongly dependent on imports of natural gas. While it is expected that European gas demand declines in long-term, indigenous production in Europe also declines. Thus, European import dependency persists. An important supplier of natural gas is Russia. Even if Russia should increase its market share, there is still enough transport capacity existing to bring Russian gas to Europe. However, the pipeline Nord Stream 2 with an additional annual capacity of 55 billion cubic meters (bcm) is under construction. This pipeline probably starts operation in 2020 and has the potential to change gas flows in Europe significantly. Stadtwerke München GmbH (SWM) operate the worldwide gas market model WEGA to calculate gas flows and gas prices in daily resolution until 2040. This model is based on the commercial solution Pegasus from Pöyry Management Consulting. Public sources as well as commercial services are used by SWM to constantly update the dataset of WEGA. For plausibility checks, NBP, NCG and TTF future prices are also frequently calculated. To analyse the impact of Nord Stream 2 on European gas flows, different scenarios are calculated in WEGA. The following exemplary results of 2028 reveal that Nord Stream 2 has significant effects on European gas flows: Transit flows through Germany increase by 20 bcm in comparison to a scenario without Nord Stream 2. On the other hand, gas flows from Poland to Germany are reduced by 8 bcm due to Nord Stream 2. Other effects are reduced gas flows via Ukraine and a redirection of Norwegian gas (13 bcm) from Germany to other North West European countries. Furthermore, North Stream 2 has also an impact on European gas prices. In general, this pipeline has a slightly dampening effect, with gas prices in Western Europe falling slightly more than in Eastern Europe.

Session 10:45 – 11:45

Local Energy Markets

Room: St. Petersburg Hall
Chair: Thomas Walther (TU Dresden)

On the Stability of Energy Communities with limited generation capacities

Andreas Fleischhacker, TU Wien

Pricing mechanisms and market designs in peer-to-peer electricity trading: fostering energy access and self-sufficiency

Jens Weibezahn, TU Berlin

Techno-economic evaluation of combined micro power and heat generation assets: Implications for the multi-tenant building market in Germany

Reinhard Madlener, RWTH Aachen University

On the Stability of Energy Communities with limited generation capacities

Andreas Fleischhacker[(1)], Johannes Radl[(1)], Georg Lettner[(1)]

[(1)]*Technische Universität Wien (TU Wien), Energy Economics Group (EEG)*

In the past years, the term energy communities (EC) has been established to promote a better market integration of DERs and implement energy efficiency measures. Compared to microgrids, ECs ensure consumers choice but need proper allocation of costs and revenues. In this paper, we address the optimal strategy of an EC for investment and operation of distributed generation and storages for electricity and heat provision. The EC includes two types of players, tenants, and owners of an area for solar PV and the house, respectively. In this case, the members of the EC form a coalition to share the benefits, e.g., economic benefits by the increase of self-consumption and economies-of-scale. Consequentially, there are two questions: First, how to allocate the value gained by the joint investment and second, how to ensure a stable EC. The method we develop in this work bases on an optimization model and game theoretic concepts. Firstly, it calculates the optimal investment and operation within an EC. Secondly, the Shapley value and Coalitional Nash Bargaining ensures an optimal allocation basing on the cooperative game theory. The method is applied to a case study in Austria. The study includes an apartment house with two residential and two commercial consumers. The results show that the EC faces the situation of instability if the area suitable for PV is small enough. The results show that the EC is unstable if the area for solar PV is small enough. Firstly, we show that internal payments, therefore members of the EC get penalized if they intend to leave the EC, provide incentives to stabilize the EC. Secondly, external payments to the third party, e.g., to an owner of a suitable greenfield, stabilize the EC as well but reduces the economic viability of the EC. The solutions suggest a "fair" and transparent allocation to all players and help to decrease the negotiation effort necessary to found an EC. One setback is that the problem is computationally hard and the effort raises with the size of the EC. Therefore future research may focus on increasing the performance of the model.

Disclaimer: The project PV-Prosumers4Grid has received funding from the European Union’s Horizon 2020 research and innovation programme under grant agreement No 764786.

Pricing mechanisms and market designs in peer-to-peer electricity trading: fostering energy access and self-sufficiency

Jens Weibezahn[1*], Alexandra Lüth[1], Jan Martin Zepter[1]

[1] *Technische Universität Berlin, Workgroup for Infrastructure Policy (WIP), Germany*
**jew@wip.tu-berlin.de*

Keywords: peer-to-peer electricity trading, market design, pricing mechanism, energy access

Motivation

The decline in the price of photovoltaic (PV) cells and battery storages in recent years has led to a broad implementation of small-scale PV installations in households – some including residential storage systems –, transforming customers into "prosumers" and increasing the rate of self-consumption in those households. This development also brought up the first pilot projects of local electricity markets in the form of so-called peer-to-peer trading platforms, in part based on the blockchain technology. Many pricing schemes lack however incentives to persuade households to invest e.g. in generation infrastructure. In this paper we examine how local electricity markets with peer-to-peer options could foster the access to energy in currently underdeveloped areas and enhance the self-sufficiency of prosumer communities by optimizing the local usage of electricity in contrast to the dependency on connections to the national grid.

Methods

We develop a model to assess different pricing mechanisms and market designs in order to identify the necessary incentives for a peer-to-peer market to develop. Different scenarios for the situation of an alternative to the existing trans-regional electricity grid as well as for the construction of a local micro grid are being analyzed. The model is set up as an optimization model, resembling a local/regional market comprised of a number of model households representing heterogenous types of consumers and prosumers as well as battery storage owners/operators.

Results

Preliminary results give an indication how local energy markets should be set up and operated with respect to remuneration schemes and pricing options in order to incentivize households to part-take and invest in the necessary infrastructure (rooftop PV systems and battery storages but also micro grid infrastructure for situations where no grid access currently exists).

Techno-economic evaluation of combined micro power and heat generation assets: Implications for the multi-tenant building market in Germany

Gedeon Zimmermann[1] and Reinhard Madlener[2,*]

[1] RWTH Aachen University, Templergraben 55, 52056 Aachen, Germany
[2] Institue for Future Energy Consumer Needs and Behavior (FCN), School of Business and Economics / E.ON Energy Research Center, Mathieustraße 10, 52074 Aachen, Germany

Keywords: distributed generation; prosumer households; multi-family housing market

The multi-tenant *prosumer* concept (MTPC) is a young concept for the changing German energy market. The MTPC refers to energy being directly *pro*duced and (partly) con*sume*d within tenements. Here, the multi-tenant energy service provider (MTESP) fulfills the role of negotiating between owners and tenants, which creates a win-win situation for the participants. The energy supplier profits from the produced energy. Because energy is generated at the location of consumption, infrastructure such as power grids and distributors are avoided, thus the energy supplier is able to reduce costs. Cost savings are shared with tenants, which results in them having lower costs for energy, and owners receiving rents for providing space in the basement and on the roof. In this research, a deterministic techno-economic model is built that defines optimal local power and heat generation setups for multi-tenant buildings in Germany. The model considers sets of micro-generation technologies, such as solar photovoltaics (PV), combined heat and power, heat pumps, and storage systems for thermal energy. Technical and economic data for devices, prices and remunerations for electricity and thermal energy, local demand profiles and specifications for houses, as well as PV production profiles are the input data for this “big data” model. The goal is to investigate whether the investment in new power plants is worthwhile for the MTESP. Therefore, the results from the optimization process are opposed to obstacles and additional expenses for the MTESP, such as the degree of participating tenants in one tenement on the MTPC, or on-site inspections. The overall results indicate that for small tenements PV only is the best option. For larger tenements, scale effects occur and a complete technical energetic refurbishment is an economical option. Medium sized tenements are in between and highly dependent on local conditions. For Germany, we find a total market size of around 370,000 buildings suitable for a MTPC.

[*] Corresponding author. Tel. +49 241 80 49 822; e-mail: Rmadlener@eonerc.rwth-aachen.de (R. Madlener).

Session 10:45 – 11:45

Economics of consumer behavior

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

Digital labels as the next step for informed consumer decisions - experiences from an EU field trial
Uta Burghard, Fraunhofer-Institut für System- und Innovations-forschung ISI

Households‘ Dynamic Investment Choice in Energy Efficient Technology

Sebastian Mertesacker, University of Cologne

Photovoltaic self-consumption after the support period: Will it pay off in a cross-sector perspective?

Jonas Klamka, University of Siegen

Digital labels as the next step for informed consumer decisions - experiences from an EU field trial

Uta Burghard, Elisabeth Dütschke, Simon Hirzel

Fraunhofer Institute for Systems and Innovation Research
Breslauer Strasse 48 | 76139 Karlsruhe | Germany
e-mail: uta.burghard@isi.fraunhofer.de

It is widely accepted that informed consumers make better purchasing decisions. This principle is applied through the European energy label to promote more energy-efficient appliances. While it is positively received by many consumers and also well-known a significant number of consumers admits that they do not understand all elements on the energy labels. Digital labelling tools have the potential to solve this issue.

This paper presents research into the consumer perceptions and the effectiveness of a digital energy label as an add-on to the EU energy label. The tool, called PocketWatt and developed in a European research project, includes a website and an online application, designed to be used on a smartphone or similar devices during shopping. It contains the relevant product information for appliances with energy labels on a model-by-model basis. The tool was implemented in selected shops in several EU countries (ES, UK, CZ, IT, DE). A process and outcome evaluation was part of this field trial.

The proposed paper will report on the evaluation findings focusing on the consumer and retailer perspectives on the tool which were collected via interviews, questionnaires and discussion groups. In addition, based on available sales data the evaluation tried to identify the influence on consumers' buying decisions. Conclusions will be drawn for energy policy on appliances.

Households‘ Dynamic Investment Choice in Energy Efficient Technology

Sebastian Mertesacker, Prof. Van Anh Vuong, Phd.

We estimate a dynamic structural model of household investment into energy efficient technology. Our model explicitly accounts for the dynamic nature of the investment activities with high cost of investment that occur at the time of modernization and with payoffs being realized delayed in time.

We estimate the parameters determining the period utility the household receives from thermal warmth in a first step by regressing the fuel demand predicted by the model on the one observed in the data. We then calculate the household‘s period utilty and expected gain in lifetime utility from an investment and estimate his investment costs in a second step based on modernization activities observed in the data.

Our primary data source is "The German Residential Energy Consumption Survey" (RWI and forsa, 2011), which provides information on fuel consumption, investment behavior and dwelling characteristics of 6.715 households between 2006 and 2008. Information on dwelling characteristics are used to generate heating fuel requirements relying on the procedure developed by Loga et al.

(2005).

Our estimates show a positive and highly significant impact of energy consumption on the individual's utility level. There is high level of heterogeneity in household's energy consumption pattern, with larger households and those with elderly having a higher energy consumption. Household‘s energy consumption rebounds after a reduction in the dwelling‘s fuel requirement resulting from a modernisation. Furthermore, we estimate the mean investment costs to be approximately 26.000 Euros, indicating a high importance of non-monetary costs in the investment decision.

The simulation of counterfactual policy experiments clarifies that these high investment costs, can make it very hard to design policies that trigger new investments on a relevant scale. The high level of consumer heterogenity implies that policy makers should carefully target their policies, to maximise their impacts. Furthermore, the importance of high non-monetary costs indicates that there may be large benefits in the provision of additional information and the simplification of application processes. Finally, a tax on fuel prices has the advantage of increasing the investment incentives and reducing rebound effects at a time, thus minimising the amount of emissions.

Photovoltaic self-consumption after the support period: Will it pay off in a cross-sector perspective?

