Working Group on Energy
Arbeitskreis Energie (AKE)

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Overview of Invited Talks and Sessions

(Lecture hall AKE-H16)

Plenary Talk by AKE

PV IV	Tue	8:30– 9:15	Audimax	**Reduce, Reuse, 'Restore'. GHG Emissions from the Viewpoint of a Rock Physicist** — •Frank R. Schilling

Invited Talks

AKE 1.1	Tue	10:30–11:00	AKE-H16	**Ammoniak als Schiffsantrieb** — •Angela Kruth
AKE 2.1	Tue	13:30–14:00	AKE-H16	**Systemstudien von Fusionskraftwerken** — •Jorrit Lion
AKE 3.1	Wed	14:00–14:30	AKE-H16	**The perspective of plasma conversion within the Power-to-X initiative** — •Ursel Fantz, Ante Hecimovic, David Rauner

Sessions

AKE 1.1–1.6	Tue	10:30–12:30	AKE-H16	**AKE 1**
AKE 2.1–2.4	Tue	13:30–14:45	AKE-H16	**AKE 2**
AKE 3.1–3.4	Wed	14:00–15:15	AKE-H16	**AKE 3**

AKE 1: AKE 1

Time: Tuesday 10:30–12:30 Location: AKE-H16

Invited Talk AKE 1.1 Tue 10:30 AKE-H16
Ammoniak als Schiffsantrieb — •Angela Kruth — Leibniz-Institut Plasmaforschung und Technologie (INP), Greifswald

AKE 1.2 Tue 11:00 AKE-H16
Net-zero greenhouse gas emission in 2045 - A challenge for the Energy Infrastructure — •Tanja Kneiske — Fraunhofer IEE, Königstor 59, 34119 Kassel

The focus of this contribution is on the transformation of the energy infrastructures to reach the new climate targets. Therefore the main challenges for the energy grids are presented which is the integration of renewable energy resources but also electric vehicles, heat pumps and electrolysers while providing energy reliable for the customers. The contribution will give a holistic view on the connection between the expansion planning of power grids, the transformation of gas grids to a new hydrogen infrastructure and the challenge of installing more low exergy heating grids. A connection of the results from national energy system optmization models with regional energy system simulations in cities and districts will lead to an integrated transformation path.

AKE 1.3 Tue 11:15 AKE-H16
Sektorenkopplung mit dem Entropiesatz - Exergy is the Economy! — •Gunnar Kaestle[1] und Olaf Schilgen[2] — [1]Clausthal-Zellerfeld, Deutschland — [2]Schandelah, Deutschland

Im Rahmen der Sektorenkopplung ist die Beachtung des Arbeitswertes der Energie (Exergie) wesentlich, da die Energie eine Erhaltungsgröße ist, nicht aber die Exergie. Letztere ist das knappe Gut. Exergieverluste bei der Energiewandlung können als variable Kosten angesehen werden.

Bei einer rein monetären Optimierung besteht die Gefahr eines Zirkelschlusses: der Geldwert (Inflation) definiert sich über einen Warenkorb und das Bruttoinlandsprodukt (BIP) wird wiederum in Geldeinheiten gemessen, d. h. Geld als Maßstab ist relativ.

Die Exergie, die zur Herstellung von Waren und Gütern sowie Erbringung von Dienstleistungen benötigt wird, ist daher eine einheitliche physische Eigenschaft aller Teile des BIP. Sie ist eine absolute Größe. Der Exergieverbrauch wird somit als zu messende Eigenschaft von Volkswirtschaften vorgeschlagen. Dieses physische Maß stellt 100% des BIP-Warenkorbs dar und kann einer Geldmenge gegenübergestellt werden. Die Erfassung wirtschaftlicher Aktivitäten kann auf diese Weise sowohl monetär als auch physisch erfolgen. Die Grenzen wirtschaftlichen Wachstums ergeben sich in Abhängigkeit der verfügbaren Exergie.

Um die Größen Energie und Exergie zu unterscheiden, sollten unterschiedlichen Einheiten verwendet werden, z. B. Joule und Rant.

AKE 1.4 Tue 11:30 AKE-H16
Controlling volatility of wind-solar power in Germany — •Hans Lustfeld — Peter Grünberg Institut (PGI-1), Forschungszentrum Jülich, 52425 Jülich, Germany.

The main advantage of wind-solar power is the electric power production free of CO_2. Its main disadvantage is the huge volatility of the system. In fact, if the power production, averaged over one year, corresponds to the averaged electric consumption and is intended to replace all other electric power generating devices, then controlling the volatility of this system by using storage alone requires huge capacities of about 30TWh, capacities not available in Germany. However, based on German power data over the last six years (2015 till 2020) we show that the required storage capacity is decisively reduced, provided i) a surplus of wind-solar power is supplied