Jonas Klamka* (a), André Wolf (b), Lars G. Ehrlich (b)

a: Universität Siegen – Lehrstuhl für Europäische Wirtschaftspolitik, Unteres Schloss 3, 57076 Siegen, Germany
b: Hamburgisches WeltWirtschaftsInstitut (HWWI), Oberhafenstraße 1, 20097 Hamburg, Germany
**: Corresponding author, jonas.klamka@uni-siegen.de*

We quantify the cost savings potential of photovoltaic self-consumption by single-family houses with small-scale roof-top photovoltaic (PV) systems in Germany against the background of recent storage applications after the end of the legal support period. We analyze different systems where an already installed PV system is combined with battery storage and/or a power-to-heat solution (heating rod plus thermal storage). A comparison is made in terms of a household’s electricity and heating costs under cost-minimizing operation of each system. For this purpose, we carry out comprehensive simulations of site-specific PV production and determine the optimal self-consumption as well as the optimal charging of the hot water thermal storage and the battery system. We use 25 representative electricity load profiles, which differ only in the temporal distribution of consumption, to obtain a broader picture of the cost savings potential. Results suggest that the major share of the savings potential is due to direct PV selfconsumption and thus concerns the electricity costs. A profitability analysis reveals that the inclusion of a hot water thermal storage and/or a battery storage system does not pay off when juxtaposing cost savings and investment expenses, at least at current prices.

Further, our findings support the intuitive assumption that the higher the household's night share of consumption, the greater the benefit of a storage application. We find a positive relationship between the NPV of investing in a storage application and the night share of consumption. Furthermore, the range of our results is only driven by the different temporal distributions of consumption, not by the magnitude. As an additional side finding we can show that the use of the standard load profiles (BDEW) rather underestimates the cost savings potential of SFH in our simulations. These results underpin the necessity to consider different consumption patterns when evaluating the benefits of self-consumption.

Session 11:50 – 12:50
Low-Carbon Energy System Transformation II/III

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

Decarbonization of the European energy system with strong sector couplings

Martin O.W. Greiner, Aarhus University

Analyzing Potential Stranded Assets – A Challenge for the European Low-Carbon Transition?

Konstantin Löffler, TU Berlin

Modelling of the European Union's Long-Term Strategy towards a carbon-neutral energy system

Alessia De Vita, National Technical University of Athens

Decarbonization of the European energy system with strong sector couplings

Kun Zhu[1], Marta Victoria[1], Tom Brown[2], Gorm B. Andresen[1], and **Martin Greiner[1]**

[1]*Department of Engineering, Aarhus University*
[2]*Institute for Automation and Applied Informatics, Karlsruhe Institute of Technology*

Ambitious targets for renewable energy and CO_2 taxation both represent political instruments for decarbonization of the energy system. We model a high number of coupled electricity and heating systems, where the primary sources of CO_2 neutral energy are from variable renewable energy sources (VRES). The model includes hourly dispatch of all technologies for a full year for every country in Europe. The amount of renewable energy and the level of CO_2 tax are fixed exogenously, while the cost-optimal composition of energy generation, conversion, transmission and storage technologies and the corresponding CO_2 emissions are calculated. Even for high penetrations of VRES, a significant CO_2 tax of more than 100 EUR/tCO2 is required to limit the combined CO_2 emissions from the sectors to less than 5% of 1990 levels, because curtailment of VRES, combustion of fossil fuels and inefficient conversion technologies are economically favored despite the presence of abundant VRES. A sufficiently high CO_2 tax results in the more efficient use of VRES by means of heat pumps and hot water storage, in particular. We conclude that a renewable energy target on its own is not sufficient; in addition, a CO_2 tax is required to decarbonize the electricity and heating sectors and incentivize the least cost combination of flexible and efficient energy conversion and storage.

Related publications:

(1) K Zhu, M Victoria, T Brown, GB Andresen, M Greiner: Impact of CO_2 prices on the design of a highly decarbonized coupled electricity and heating system in Europe, Applied Energy 236 (2019) 622-34.

(2) T Brown, D Schlachtberger, A Kies, S Schramm, M Greiner: Synergies of sector coupling and transmission reinforcement in a cost-optimised, highly renewable European energy system, Energy 160 (2018) 720-39.

Analyzing Potential Stranded Assets – A Challenge for the European Low-Carbon Transition?

Konstantin Löffler[1,2]*, Thorsten Burandt[1,2,3], Karlo Hainsch[1], Pao-Yu Oei[1,2]

[1] *Technische Universität Berlin, Germany*
[2] *Deutsches Institut für Wirtschaftsforschung (DIW) Berlin, Germany*
[3] *Norwegian University of Science and Technology (NTNU), Norway*
* *kl@wip.tu-berlin.de, Germany*

Keywords: Energy System Modeling, Decarbonization Pathways, Stranded Assets, Climate Policy

Overview

This paper computes multiple pathways for the European energy system until 2050, focusing on one of the challenges of the low-carbon transition: the issue of unused capacities and stranded assets. The paper computes three different scenarios, utilizing the Global Energy System Model (GENeSYS-MOD) for calculations. A special focus is placed on capacities and the eventually arising stranded-asset problem, as ambitious decarbonization goals force fossils out of the energy mix. In order to reach the 2°C goal, a swift transition towards renewable energy sources is needed, leading to unutilized capacities of fossil-fueled plants - an effect that is even stronger, when short-term goals are prioritized over long-term targets. Thus, the need for strong, clear signals from policy makers arises to combat the threat of investment losses.

Methods

To analyze these scenarios, an extended version of GENeSYS-MOD is used. The model uses a system of linear equations to search for lowest-cost solutions for a secure energy supply, given externally defined constraints on GHG emissions. A major addition to previous studies is the inclusion of scenarios featuring reduced foresight, as well as current policy trends, in order to quantify the magnitude of the potentially arising stranded asset problem. By including all three major sectors of the energy system (power, heating, and transportation), a comprehensive outlook can be given which also includes the interdependencies between the single sectors.

Results

The results show that there could be massive amounts of unutilized capacities in Europe in the upcoming years if climate targets are taken seriously. Introducing reduced foresight similar to short-sighted political and business point of views to the model further increases this problem, leading to new constructions of conventional generation capacities in the 2020s that quickly become obsolete. The decreasing competitiveness of conventional energy generation poses difficult challenges for investors, owners, and policy makers, as issues such as stranded assets and job security arise. Thus, strong and clear signals from policy makers are needed to combat the threat of investment losses that could increase significantly when short-term goals are prioritized over long-term targets.

Modelling of the European Union's Long-Term Strategy towards a carbon-neutral energy system

Georgios Zazias, Stavroula Evangelopoulou, Theofano Fotiou, Maria Kannavou, Pelopidas Siskos, Yannis Moysoglou, Stergios Statharas, Alessia De Vita, Pantelis Capros

E3MLab, National Technical University of Athens
Email: central@e3mlab.eu

Keywords: energy system modelling; long term energy strategy; climate change mitigation policy; energy economics; energy transition.

The 2015 Paris Agreement has invited all parties to submit, by 2020, mid-century strategies compatible with the goal of containing the rise in average global temperature to well below 2oC above pre-industrial levels and pursuing efforts to limit it to 1.5oC. The European Commission communicated in November 2018 a long-term strategy towards near-zero greenhouse gas emissions by 2050 and beyond. The communication uses several alternative quantitative projections of the EU energy system until 2070, with emphasis on the year 2050. The PRIMES model, developed and operated by E3MLab, was employed to quantify the alternative pathways and assess the impacts on energy indicators, investments and costs. The alternative pathways target greenhouse gas emission reductions between -80% and -98% by 2050 (compared to 1990).

All pathways share the same view that energy efficiency and renewables are the main pillars of the EU strategy towards decarbonisation. However, they differ regarding the carbon-free energy carrier (such as electricity, hydrogen or GHG-neutral hydrocarbons) that will dominate the final energy demand sectors in the long-term. The conception of the pathways puts emphasis on sectorial integration, with the main examples being power and mobility, power and heat, CO2 capture and re-use in industry, biomass cultivation and advanced biofuels in mobility, power and production of hydrogen and GHG-neutral hydrocarbons. The dominance of a certain energy carrier implies high industrial maturity levels and learning-by-doing cost reductions for the associated technologies for its production and use. Data supporting the estimation of learning-by-doing potentials for each key technology have been derived after a consultation with a large number of industry stakeholders.

The modelling of the pathways required considerable enhancement of the PRIMES model in order to represent all sectorial integration possibilities, include new technology chains (in particular for the production and use of GHG-neutral hydrogen and hydrocarbons) and represent endogenous integration of learning-by-doing mechanisms in the uptake of technologies. It was also necessary to considerably enhance the model regarding the representation of energy efficiency possibilities in the buildings and industrial sectors. The modelling of the power sector has also been a challenging task in view of the integration of (variable) renewables at a very large scale together with the deployment of various storage technologies and flexibility options. The model enhancements improved the representation of the electricity system's operation, giving the model the capability to coordinate the use of variable renewables, battery storage, chemical storage via power-to-X technologies and the production of GHG-neutral hydrogen, hydrocarbons and chemicals.

Apart from the pathways that achieve the majority of emission reductions via fuel switching to carbon-neutral energy carriers, the exercise also quantified ambitious energy efficiency and circular economy pathways that deliver the required GHG emissions abatement. The main challenge in these cases was to include in the modelling reasonable behavioural changes, mainly in heating and mobility, as a means to reduce the energy and carbon intensity of the EU economy.

The modelling of the pathways firstly identified which of the decarbonisation options and policies can be considered as “no-regret” options; these appear in all pathways independently of the uncertainties surrounding technology developments. The “no-regret” options include increased electrification in heating, industry and transport, which climbs to 40%-50% by 2050 depending on the scenario, up from roughly 20% in 2015. Electrification emerges primarily in the buildings sector via the widespread adoption of heat pumps (especially as a solution of preference in deeply renovated buildings) and in the transport sector. In the latter case, it fuels the decarbonisation of private short-distance mobility with tremendous positive externalities for urban areas (reduced air pollution and noise). Another common pillar of the transition is energy efficiency; the energy consumption of final demand sectors reduces between 27% and 45% (depending on the pathway) in 2050 with respect to 2015. Building renovations, highly efficient (and smart) appliances and equipment, heat recovery in industrial units and intelligent transportation boost energy efficiency progress. All pathways show a vast increase in the penetration of variable RES in the power system, favoured also by rapidly reducing investment costs. Renewables generate more than 80% of the total electricity needs in 2050, with variable renewables covering more than 70% of electricity generation, in all pathways. The rapid expansion of variable RES induces a rapid increase in storage needs, be it direct (pumping, stationary or mobile batteries) or indirect (via the production of GHG-neutral hydrogen or e-gas and their combustion at a later stage). In the most extreme case, the storage needs are estimated at 450 TWh per annum. The model results also confirm the hypothesis that the production of synthetic fuels has system benefits, as the synthesis of the latter results in smoother load curves, thus avoiding excess investments in peak-units and increases in electricity prices. The integration of RES is assisted via the completion of the EU internal market and increased interconnections between Member States. Other no-regret options comprise advanced biofuels production, nuclear power and geological storage of CO2 where acceptable.

The analysis of pathways introducing GHG-neutral hydrogen and hydrocarbons in the energy system implies that, through a high level of sectorial integration, the energy system must be able to provide i) the energy required for the energy-intensive production of the new fuels (especially electrolysis), ii) the necessary feedstock elements for their production. The enhanced version of the PRIMES model takes these requirements and interactions into consideration. It calculates not only the volume of feedstock (hydrogen, carbon) needed but also how these can be obtained. The electricity needs of the energy system are significantly augmented in pathways focusing on decarbonisation via e-fuels; i.e. the pathway focusing exclusively on e-fuels demands 800 TWh (or 33%) more electricity than the one focusing on the strong electrification of final demand sectors. The simulations showed that the renewables potential is sufficient for such a very large enlargement of the power sector in entire Europe if a strongly interconnected European grid operates efficiently in order to provide access to remotely located renewables and facilitate the sharing of balancing resources. In the aforementioned pathway, 175 Mtoe of clean energy carriers (including hydrogen) are used in mobile or stationary applications, the production of which requires 370 Mt of CO2 feedstock, obtained via Direct Air Capture and biogenic sources. It is found that the competitiveness of the new energy carriers depends not only on the learning assumptions of new technologies for their production but also on the electricity prices available to e-fuel producers. The pricing of the e-fuels benefits from purchasing electricity at times of lowest marginal system costs, due to the excess electricity generation from

RES. The carbon-neutral pathways include negative emissions achieved either via the underground sequestration of CO_2 or by embedding in materials the CO_2 captured from biomass-fired power plants. In the most extreme pathways, negative emissions amount to 260 $MtCO_2$ in 2050.

The quantitative analysis undertaken via the model confirmed that the decarbonisation of the EU economy by mid-century is viable both technically and economically, regardless of the ambition level (well below 2oC or 1.5oC temperature rise); the pursuit of a carbon-neutral EU economy by 2050 is a plausible target. Some of the technologies included in the analysis are at low or medium technology readiness levels, however, the number of the pathways assessed indicates that the energy system has a plethora of innovative options available, none of which can be considered irreplaceable, besides some no-regret ones. The analysis should be complemented in the future with further exercises regarding both technological and strategic aspects around key issues, such as the origin of hydrogen, the origin of carbon molecules for feedstock purposes, the organization of energy markets incorporating very high levels of (variable) RES and competition of resources for energy storage and production of GHG-neutral fuels.

Session 11:50 – 12:50

Energy transition on a local level

Room: Rotterdam Hall
Chair: Jens Maiwald (TU Dresden)

A Generic Evaluation Process for Power-to-X Business Cases in an Urban Setting

Stefan Scharl, RWTH Aachen University

The transition of the energy system towards (almost) complete decarbonization from an utility perspective

Dr. Holger Wiechmann, Energie Baden-Württemberg AG

Sustainability assessment of the energy transition: Insights from Saxon municipalities, Germany

Kendisha Soekardjo Hintz, TU Dresden

A Generic Evaluation Process for Power-to-X Business Cases in an Urban Setting

Stefan Scharl,
RWTH Aachen University,
Institute for Future Energy Consumer Needs and Behavior (FCN),
+49 241 80 49845, sscharl@eonerc.rwth-aachen.de

Aaron Praktiknjo,
RWTH Aachen University,
Institute for Future Energy Consumer Needs and Behavior (FCN),
+49 241 80 49691, APraktiknjo@eonerc.rwth-aachen.de

Keywords: Power-To-X, Sector Coupling, New Mobility,

Motivation

The goal of this research is to support local utilities in the implementation of the right regional PtX projects. Consequently we address the question: What are the most economically viable PtX business cases for local utilities in an urban setting? During the research project we apply our methodology to a Power-to-Mobility (PtM) project, with a EU-wide unique configuration. For the PtM a waste power plant generates electricity, which subsequently charges a hydrolyser. The produced hydrogen fuels H_2-buses in the public transport of the utilities' city.

Methods

Monte-Carlo simulation; Real-Option Analysis

Results

The analysis of cost structure revealed a high share of operational costs. This results in a high sensitivity of profitability to market prices, electricity levies and power efficiencies. Unfortunately, current energy levies in Germany are in conflict with the implementation several PtX business cases. Since repeated grid charges or renewable energy levies cut into the profitability, most business cases are currently not worthwhile.

However, the PtM proved to be an interesting new business case. First, it survived the initial preselection. Second, the simulation of the levelized cost of hydrogen (LCOH) results in an expected value of 3.98 €/kg H_2, which is cheaper than external delivery. Additionally, since the hydrogen is produced on the premise of a power plant and only used in busses of the same company, the utility can avoid additionally taxation.

The transition of the energy system towards (almost) complete decarbonization from an utility perspective

Dr. Holger Wiechmann

Energie Baden-Württemberg AG

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

More local generation, self-consumption approaches, e-mobility, battery storage and electricity-based heating systems are the basis for these upcoming changes. But what does that mean for utilities?

Well, the customers – large or small – becomes their own energy manager and the utilities are becoming a kind of insurance company, that takes over the rest of the energy supply (feed in and supply). In particular, battery storage systems and local self-generation will cause the temporal structure of the use of the grid connection to change completely. Instead of the usual "around the clock" use of the grid connection, the network usage behaviour will evolve to the effect that for many customers only a few hours a day a grid connection is needed. This leads to completely changed requirements for grid management and corresponding effects on energy logistics (including the storage topic with PtG).

In summary, utilities (gas and electricity) will become – even more – a manager of the energy transition resp. decarbonisation and this means that utilities will in the future have the following main tasks:

1. Construction and Operation of Renewable Energy Plants
2. Provide backup and storage capacities
3. Introduction of hydrogen as the "new" CO_2-free energy source in combination with electrolysers
4. Implement intelligent network management (focus electricity) and increase the hydrogen compatibility in the gas system
5. More customer focus: Guarantee the residual power supply of customers as a kind of insurance company
6. Drive forward the sector coupling and here in particular the PtG topic and in the transport sector (e-mobility, operation of charging stations)

However, to be able to implement this, an adaptation of the regulatory framework is necessary.

Sustainability assessment of the energy transition: Insights from Saxon municipalities, Germany

Kendisha Soekardjo Hintz[1*], Katharina Sartison[1]

[1]*Institute for Infrastructure and Resources Management*
Leipzig University, Germany
[*]*Corresponding author: kendishahintz@gmail.com*

Keywords: Energiewende, climate protection strategy, climate protection manager, municipality, Saxony

Motivation

The energy transition in Germany 'Energiewende' aims to increase the renewable energy share to 80% by 2050 against the 1990 level, with measures set at the municipal to federal level. This research aims at assessing the sustainability of the Energiewende on the municipal level by using the planetary and social boundaries framework. It compares two case studies of shrinking and ageing middle-size Saxon municipalities with a climate protection strategy in place (Reichenbach) and without (Torgau). The following questions were sought: Which positive and negative effects do stakeholders associate with the local Energiewende in their municipality? Can a municipal climate protection manager (CPM) enhance the process of Energiewende?

Methods

Literature review and media analysis were employed to firstly identify key decision-makers of the local Energiewende in Saxon municipalities. Semi-structured interviews with six focal decision-makers in Reichenbach and five in Torgau were conducted by the authors. These key informants represented the municipal government (e.g. head of municipality and department of building and city development), private sector (e.g. municipal energy provider, renewable energy consultants), civil society (e.g. housing cooperative and educational association), and institutions (e.g. consumer protection agent). Category-based text analysis and matrix ranking were employed to evaluate data and generate actor mapping.

Results

In both municipalities, the positive effects are dominated by the economic dimension (i.e. cost savings, the enhancement of regional value chain, and job creation). Negative effects are dominated by the social dimension in Torgau and the economic dimension in Reichenbach (i.e. new costs for energy efficiency investments). Concerning CPM, who would have to cooperate closely with these interviewed actors, all respondents in Torgau and 67% in Reichenbach acknowledged its steering function in Energiewende. 80% respondents in Torgau agreed that the municipality should fund the CPM, while 50% in Reichenbach suggested the federal government or state.

Session 11:50 – 12:50

Flexibility in energy systems

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

How to Estimate the Balancing Capability of Hydropower? – A Proposed Method that Reveals Insights in Factors Affecting Flexibility

Richard Scharff, Vattenfall

The impact of sector coupling options on electricity systems – An evaluation of different flexibility options

Mario Kendziorski, TU Berlin

Find your way around the various flexibility mechanisms under the European burden-sharing

Marc Vielle, École Polytechnique Fédérale de Lausanne

How to Estimate the Balancing Capability of Hydropower? – A Proposed Method that Reveals Insights in Factors Affecting Flexibility

Jonas Funkquist[1], Joakim Näsström[1], Richard Scharff[1,2]

[1] *Vattenfall AB, Research & Development, Sweden*
[2] *Corresponding author, richard.scharff@vattenfall.com*

Keywords: flexibility, wind power integration, balancing potential of river systems

Motivation

After having studied historic balancing contributions, we are now estimating potential balancing possibilities for hydro power in Sweden. Hydropower is an important source of flexibility, but its balancing capabilities are limited by several factors, e.g. inflows (precipitation), hydrological coupling (dispatch of stations in a river system is dependent on each other) and water rights. While the dispatchable flexibility of hydro power facilitates the integration of wind power and other variable renewable energy sources, it also affects the environment. Predominant examples are barriers for fish migration, hydro reservoirs with varying water levels and a significant change of natural water flows. In order to increase the ecological values (e.g. biodiversity) of river systems used for power generation, different measures can be taken. Some of them will affect the power stations' yearly energy production, some its balancing capability, some both of them and some probably neither the one nor the other. While energy production (MWh) can be substituted by other renewable energy sources, dispatchable electric power (MW) is less easy to replace. In order to provide more insights in the values of system balancing, we are developing a method to estimate the balancing capabilities of the lager Swedish river systems that are used for power production.

Methods

As dispatchable hydropower is especially valuable to balance those wind power variations that are not only including significant power, but also significant energy (hard to be replaced by batteries and demand response), we focus on wind variations between several days (about 4-8 days, due to weather patterns) as well as seasonal variations. We feed an optimisation problem for production planning with historic inflows and a parametrized demand that has to be met (superimposed sinusoidal functions). Then, we adjust the amplitude of the sine waves until a solution that is both feasible and that allows for a reasonable "recovery" of the river system's flexibility cannot be found any longer. This way, a multi-dimensional surface is created that shows a river system's balancing capability as a function of the different variations that have to be balanced (corresponding to flexibility needs with different period lengths).

Results

We expect preliminary results to exist by end of February. Currently, we have implemented Lule River and the first results give insights into factors that affect the potential balancing contributions.

The impact of sector coupling options on electricity systems – An evaluation of different flexibility options

Mario Kendziorski[1]
Wolf-Peter Schill[2]

[1] *Workgroup for Infrastructure Policy (WIP), Germany, mak@wip.tu-berlin.de*
[2] *DIW Berlin, Germany, wschill@diw.de*

Keywords: power system modelling, energy system modelling, sector coupling, energy sector integration

Motivation

The challenge of decarbonizing the energy system involves not only the electricity sector, but also transportation and heating. Yet, there is no clear vision about how these sectors are going to merge into an integrated system with almost zero emissions. Given that the power sector is arguably easier to decarbonize, as well as the versatility of electricity as an energy carrier, a transition towards a fully renewable power sector is mandatory. However, the level of integration of electric vehicles and the additional demand coming from residential heat pumps have an influence on the power demand. On the other hand, the value of flexibility options increases with a high penetration of intermittent renewable energy sources.

Methods

The presented work aims to analyze different power sector scenarios in a highly decarbonized energy system. A focus is set on different configurations for sector coupling and resulting implications on flexibility option. Following variations will be subject to a sensitivity analysis:

(1) The deployment of electric vehicles and their interaction with the power grid, (2) installed heat pumps resulting in different heat demand profiles and potentially additional flexibility for the power system, and (3) demand for hydrogen (e.g. in the chemical industry or the transportation sector). We use the open source electricity system model DIETER to identify determining factors on the generation expansion as well as needed storage capacity.

Results

While additional electricity demand coming from other sectors increase the required installed generation capacity, the needed investments into storage technologies can be reduced. Both, utilized electric vehicles and power-to-gas infrastructure can diminish curtailment of renewables. Investing into Solar PV becomes more valuable with a higher degree of sector coupling and the provided flexibility.

Find your way around the various flexibility mechanisms under the European burden-sharing

Marc Vielle[1]

[1] *LEURE Laboratory, Swiss Federal Institute of Technology at Lausanne (EPFL), CH-1015 Lausanne, Switzerland, marc.vielle@epfl.ch*

Keywords: Effort Sharing Decision, European Union, Climate Policy, Computable General Equilibrium Model

Motivation

The European climate change policy has allocated GHG emissions in two categories: firstly, emissions from power generation and energy intensive industries which are covered by the European Union emissions trading scheme and, secondly, the other GHG emissions that are subject to domestic targets according to the so-called Effort Sharing Decision (ESD). The ESD is based on a GDP per capita rule and wants to reflect the economic capacity of each EU Member State (MS) on the basis of their relative wealth. However, several papers have already pointed out that this way to allocate emissions can create great cost inefficiencies as the allocations do not take into account MS abatement costs.

The EU proposal acknowledges this issue and proposes a range of flexibility instruments (i.e. more than 15 flexibility options) that aim to enhance cost-effectiveness. This paper evaluates the EU proposal and analyses the economic impacts of each of these flexibility options with respect to fairness and cost-effectiveness.

Methods

I use the GEMINI-E3 model to analyse the economic impacts of the ESD. GEMINI-E3 is a CGE model that has been specifically design to assess climate and energy policies. First, I simulate a reference scenario on the time period 2011-2030. Then, I simulate the forthcoming European climate policy and especially the post-2020 binding targets within the architecture defined ny the European Commission. Finally, I simulate more than 15 scenarios that aim to analyse the potential of each flexibility option regarding CO_2 prices, welfare cost, CO_2 emissions and fairness in burden sharing for each MS.

Results

My analysis shows that flexibility mechanisms that allow “inter-Member state flexibility” are the most efficient option. They reduce the compliance cost and in a same time increase fairness between low-income MSs and high-income MSs.

Session 11:50 – 12:50

Alternative fuels for transportation

Room: Florenz Hall
Chair: Hendrik Scharf (TU Dresden)

LNG from renewable sources as an alternative fuel for maritime shipping?

Andreas Seeliger, Hochschule Niederrhein

Application-side merit-order-curves for synthetic fuels in the german energy system

Tobias Hübner, Forschungsgesellschaft für Energiewirtschaft mbH

Economic comparison of electric fuels produced at excellent sites for renewable energies: A Scenario for 2035

Philipp Runge, Friedrich-Alexander-Universität Erlangen-Nürnberg

LNG from renewable sources as an alternative fuel for maritime shipping?

Prof. Dr. Andreas Seeliger[1]

[1] SWK E2 Institut für Energietechnik und Energiemanagement an der Hochschule Niederrhein, Krefeld, Germany, andreas.seeliger@hs-niederrhein.de

Keywords: LNG, maritime shipping, cruise ships, power-to-gas (PtG), emissions

Motivation

Transport is the only sector in the European Union that failed to reduce its greenhouse gas emissions. Given this, policy and industry currently discussing various technologies and instruments which (possibly) could help to achieve the targets derived from the Paris conference. As road transport is responsible for the largest share of total transport emissions, the discussions mainly focus on this segment. However, also shipping is a major producer of greenhouse gas and other emissions (such as particulate matters and sulfur dioxide). This accounts in special for large scale transport and cruise ships.

Methods

The paper is a literature survey which will be supplemented by a questionnaire sent to various stakeholders such as shipping companies, harbor operators and industry associations.

Results

LNG (which is liquefied natural gas) could be an option to reduce all types of emissions from these ships, however, some technical and economic restrictions exists. Another critical point is that on the one hand LNG could reduce emissions compared to fuel oil or diesel but on the other hand is still a fossil resource, which is not compatible to climate ambitions of some European governments. As biogas potential is very limited, alternative ways to produce renewable gas are needed. Power to gas could convert renewable power, e.g. from offshore wind parks in the North Sea, to a synthetic natural gas ("green gas").

(Further findings depend on the answers from the questionaires.)

Application-side merit-order-curves for synthetic fuels in the german energy system

Tobias Hübner[1], Andrej Guminski, Steffen Fattler, Simon Pichlmaier, Felix Böing, Jochen Conrad, Anika Regett, Serafin von Roon

[1] *Research association for energy markets and technology (FfE), Germany, thuebner@ffe.de*

Keywords: application related merit-order, synthetic fuels (synfuels), energy transition, climate protection ambition level, decarbonization, complete defossilization, indirect electrification, cost curves, greenhouse gas (GHG) abatement measures, green fuels

Motivation

The analysis of energy and climate policy scenarios shows that a massive use of synthetic fuels is expected by the year 2050 /FFE-38 18/, /DENA-02 18/, /BCG-01 18/, /BMUB-06 15/, /BMWI-01 14/. Besides the GHG-emission reduction, the use of synthetic fuels offers short-term and long-term flexibility in the energy system as well as the use of existing infrastructure and trading networks /AGORA-11 18/, /RUH-02 18/, /IEA-108 17/, /FFE-145 17/, /ENER-02 17/. However, in this context, the use of synfuels risks causing inefficiencies in the energy system as they could be used, although cheaper and more efficient alternatives measures to reduce GHG-emissions are available. Since synfuels deployment is often not the most efficient option for defossilizing the energy system, renewable alternative measures must be included in the decision-making process.

Methods

For the analysis of synthetic fuel use, cross-sectoral static merit-order-curves will be compiled in the base year 2020 and with a time horizon to 2050 for the German energy system. Two investigations are carried out: On the one hand, the synthetic fuel input in a merit-order is compared with fossil alternatives (Case 1). On the other hand, if possible, renewable alternatives (mainly electrification) are identified and compared with the synthetic fuel input in a differential-analysis (Case 2). In order to create a cross-sectoral merit-order for synthetic fuel use, the first step is the identification of applications and processes that are suitable for the use of synthetic fuels. In both cases, capital expenditure (CAPEX) and operational expenditure (OPEX) of the respective applications are to be recorded. This data is collected via literature research and validated by expert interviews. In a third step, the amount of energy relevant to synthetic fuel use is quantified. The respective specific costs are allocated to energy.

Results

In each case, a merit-order curve is created according to /FFE-20 17/ for the difference between fossil or alternative renewable technology and synthetic fuel application. If the difference between the most cost-efficient renewable alternative and the synfuels application is presented in a merit-order, under the given assumptions, it can be concluded that all measures below the abscissa can be used for a cost- efficient defossilation.

Economic comparison of electric fuels produced at excellent sites for renewable energies: A Scenario for 2035

Philipp Runge[a,e], Christian Sölch[b,e], Jakob Albert[c,e], Peter Wasserscheid[c,d,e], Gregor Zöttl[b,e], and Veronika Grimm[*a,e]

[a] *Chair of Economic Theory, Friedrich-Alexander-University Erlangen-Nürnberg (FAU), Lange Gasse 20, D-90403 Nürnberg, Germany*
[b] *Professorship of Industrial Organization and Energy Markets, Friedrich-Alexander-University Erlangen-Nürnberg (FAU), Lange Gasse 20, D-90403 Nürnberg, Germany*
[c] *Institute of Chemical Reaction Engineering, Friedrich-Alexander-University Erlangen-Nürnberg (FAU), Egerlandstrasse 3, D-91058 Erlangen, Germany.*
[d] *Forschungszentrum Jülich Gmbh, Helmholtz Institute Erlangen-Nürnberg for Renewable Energy (IEK-11), Egerlandstr. 3, D-91058 Erlangen, Germany.*
[e] *Energie Campus Nürnberg, Fürther Str. 250, D-90429 Nürnberg, Germany.*

Keywords: Electric fuels, LOHC, Hydrogen Utilization, Mobility

Motivation

In 2015 the transport sector was responsible for about 24% of the global emissions of greenhouse gases (GHG). In order to achieve the transition to a GHG free world economy, as described in the Paris climate agreement, the mobility sector needs to be decarbonized. Electric fuels (e-fuels) enable CO_2-neutral mobility and are therefore an alternative to fossil-fired engines or battery-powered electric motors. The production costs of those fuels are to a large part driven by the energy-intensive electrolytic hydrogen production. The option of producing synthetic fuels in Germany competes with international locations with excellent conditions for renewable energies and thus very low electricity costs. This paper compares the cost-effectiveness of Fischer-Tropsch diesel, methanol, cryogenic hydrogen and Liquid Organic Hydrogen Carriers (LOHC) at different production sits around the world.

Methods

We developed a single level linear mathematical model that covers the entire process chain. Starting with the production of the required resources such as water, hydrogen, carbon dioxide, carbon monoxide, electrical and thermal energy, the subsequent chemical synthesis, the transport to filling stations in Germany and finally the energetic utilization of the fuels in the vehicle.

Results

We found, especially with diesel, which is characterized by a very high heating value, the low electricity costs far outweigh the transport costs from overseas. In addition, a continuous energy supply, e.g. from hydro or geothermal plants, is more cost-effective than volatile wind or solar power generation, since downstream processes can be operated under nominal load and almost no intermediate storage is required. Due to its good dynamic properties, LOHC technology is particularly suitable for fuel production from wind or solar energy.

Session 13:50 – 14:50
Market design

Room: Hamburg Hall
Chair: Constantin Dierstein (TU Dresden)

Strategic reserve for Switzerland: Is it needed and (how) would it work?

Hannes Weigt, University of Basel

Incentive-based Subsidy and Tax for Efficient Generation Investment

Lamia Varawala, KTH Royal Institute of Technology

Low-carbon energy system transformation: the role of markets

Mike Bostan, European Federation of Energy Traders

Strategic reserve for Switzerland: Is it needed and (how) would it work?

Jonas Savelsberg, Moritz Schillinger, Ingmar Schlecht, Hannes Weigt

Many European countries are currently debating or staring to implement capacity mechanisms to enhance their system security in times of increasing intermittent generation. Switzerland does not have a capacity problem (22 GW supply vs. 10 GW peak demand) and therefore does not consider the introduction of conventional capacity mechanisms. However, policy makers are worried about whether the capacity is available at the time when needed. A large part of the capacity (about 10 GW) is based on storage or pumped-storage hydropower – which is only able to produce if reservoirs are filled. The Swiss Federal Office of Energy has proposed a storage reserve that would essentially pay hydro generators to leave a part of their stored energy unused throughout the winter, unless specifically called up in a defined contingency situation.

In this paper, we take up this approach and aim to identify for which cases a storage reserve would actually be needed and quantify the potential cost and market impact of different reserve designs. We will investigate market power problems in procuring the reserve and identify whether the procured energy and capacity is actually sufficient in case of an unforeseen emergency. The assessment is based on the Swiss electricity market model Swissmod developed at the University Basel covering the transmission system and a detailed representation of Swiss hydropower structures.

Incentive-based Subsidy and Tax for Efficient Generation Investment

L. Varawala[1], M. R. Hesamzadeh[2], G. Dán[3], I. Vogelsang[4], J. Rosellon[5]

[1]Networks and Systems Engineering and Electricity Market Research Group (EMReG), KTH Royal Institute of Technology, Sweden, varawala@kth.se
[2]Electricity Market Research Group (EMReG), KTH Royal Institute of Technology, Sweden, mrhesamzadeh@ee.kth.se
[3]Networks and Systems Engineering, KTH Royal Institute of Technology, Sweden, gyuri@kth.se
[4]Department of Economics, Boston University, US, vogelsan@bu.edu
[5]CIDE, Department of Economics, Mexico, juan.rosellon@cide.edu

Keywords: Electricity spot market, incentive regulation, capacity investment, pollution tax, multi-level optimisation, asymmetric information

Motivation

In an electricity spot market, several generation companies compete to generate electricity where each of them owns a variety of generators. Each generator has a finite generation capacity, determined by the amount of investment made by the company that owns it. Electricity spot markets often have price caps to prevent the use of oligopolistic market power, which limit the profit of generation companies and thus their incentive to invest in generation capacity. On the one hand, and increased generation capacity allows for increased producer and consumer surplus that positively affects social welfare. One the other hand, generation causes environmental damage that negatively affects social welfare.

Methods

In this paper, we propose a subsidy and tax scheme for oligopolistic electricity markets to promote economically and environmentally efficient investments in generation capacity. Our proposed scheme subsidises each generation company with the incremental increase in the consumer surplus that can be attributed to its generation. In addition, our scheme taxes each generation company with the incremental damage caused by its generation. We obtain this by aligning the generation companies' profit maximising objectives with the system operator's social welfare maximising objective. Our proposed scheme is inspired by the work in [1].

Results

Our proposed scheme is non-discriminatory, and in order to implement it the regulator requires no information about costs incurred by the companies. The subsidy adds to the generation's profit and encourages companies to invest in capacity over time. The tax encourages companies to minimise damage and invest in environmentally friendly technologies. In the socially optimal outcome, the subsidy is always greater than the tax, making participation voluntary. We show that implementing the proposed scheme eliminates the need for price caps. We also show that a Cournot equilibrium exists and we discuss the effects of collusion.

Reference

[1] J.-C. Kim, K.-B. Chang, An optimal tax/subsidy for output and pollution control under asymmetric information in oligopoly markets, Journal of Regulatory Economics 5 (2) (1993) 183–197.

Session 13:50 – 14:50

Carbon mitigation and EU ETS

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

The amendment of the EU ETS: decomposition of effects and dynamic efficiency

Theresa Wildgrube, ewi Energy Research & Scenarios

CO2 mitigation costs of smart space heating systems for private households in Germany

Dominik Schäuble, Institute for Advanced Sustainability Studies

Carbon avoided costs for the low-carbon technologies in Russia and EU

Andrey Khorshev, Russian Academy of Sciences

The amendment of the EU ETS: decomposition of effects and dynamic efficiency

Theresa Wildgrube[1]

[1] *Institute of Energy Economics at the University of Cologne, Germany, theresa.wildgrube@ewi.uni-koeln.de*

Keywords: Market Stability Reserve, Dynamic Optimization, EU ETS, Cancellation Mechanism

Motivation

With the increase of the linear reduction factor (LRF), the implementation of the market stability reserve (MSR) and the introduction of the cancellation mechanism (CM), the EU ETS has been fundamentally reformed in the past years. It is unclear how much emission and price paths are going to change and which of the three amendments has the most significant impact.

Methods

We develop a discrete time model of the intertemporal allowance market that accurately depicts these reforms. A sensitivity analysis ensures the robustness of the model results regarding its input parameters. The accurate modelling of the EU ETS allows for a decomposition of the effects of the individual amendments and the evaluation of the dynamic efficiency.

Results

The results show that prices increase with the interest rate as long as the total number of allowances in circulation (TNAC) is positive. Once the TNAC is depleted, prices grow at a lower rate. With the CM, 5% of all allowances issued from 2018 onwards will be invalidated. Remaining allowances in the MSR are reinjected into the market between 2029 and 2036. The MSR shifts emissions to the future but is allowances preserving. Since the MSR adds a constraint on banking and thus contradicts firms' time preferences, it increases firms' discounted abatement costs and deteriorates dynamic efficiency. The CM reduces the overall emission cap, increasing allowance prices in the long run, but does not significantly impact the emission path in the short run. Alternative cancellation designs, such as reducing allowance supply on the long end, may outperform the current CM. The increased LRF leads with 9 billion allowances to a stronger reduction than the CM and is, therefore, the main price driver of the reform.

CO_2 mitigation costs of smart space heating systems for private households in Germany

Dominik Schäuble[1], Adela Marian[1], Lorenzo Cremonese[1]

[1] *Institute for Advanced Sustainability Studies Potsdam, Germany, Dominik.Schaeuble@iass-potsdam.de*

Keywords: smart space heating, mitigation costs, ecologic-economic efficiency, private households, modeling case study

Motivation

The decrease in heat energy consumption is lagging behind the political targets in Germany. One major reason for the reluctance to invest in efficiency measures are the relatively high upfront costs e.g. for the thermal insulation of buildings. Smart systems that can improve the efficiency of space heating, especially in the inefficient building stock, may be one part of the solution as they are relatively low-cost. However, besides the lack of empirical data on energy savings through smart space heating, there is insufficient data on the ecologic-economic efficiency of these systems.

Methods

CO_2 mitigation costs of smart space heating systems from an investor/user perspective have been estimated based on net present value calculations and comparison of intervention and reference scenario. Two cases have been investigated: an average single-family house and an average apartment in an apartment building. Relative savings through smart space heating have been used as independent variable as the spectrum of relative savings in different households is large and empirical data is missing. Sensitivity tests were carried out for all input parameters, e.g. specific consumption, investment cost, operating life or fuel price.

Results

CO_2 mitigation costs of smart space heating systems depend strongly on the relative savings that can be achieved and on the specific energy consumption for space heating. Both variables have a 1/x relationship to mitigation costs. For average specific consumption (159 kWh/(m²a)), mitigation costs become negative for relative savings of at least 7.5% in the single-family house case, while relative savings of more than 10% need to be achieved to yield negative mitigation costs in the apartment case (134 kWh/(m²a)). The differences in mitigation costs between single-family house and apartment are mainly attributable to higher average specific consumption in single-family houses and the way heating costs are allocated in apartment buildings in Germany. Especially for investors/users in inefficient buildings, smart space heating systems can be absolutely beneficial from an economic as well as an ecologic-economic perspective even if only small relative savings are realized.

Carbon avoided costs for the low-carbon technologies in Russia and EU

Andrey Khorshev[1], Tatiana Pankrushina[1]

[1] *The Energy Research Institute of the Russian Academy of Sciences, Moscow, Russia epos@eriras.ru*

Keywords: GHG emissions, carbon avoided costs, power generation, low-carbon technologies

Motivation

Global environmental problems are triggering powerful international cooperation to limit greenhouse gas (GHG) emissions. Electric power industry plays a key role in this process. Economic mechanisms based on the GHG emission cost/price are widely used here to stimulate the low-carbon technologies that still remain more expensive (in terms of LCOE) than conventional fossil fuel plants. At this, it is necessary to estimate the economically reasonable level of the GHG emissions cost/price for the market-based low-carbon transformation of power industry. In the competitive environment this value is determined by the long-term marginal unit cost of GHG emissions reduction by a particular low-carbon generating technology and it is dependent on the many factors at the national level.

Methods

Here we applied a widely used methodology of carbon avoided cost (CAC) calculation for the quantitative assessment of the economically reasonable value of GHG cost/price for different low-carbon technologies (RES, CCGT and nuclear) taking into account the gaps in fuel prices, capital costs which affect their LCOE in Russia and the EU. CAC value is determined as a difference between LCOE of the reference (usually coal) and alternative generating technologies divided by a difference of the specific GHG emissions per kWh. Special attention was paid to a proper accounting of the additional reserve requirements for the intermittent RES capacities and its influence on the CAC values.

Results

The results of LCOE and CAC calculation for the same types of low-carbon technologies in Russia and the EU are presented for present and future economic conditions. Differences in the economic factors affect the ranking of low-carbon technologies as an investment options for the power sector transformation in Russia and the EU. Comparison of the technological priorities and required GHG costs/prices are presented and discussed as a rationale of the national energy policies.

The research was supported by the Russian Science Foundation (project No. 17-79-20354).

Session 13:50 – 14:50

Modelling and Simulation of Energy Markets

Room: St. Petersburg Hall
Chair: Dirk Hladik

Is the more complex model always the better one? Evidence from the assessment of security of electricity supply

Lars Nolting, RWTH Aachen University

Reliability constrained generation expansion planning: Case study for different system sizes and characteristic renewable profiles

Markus Groissböck, University of Innsbruck

Modelling of imports and exports for the German electricity system

Timona Ghosh, TU Berlin

Is the more complex model always the better one? Evidence from the assessment of security of electricity supply

Lars Nolting[1], Aaron Praktiknjo[1]

[1] *RWTH Aachen University,*
Institute for Future Energy Consumer Needs and Behavior (FCN),
[LNolting, APraktiknjo]@eonerc.rwth-aachen.de

Keywords: Energy System Modeling, Security of Electricity Supply, Complexity

Motivation

Against the backdrop of the ongoing expansion of renewable energies, the current phase-out of nuclear power stations, and the planned mothballing of coal-fired power plants in Germany, the question arises as to whether security of supply can still be guaranteed. Many different studies are currently being conducted in this field of research, using different input-data and varying approaches that often lead to opposing results.

Methods

In this context, we distinguish two categories of approaches and compare their methodological advantages and drawbacks both from the perspective of the modeler, i.e. scientist, and from the perspective of the interpreter of results, i.e. policy-maker: first, rather simple deterministic balance sheets of available capacities and peak load; second, complex probabilistic simulations in high temporal resolution that reflect stochastic fluctuations and weather dependencies of available feed-in and electricity load. By implementing, applying, and evaluating both approaches, we investigate whether the more complex model is per se more suitable to answer relevant research questions.

Results

Our analysis reveals significant differences with regards to complexity during the processes of data collection, modeling, and interpretation of results. Further, our results indicate that the different levels of complexity lead to different applicability for certain research questions: whereas the rather simple, spread-sheet based approach of conducting capacity balances is suitable to answer basic research questions, answers to questions with an intrinsically probabilistic character can only be found using more sophisticated modeling approaches. On the other hand, the more complex interdependency between given input data and model output in case of the probabilistic simulation model leads to a higher dependency of the accuracy of outcomes on the quality of input data. Data errors or manipulations can deteriorate results more significantly when highly elaborated simulation methods are applied. Overall, we find that both rather simple approaches and more complex models have benefits and drawbacks, so a tailor-made combination and a clear weighing of pros and cons with regards to the underlying research question and the availability of necessary input data are important.

Reliability constrained generation expansion planning: Case study for different system sizes and characteristic renewable profiles

Markus Groissböck [1], Alexandre Gusmao [2]

[1] *University of Innsbruck, Austria, markus.groissboeck@student.uibk.ac.at*
[2] *Portugal, lapas.gusmao@gmail.com*

Keywords: generation expansion planning, reliability, loss of load hours, correction curves;

Motivation

World-wide fluctuating renewable energy (solar photovoltaic and wind) is competitive compared to new build conventional generation. Policy support towards decarbonization of power drives the installation of renewables even further. While 'transmission expansion planning' (TEP) is traditionally based on probabilistic assessments this in not always the case for 'generation expansion planning' (GEP). In all optimization approaches security of supply is covered implicitly through hourly profiles of energy demand and renewable power generation, an explicit assumption of a 'reserve margin' (RM) and/or an 'expected value of energy not supplied' (EENS).

Methods

This work assesses security of supply through a dynamic programming (DP) approach where the RM is a result to fulfil the predefined reliability level (measured in 'loss of load hours', LOLH). To guide medium- and long-term GEP the assessment includes for example multiple years of data, several European countries with different qualities on renewable profiles (e. g. low PV/low Wind, low PV/high Wind, high PV/high Wind, and high PV/low Wind), different 'Forced Outage Rates' (FOR), different technologies (e.g. gas turbine, steam turbine, and internal combustion engine) with specific costs and efficiency based on selected size ('economy of scale', EoS), different level of renewable penetration, as well as different fuel price scenarios. In addition, correction curves for power output and efficiency are applied to conventional generation fleet for an even more realistic assessment and sensitivity analysis.

Results

Results will show the impact of system size (0.1, 1, 10, and 100 GW) and FOR (10%, 7%, 4, and 1%) on the required RM to design a reliable power system. Considering EoS effects preliminary results show that the RM to fulfil the LOLH criteria is between 2 to 3 times the assumed FOR. Even with high shares of renewables the RM does not change much.

Modelling of imports and exports for the German electricity system

Timona Ghosh[1]

[1] *TU Berlin, Department of Energy and Resource Management (TUB-ER), Germany, sektorenkopplung@er.tu-berlin.de*

Keywords: electricity imports and exports, modelling, oemof, interconnector capacity

Motivation

The electricity system is undergoing a rapid change. Increasing shares of fluctuating renewable energies show the need for a system transformation. International electricity exchange is one option for buffering parts of their fluctuations. Thus, an adequate depiction of the imports and exports within models for the electricity system is useful and necessary. However, there exist several solutions to model the electricity exchange between Germany and its neighboring states. This holds especially for fundamental power market models, not covering the electricity grid in detail.

Methods

The paper presents a systematization for several methods of modelling the electricity exchange between Germany and its "electrical neighbors" currently used in science and practice. The analysis is based on current publications and interviews with model developers, as only few information on this topic can be found in literature. Based on this overview, a new approach with flexible granularity is presented, taking into account differences between AC and DC interconnections, maximum and hourly NTCs, a projection of NTCs up to 2030 as well as the technical profiles (formerly) used for determining cross-border exchange limits.

Results

By this, the approach closes the gap between very simple modelling approaches with fixed NTCs and extreme computation-intense ones based on load flow calculations. By allowing flexibility in granularity, the model can be used at different hardware configurations. This implies that an adequate tradeoff between model complexity and computation time can be found for the particular analysis.

Thus, the model can be used as a building block for fundamental power market models, expanding these models with an adequate guess for international exchange at the level of detail needed. Finally, the implementation of the presented approach in the open energy modeling framework (oemof) is shown and some insights into model accuracy are given.

Session 13:50 – 14:50

Renewable energies

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

Paradoxa, anomalies and limits – the collective dynamics of energy systems

Marc Timme, TU Dresden – cfaed

The impact of multi-year weather variability on the security of supply in highly renewable power systems: a case study for Germany

Fridolin Pflugmann, TU München

Interaction of sector coupling technologies with further flexibility options in energy systems with different PV-Wind shares

Christoph Zöphel, TU Dresden

Paradoxa, anomalies and limits – the collective dynamics of energy systems

Benjamin Schaefer[1], Sara Katharina Chinnow[1,2], Raoul Schmidt[1], and Marc Timme[1,2]*

[1]Chair for Network Dynamics, TU Dresden, Germany,
[2]Institute for the Dynamics of Complex Systems, Univ. Göttingen, Germany,
**presenting author: marc.timme@tu-dresden.de*

Keywords: energy trading, direct atmospheric heating, fluctuations, energy system rebuilding, systainability

Motivation

To achieve a robust transition towards a systemically sustainable (*systainable*) energy strategy on the large scale and in the long term, energy supply and usage need to become drastically more effective and efficient, while simultaneously greenhouse gas emissions need to be reduced. Most research on energy technology and energy economics thus focusses on replacing system elements, such as fossil fuel by renewable energy resources, adapting market conditions, or optimizing efficiencies. Yet fully enabling the energy transition in time and in line with the 1.5 degrees Celsius climate goals requires us to understand the nonlinear collective dynamics of energy generation, supply and consumption on the systemic level, up to planetary scales.

Methods

We combine data analytics with tools from stochastic modeling, nonlinear dynamics, and statistical physics to reveal a number of anomalies, limits and paradoxa in the collective, dynamics of energy systems consisting of multiple, nonlinearly interacting units.

Results

We illustrate the importance of systemic analyses by three examples. First, we find that energy trading that is supposed to balance energy demand and supply, may simultaneously induce major imbalances. Second, installing renewable energy plants too rapidly may increase greenhouse gas emissions for decades if those plants are produced within the current, largely non-renewable system. Finally, even a planet-wide energy system without any greenhouse gas emissions would not be sustainable, because increasing consumption is projected to contribute substantially to climate change due to direct atmospheric heating.

The impact of multi-year weather variability on the security of supply in highly renewable power systems: a case study for Germany

Fridolin Pflugmann[1]

[1] *Technical University Munich, Germany, fridolin.pflugmann@tum.de*

Keywords: Multi-year weather variability, security of supply, value of stored energy, intermittent renewables

Motivation

With rising deployment of renewables, it gets increasingly important to understand the impact of weather fluctuations on power system operations. In particular, long-term fluctuations challenge power system stability, as conventional back-up capacity is phased-out and existing storage solutions (e.g. batteries) are rather designed for short-term buffering. Traditional power models that rely on one year of representative weather data do not adequately capture the true impact of weather fluctuations and underestimate the required capacity to balance electricity supply and demand over the long-term.

Methods

My research uses a power model that incorporates most components of a highly renewable power system with a high spatial and temporal resolution as well as extensive time series of fluctuating wind and PV generation profiles to model multi-year weather variability. The model is calibrated to the German power system (reflecting a 2050 perspective). Security of supply is studied by lifting the common assumption of full demand fulfillment and instead explicitly modelling the welfare loss of unfulfilled demand as macro-economic opportunity cost. In addition, the paper discusses if the valuation of stored energy at the end of the optimization period could help to derive more realistic renewable and storage capacity estimations (when modelling only one weather year).

Results

The results show that the multi-year variability of intermittent renewables is severe. Therefore, energy research should move towards multi-year analysis, when analyzing power system with high shares of intermittent renewables. Otherwise, the risk from weather fluctuations and its impact on security of supply might be underrated. When optimizations are limited to one year, incorporating a fair valuation of stored energy at the end of the optimization period can help to achieve greater power system robustness against multi-year fluctuations of intermittent renewables. Moreover, with rising renewable share, ensuring security of supply will be of growing importance for energy policy.

Interaction of sector coupling technologies with further flexibility options in energy systems with different PV-Wind shares

Christoph Zöphel[1]

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

Keywords: RES integration, flexibility options, sector coupling, energy system modeling

Motivation

Due to their weather dependency the renewable energy sources (RES) wind and PV are characterized by different electricity generation patterns. The resulting flexibility requirements to integrate high shares of wind (onshore and offshore) and PV is therefore affected by the shares of these technologies. Since the RES expansion pathway in Europe is influenced not only by cost developments, but also by factors like public acceptance and available area, the future European energy system might be more or less dominated by wind and PV respectively. To balance the weather dependency of the RES different flexibility options exist. Besides flexible power plants, electricity storages, demand side management and the electricity transmission grid, sector coupling technologies become more important. The role of the latter ones is crucial to decarbonize further energy sectors, namely the heating and transport sector. Within this framework there are still further research needs to understand the interactions between flexibility demand and flexibility provision as well as between different flexibility options including sector coupling technologies. The present works contribution is threefold. First, the influence of different wind shares of overall RES electricity generation on flexibility requirements is presented. Second, a model based optimal flexibility provision and the interactions with different flexibility demands is discussed. Third, the influence of an enforced sector coupling on the results is finally analyzed.

Methods

Based on weather data, three scenarios with different wind-PV shares in the overall RES generation are developed for central-western Europe. Each scenario is characterized by a total RES share covering theoretically 80 % of today’s electricity demand. The varying wind-PV share and the impact on the flexibility need is discussed by analyzing the resulting residual loads. By readjusting and applying the electricity market model ELTRAMOD, optimal model-endogenous investments in several available flexibility options are calculated for each scenario. Within the linear optimization model a Greenfield approach is applied to isolate the interactions of flexibility demand and flexibility provision from possible path dependencies. In a second step, the impact of an increased electrification of further sectors with selected sector coupling technologies on the optimal mix of flexibility options is analyzed. This includes heat pumps for the district heating sector, battery electric vehicles for passenger transport as well as electrolysis for industry’s hydrogen demand.

Results

The flexibility demand based on a higher share of wind and PV respectively differs significantly, due to their electricity generation pattern. This results in different flexibility capacity mixes to balance the weather dependent feed-in. Particularly the role of storages and the transmission grid is strongly influenced by the wind-PV share in the RES generation. An increase of electricity demand by sector coupling additionally affects these interactions. Here, the different flexibility options compete for the RES surplus energy.

Keynote 15.00– 15.45

Room: Hamburg Conference Hall

Impulses for a new heat market design

Florian Weiser

MVV Energie AG

The German climate targets cannot be reached without decarbonizing the heating sector that currently accounts for approximately one third of Germany's yearly CO_2 emissions. Green heating technologies will continue to be significantly more expensive than fossil-fired heating systems. Closing the CO_2 gap between a "businesses as usual" path with current policies and a path consistent with the climate targets in the building heating sector will cost approximately 9 billion euros in the year 2030. The MVV study "Take-Off Wärmewende" proposes a mixture of instruments in order to accelerate the decarbonization of the building heating sector consisting of a CO_2 tax on fossil fuels, CO_2 limits for the building stock, municipal heat plans as well as funding schemes for green heat and energy efficiency. Furthermore, decarbonization policies for the building heating sector in Switzerland, Denmark, UK and France are analyzed.

Session 16:15 – 17:15
Modelling of the heating sector

Room: Hamburg Hall
Chair: Philipp Hauser (TU Dresden)

Bottom-up modelling of heating investment using clustered time series data

Berit Hanna Czock, ewi Energy Research & Scenarios

Nearly Zero Energy Cities: Scalability of energy self-consumption from buildings to large urban areas

Manuel Villa, FUNSEAM

Active retrofitting for multi-apartment buildings: use case analysis with a special focus on photovoltaics and different heating systems

Bernadette Fina, TU Wien

Bottom-up modelling of heating investment using clustered time series data

Fabian Arnold[1], Berit Hanna Czock[1], Cordelia Frings[1]

[1] Department of Economics and Institute of Energy Economics at the University of Cologne, Germany, fabian.arnold@ewi.uni-koeln.de

Keywords: heating, household, bottom-up, building stock, consumer choice, clustering, scaling

Motivation

In order to achieve the German emission reduction targets, greenhouse gas (GHG) emissions should be reduced in all sectors jointly. Energy consumption of households accounts for roughly a quarter of the final energy consumption in Germany. Reducing GHG emissions in households may mean greater electrification of the heat supply system or investment in less GHG intense heating technologies. We propose a bottom-up approach that allows to holistically investigate developments in the building sector, accounting for the fact that the development of the heating and building infrastructure is the result of investment decisions of individuals. The approach allows to examine the effects of regulatory changes or cost changes on the technology installation rates, and operation profiles as well as the resulting energy consumption and GHG emissions.

Methods

We analyse the German heating sector development based on publicly available building stock and weather data. Categorizing household into types based on e.g. building type, number of people and region, and clustering time series data to derive typical periods addresses the trade-off between the granularity of the data and the computational requirements for modelling. Typical periods describe data sets that match household types with market, household demand and weather time series (TS). This enables maintaining the original correlation or dependence between the different TS. This is especially relevant as weather determines heating demand and thus heating technology investment and operation decisions, while being subject to regional differentiation. The existing model for consumer opportunity (COMODO) uses the typical periods as inputs in order to compute the cost-optimal heating technology installation and operation for defined consumers. Scaling the COMODO results for the typical households will allow compute results for the whole of Germany.

Results

We are currently implementing the categorization of household types and clustering of time series, hence there are no (validated) results so far. At the ENERDAY first results would be presented.

Nearly Zero Energy Cities: Scalability of energy self-consumption from buildings to large urban areas

Manuel Villa-Arrieta[1], Andreas Sumper[2], Joan Batalla[3]

[1] *Foundation for Energy and Environmental Sustainability (FUNSEAM) and Universitat Politècnica de Catalunya (UPC), Spain, (Corresponding author) mvilla@funseam.com*
[2] *Centre d'Innovació Tecnològica en Convertidors Estàtics i Accionaments (CITCEA-UPC), Spain, andreas.sumper@upc.edu*
[3] *Foundation for Energy and Environmental Sustainability (FUNSEAM), Spain, jbatalla@funseam.com*

Keywords: Nearly Zero Energy Cities, Nearly Zero Energy Buildings, Urban energy transition, Global Cost, Optimal-Cost

Motivation

Cities are home to more than half of the world population and this has an impact in that 70% of the world energy consumption and greenhouse gas emissions are concentrated in them. Because of this, these urban areas play a fundamental role in the low-carbon energy system transformation. To address this problem, Distributed Generation (DG) and mainly energy self-consumption are mechanisms that make it possible to take advantage of local renewable energy resources to the detriment of the consumption of external energy resources. In this sense, this work presents the economic evaluation of a Nearly Zero Energy City (nZEC) model for Barcelona (Spain) that include the investment of a hypothetic community of prosumers peer-to-peer and the investment of DG systems by energy producers.

Methods

The evaluation procedure used is novel and is based on calculating at the city scale of Global Cost and Optimal-Cost indicators, originally proposed in the Energy Performance of Buildings Directive (EPBD) of the European Union. In this model, we use public data from the city of Barcelona to evaluate the investment in the energy rehabilitation of Nearly Zero Energy Buildings (nZEB) and the use, by energy producers, of the photovoltaic capacity of the rooftops of the city.

Results

The results indicate that consumers, prosumers and producers could participate in the energy supply of the city with the aim of reducing its the consumption of fossil primary energy and its associated costs.

Active Retrofitting for Multi-Apartment Buildings: Use case analysis with a special focus on photovoltaiks and different heating systems

Bernadette Fina[1], Hans Auer[2], Werner Friedl[3]

[1] *AIT Austrian Institute of Technology, Giefinggasse 4, 1210 Vienna, and Energy Econonomics Group (EEG), Technische Universität Wien, Gusshausstraße 25-29, E370-3, fina@eeg.tuwien.ac.at*
[2] *Energy Econonomics Group (EEG), Technische Universität Wien, Gusshausstraße 25-29, E370-3, auer@eeg.tuwien.ac.at*
[3] *AIT Austrian Institute of Technology, Giefinggasse 4, 1210 Vienna, Werner.Friedl@ait.ac.at*

Keywords: retrofitting of multi-apartment building, net present value, mixed-integer linear programming, electricity and heating technologies, building-attached/integrated photovoltaics

The European building stock, consisting of 50% multi-apartment buildings, is to a large extend old and energy inefficient, making multi-apartment building retrofitting most important. This work aims to contribute by assessing the profitability of investments in active retrofitting measures for multi-apartment buildings.

To examine a variety of use cases, a modular approach is used to model different building set-ups (orientation, location, static heat load, roof pitches and so on can be varied). Electricity and/or heating technologies can be chosen out of a building energy technology portfolio. This portfolio contains building-attached/integrated PV which can be implemented on different parts of the building skin, battery storage, pellet heating, district heat and mono-/bivalent heat pump. To examine the profitability of different combinations of active retrofitting options, a mixed-integer linear programming optimization model is developed with the objective of maximizing the net present value (NPV) over a time horizon of 20 years. The model's major output besides the NPV is the determination whether the installation of individual building energy technologies is economically viable. Furthermore, the according optimal technology capacities are determined.

From a financial perspective, named heating systems cannot yet compete with a conventional gas heating. District heating is the cheapest option after gas, followed by pellet heating. However, once CO2 emissions are considered, it is recommendable to install a pellet heating or a heat pump. All kinds of PV systems can achieve break-even within a time horizon of 20 years, even façade PV systems despite weak solar irradiation and building-integrated PV despite additional basic renovation costs (building envelope is harmed). Sensitivity analyses show that including businesses, compared to a purely residential load, can positively influence the profitability of PV systems, as does a combined installation of PV systems and heat pumps. The profitability gap between investment costs for passive building renovation and resulting energy cost savings is significant. However, it is the smallest for buildings with quality standards. This profitability gap can be mitigated, for example, by true cost pricing of CO2 emissions.

Session 16:15 – 17:15

Low-Carbon Energy System Transformation III/III

Room: Rotterdam Hall

Chair: Christoph Zöphel (TU Dresden)

Survey and classification of business models for the energy transformation

Johannes Giehl, TU Berlin

Cost and Metal Savings through a Second-Life for Electric Vehicle Batteries

Anika Regett, Forschungsstelle für Energiewirtschaft e.V.

Pathways for Germany’s energy transition towards 2050

Frederik Seehaus, TU Berlin

Survey and classification of business models for the energy transformation

Johannes Giehl[1]

[1] Technische Universität Berlin, Germany, giehl@er.tu-berlin.de
Co-authors: Hayri Göcke, Benjamin Grosse, Johannes Kochems, Joachim Müller-Kirchenbauer (all Technische Universität Berlin)

Keywords: energy transformation, business models, value creation network, decarbonization, digitalization, decentralization

Motivation

The energy transition requires a fundamental conversion of the energy supply to renewable, CO2-neutral energies. In addition to the decarbonization, this includes the tendency towards decentralized structures. Furthermore, the digitalization of processes and industries is having an increasing impact on the energy industry, with new players entering the energy markets. The "traditional" structures of the energy industry that emerged after the liberalization of the electricity and gas markets, including the established business models, are subject to massive change as a result of the developments.

Methods

The analysis of structural changes is based on an empirical survey of current and future business models. In order to understand the deep change of the energy industry, a comprehensive picture of the business models of the energy industry is determined. Therefore, business models are analyzed based on primary and secondary data collection. The authors classify the qualitative data of the actually implemented business models into the logic of the Business Model Framework Energy Industry (BMFE), which is developed for this purpose. Furthermore, the business models are generalized and converted into a model of the sector.

Results

The study shows the current status of the energy business models. Fist, the BMFE was developed as a tool to describe the business models of the energy industry. A total of 638 business models have been found, described by the logic of the BMFE and grouped together into 69 prototypes based on value proposition, customers and revenue model. Finally, these were grouped into 17 business model classes according to the dimensions of customer proximity and proximity to the traditional value chain of the energy industry. Further outcome shows that the change is increasingly being driven by companies from outside the industry. This applies especially to new types of services, which are realized in value creation networks, and go beyond the pure supply of energy.

Cost and Metal Savings through a Second-Life for Electric Vehicle Batteries

Anika Regett[1], Jane Bangoj

[1] *Forschungsstelle für Energiewirtschaft (FfE) e.V., Germany, ARegett@ffe.de*

Keywords: Circular economy (CE), second-life (SL), electric vehicles (EV), batteries, material flow analysis (MFA), lithium (Li), cobalt (Co), cost assessment

Motivation

While an EV is more efficient than a combustion engine vehicle, there are currently still disadvantages e.g. in terms of costs and the demand for critical metals like Li and Co. Approaches from the CE such as SL applications are often proposed as a means to reduce material demand and initiate new opportunities for value creation. This raises the question of the extent to which the reuse of EV batteries in stationary battery applications can lead to Li/Co as well as cost savings.

Methods

The extension of the EV batteries' lifetime leads to time delays and substitution effects on stationary markets, which are met by a dynamic MFA. For this purpose a stock-and-flow model is developed, covering the German passenger car fleet and selected stationary applications from 2015 to 2050. The resulting incoming and outgoing battery flows are coupled with their stoichiometric Li/Co content and the annuity of the required battery components so as to determine primary Li/Co demand and costs in each year. To quantify Li/Co and cost savings a "recycling only" scenario is compared to a "recycling+SL" scenario. Critical parameters are identified by a sensitivity analysis.

Results

The reuse of EV batteries as home storage systems and for primary control reserve leads to a reduction of primary Li/Co demand by about 2-3 % over the considered time horizon. However, depending on boundary conditions, in the short-term an increase in Co demand is observed due to the reuse of Co-intensive traction batteries in stationary applications and the temporal shift of the recycling process. The costs savings amount to about 19 %/a in the short- to medium-term. Though, in the long-term these savings decrease because of falling prices for new battery systems.

Pathways for Germany's energy transition towards 2050

A model-based analysis on a federal level

Hans-Karl Bartholdtsen[1], Anna Eidens[2], Frederik Seehaus, Felix Wejda

[1] *TU Berlin, Germany, hkb@wip.tu-berlin.de,* [2] *TU Berlin, Germany, ae@wip.tu-berlin.de*

Keywords: Energy System Modeling, GENeSYS-MOD, Energy Policy, Energy transition

Motivation

Burning fossil fuels is the biggest driver for global greenhouse gas (GHG) emissions and therefore implies a fossil phase-out (IPCC 2015). Germany has taken the first steps to transform the country's energy system towards less CO2 intensity by setting a carbon dioxide emissions reduction target of up to 95 % by 2050 based on 1990 values (BMUB 2016). However, there are still various uncertainties affiliated with the transformation process, for instance, the question of how the decarbonization process can be realized. In this study, pathways for Germany's energy transition towards 2050 are drawn up based upon three possible future scenarios to propose solutions for these uncertainties.

Methods

The scenarios comprise the power, heat, and transportation sector on federal level, as well as trade flows within Germany and those between Germany and neighboring countries. For the analysis, the linear cost-optimizing "*Global Energy System Model"* (GENeSYS-MOD) in its second version (Burandt, Löffler, and Hainsch 2018) is used. The model computes a cost-efficient path of transformation in accordance to the respective scenario, including geographic, demographic, technologic, and economic data as model inputs. Phase-out dates for fossil sources are political measures with great impact and therefore are especially emphasized in the scenarios.

Results

The emission targets are not met without phase-out dates for fossil fuels. With a phase-out of coal until 2035, and oil and gas until 2045, the CO_2 emissions can be reduced by 89 % compared to 1990 and reach the national targets. Transitioning the energy system is related to high investment costs in new technologies. But in macroeconomic perspective any non-implementation of measures would lead to even higher expenses in the long run, especially in environmental damages.

Session 16:15 – 17:15

Modelling Aspects of Energy Markets

Room: St. Petersburg Hall
Chair: David Schönheit (TU Dresden)

Impact of Different Generation Shift Key Strategies on the Flow-based Market Coupling Domain in Germany

Richard Weinhold, TU Berlin

Acceleration strategies of the Generation Expansion Problem by Bender Decomposition

Matthias Zech, TU Dresden

Forecasting negative market prices at power exchanges using transformation approaches
Benjamin Aust, TU Bergakademie Freiberg

Impact of Different Generation Shift Key Strategies on the Flow-based Market Coupling Domain in Germany

Richard Weinhold, *TU Berlin, riw@wip.tu-berlin.de*
David Schönheit, *TU Dresden, david.schoenheit@tu-dresden.de*
Constantin Dierstein, *TU Dresden, constantin.dierstein@tu-dresden.de*

Overview

Due to the EU's goal of a liberalized single market for electric energy, based on the principle of market coupling, the accuracy of cross-border capacity calculation allocated to the market becomes increasingly important. Flow-based market coupling (FBMC), introduced in 2015 in the CWE region, better represents the network constraints by incorporating a simplified grid. The FBMC can therefore find a market optimum which was previously not obtainable. The FBMC algorithm heavily depends on zonal Power Transfer Distribution Factors (PTDFs), which express how zonal net position changes affect the critical network elements. These zonal PTDFs are obtained through nodal PTDFs, which are derived from the technical parameters of the line the so-called Generation Shift Keys (GSKs). GSKs try to predict, which nodes, i.e. which generating units, participate in net position changes, which stem from differences between the 2-Days Ahead Congestion Forecast (D2CF, also referred to as "base case") and the desired market outcome in the day-ahead market. The GSK strategy determines how GSK values are obtained and how nodes are weighted, i.e. quantifying the nodal contribution to net position changes. While PTDFs can thus mainly be traced back to given technical values, GSKs are determined using strategies based on the experience of the TSOs. Accordingly, there are several strategies within the FBMC algorithm, which are considered critical for the FBMC domain.

Methods

The aim of this paper is to quantify the effect of different GSK strategies on the FBMC domain in Germany. This results in three main parts:

1. Obtaining a synthetic base case: It is crucial to make sensible assumptions regarding the planned D-2 dispatch, which can be either an endogenous result of the model or based on historic data.

2. Compiling zonal PTDF matrices through different GSK strategies. The challenge for GSK strategies is the accuracy of GSK values, i.e. choosing appropriate weights, as well as the decision, which units to include in the GSK.

3. Computing the desired market outcome (D-1 dispatch) and the corresponding FBMC domain arising from the different GSK strategies, including the cleared cross-border capacities for each CWE border.

This procedure is implemented as an open source model, written in Python and Julia and the data is drawn from the Open Power System Data platform1. The procedure is based on the actual FBMC algorithm and allows to quantify the differences between the strategies.

Results

The results show that different GSK strategies have a significant impact on the FBMC Domain for D-1 market clearing. In the statistical analysis of the results provides insights into how the domains are composed, i.e. which lines are most relevant for the outcome, and how much capacity is made available for each GSK strategy. This way we can quantify what strategy is the most beneficial in a real-world application.

Acceleration strategies of the Generation Expansion Problem by Bender Decomposition

Matthias Zech

TU Dresden

Optimization models are complex but powerful tools to appropriately model the reality. Despite enormous gains of computation power and memory during the last decades, large-scale models often are simplified or not solved to optimality. This diploma thesis analyzes decomposition techniques namely Benders Decomposition for large-scale linear programs to accelerate computation times and to decrease memory requirements. Several modifications of the implementation and the formulation of Benders Decomposition are explained, applied and tested in two computational benchmarks. The first benchmark compares GAMS and Julia for solving large-scale stochastic programs responding to the rising research interest of open source modeling languages in energy system modeling. It shows Julia as a promising alternative which is particularly performant when applied in combination with Benders Decomposition. In the second benchmark, a new hybrid Screening Curve-Benders Decomposition algorithm is developed and several algorithmical implementations are investigated. The Dispa-SET model is extended in this thesis by the capacity expansion decision and the developed algorithm is applied on this Generation Expansion Problem. Large performance gains are obtained while satisfying high accuracy requirements.

This is the first algorithmical implementation combining Screening Curves method and general optimization problems.

Forecasting negative market prices at power exchanges using transformation approaches

Benjamin Aust[1]*, Andreas Horsch[1], Tony Klein[2], Thomas Walther[3,4], Florian Ziel[5]

[1] Technical University of Freiberg, Chair of Investment and Finance, 09599 Freiberg, Germany.
[2] Queen's University Belfast, Queen's Management School, BT9 5EE Belfast, UK.
[3] University of St. Gallen, Institute for Operations Research and Computational Finance, 9000 St. Gallen, Switzerland.
[4] Technische Universität Dresden, Faculty of Business and Economics, 01062 Dresden, Germany.
[5] University of Duisburg-Essen, Environmental Economics, esp. Economics of Renewable Energy, 45127 Essen, Germany.
** Correspondence concerning this article should be addressed to benjamin.aust@bwl.tu-freiberg.de.*

Keywords: negative energy prices; price forecasting; price transformation; power exchange

Due to the stylized facts of energy spot prices, forecasting represents a particularly tough challenge for market participants trading at power exchanges. Aside from (regular) volatility, mean reversion and seasonality, sudden price spikes impact predictions' accuracy negatively (Eydeland & Wolyniec, 2003 and Ignatieva & Trück, 2016), thus increasing the probability that the predicting party acts on wrong assumptions and misses financial targets. As negative energy prices are hardly predictable events (Keles/Genoese/Möst/Fichtner, 2012), they foremost contribute to variance instability, as current forecasting models usually contain raw untreated price data. Excluding those negative values from the underlined dataset could lead to inferior forecasting results (Fanone/Gamba/Prokopczuk, 2013). Hence, time-varying volatility models combined with price data transformation approaches should be designed to address this issue. Considering the day ahead market design, and in line with the relevant literature, 24 individual ARX-GARCHX models reflecting each trading hour during a single day (Ziel/Weron, 2016) are applied. Based hereupon, several transformation approaches (e.g. Uniejewski/Weron/Ziel, 2017 and Trück/Weron/Wolff, 2007) to modify raw price data in order to enhance forecasting robustness are considered. In addition to established transformations (e.g. Box-Cox or 3sigma), further statistical approaches are applied to the whole data set addressing their comparability with each other as they adhere to the assumption of being transferable for positive and especially negative values, respectively. In order to assess which transformation leads to increased forecasting precision, probabilistic evaluation measures such as the pinball score are employed to evaluate the individual performance of each specification. As negative energy prices, being mostly driven by large amounts of renewable energies infeed, display a relatively common phenomenon in the European day ahead markets, the analysis focuses exclusively on the German/Austrian bidding zone. In order to compile a sound sample, day ahead prices on an hourly basis covering a period from 2012 until 2017 are taken into account, which is retrieved from EPEX Spot. In addition, energy volumes from wind and photovoltaic infeed forecasts as well as associated load complete the database.

JEL classification: C53, Q41, Q47

Session 16:15 – 17:15

Transition of the transport sector

Room: Florenz Hall
Chair: Michael Burkhardt (TU Dresden)

Charging infrastructure business models and policies for electric vehicles in Karnataka

A.M. Nagaraj, Dayananda Sagar College of Engineering

The effect of digitalization on the energy consumption of the EU passenger transport

Michel Noussan, Fondazione Eni Enrico Mattei

Decarbonizing Public Transport: Implementing the Transition to Zero Emissions
Elisa Claus, KCW GmbH

Charging infrastructure business models and policies for electric vehicles in Karnataka

A M Nagaraj[1] ,Roopadarshini S[2], Vidya M[1], Nandan N[1]

[1]*Dayananda Sagar College of Engineering, Bangalore, India*
nagaraj-eee@dayanandasagar.edu,
nandan-eee@dayanandasagar.edu
vidya-eee@dayanandasagar.edu
[2]*Visvesvaraya Technological University*
Center for PG studies, Bangalore, India
roopadarshni@vtu.ac.in

Keywords: Electric vehicle, Electricity tariff, charging station, Capital Expenditure.

Motivation

The shift to electric mobility has become necessary due to the fast depletion of fossil fuels, increase in energy cost, impact of transportation on the environment and concerns over climate change. Electric vehicles are eco friendly from systemic stand point, cheaper fuel cost, lower maintenance expenses etc. with an emphasis on public charging facilities. Public charging infrastructure is a key to growing the electric vehicle market. As the global electric vehicle market grows there will be need for much more public charging infrastructure. Open standards for vehicle–charge point communication and payment may mitigate fragmentation, inconsistent data availability, and a lack of consistent standards in most markets enabling interoperability between charging networks, increasing innovation and competition and reducing costs to the users.

Methods

The business model for public charging infrastructure is to sell electricity with a sufficient markup to recover the cost of the charging infrastructure. Types of EV charging equipments, charging rate of batteries, EV equipment standards, ownership of EV charging station, Land requirement for EV charging station, electricity tariff and grid upgrade cost are the factors to be considered. The capital expenditure and operational expenditure of a typical EV charging Station with one Bharat Charger, one AC Type-2 charger and one CCS 2 ,DC Fast Charging (25 kW) are estimated. In line with central Government guide lines and standards for Electric vehicles charging, state has adopted a Karnataka Electrical Vehicle and energy storage policy-2017 to motivate the electric mobility sector and also attract investments. The expansion of charging infrastructure networks will create many opportunities.

Results

The outcome of policy measures with special initiatives for EV manufacturing includes parks/zones, transport, non-transport, goods transport vehicles, facilitation to EV battery and charging equipment manufacturing, support for charging infrastructure, Research and development. As with the broader electric vehicle market, charging infrastructure is changing quickly, causing further challenges beyond responding to the growth in charging. It is important that governments and the private sector coordinate their deployment activities to ensure that convenient, affordable, and reliable public charging infrastructure is available to all electric vehicle users.

The effect of digitalization on the energy consumption of the EU passenger transport

Michel Noussan[1] and Manfred Hafner[1]

[1]*Johns Hopkins University SAIS-Europe, SciencesPo PSIA, Fondazione Eni Enrico Mattei, Italy, michel.noussan@feem.it, manfred.hafner@feem.it*

Keywords: Digitalization, Transport, Mobility, Energy consumption, EU

Motivation

The transport sector in Europe is still heavily relying on fossil fuels and on private cars, but digital technologies are playing a major role in unleashing possible alternatives to the current mobility models. Mobility as a Service, Shared Mobility and Autonomous Vehicles are also strictly related to the strong push towards the diffusion of Electric Vehicles, which currently appears as the most supported solution by companies and regulators to decarbonize the transport sector.

Methods

This work is based on a data-driven model for the calculation of the impacts of mobility demand in Europe in terms of final and primary energy consumption and GHG emissions. Alternative scenarios are used to compare the effects of different digitalization evolutions, starting from an exogenous demand for transport and considering the evolution of each transport mode and energy source, by defining relevant parameters (including vehicle efficiency, average load factor, etc.).

Results

The results show that digitalization may have a positive effect on energy consumption and GHG emissions for passenger transport, and the benefits are maximized if digital technologies are used towards a collective optimization, by increasing the share of available mobility options. Conversely, if digital technologies are limited to increase the quality of private mobility, the environmental benefits will likely remain very limited.

Decarbonizing Public Transport: Implementing the Transition to Zero Emissions

Elisa Claus[1], Nabil Nakkash[1]

[1]*KCW GmbH*

With the ratification of the Paris Climate Agreement, the European Union (EU) has committed themselves to reducing greenhouse gas (GHG) emissions in such a way that global warming is limited to a maximum of 2°C, in the best case even less than 1.5°C, compared to the pre-industrial era. In order to achieve this goal in the transport sector for example, Germany has committed itself to reducing GHG emissions by 40-42% by 2030 and by 95-100% by 2050 compared to 1990.

Where other sectors of the economy have achieved massive reductions in their emissions, the transport sector has faltered. In order to have a chance to meet the goals set by the EU the "decarbonization" of public transport, i.e. the switch to non-fossil propulsion systems, must be achieved by the mid-2030s. Through the Clean Vehicle Directive the EU Council aims to promote increased use of zero- and low-emission vehicles by setting out minimum procurement targets for buses for each 2025 and 2030. If these targets are to be met, immediate action is necessary in order to have the appropriate infrastructure in place by that time.

This paper will take a general look at the urgent need of decarbonizing the transport sector and the ambitious regulatory instruments and goals the EU has put to achieve this feat. It will discuss how the change to zero-emission vehicles will have an effect on the business models currently used by public transport operators. As an example, the paper will share the results of a tool developed by KCW that estimates the additional costs that will arise due to the "decarbonization" of public transport in Austria. The paper will conclude by discussing what options cities and countries have to fund the transition.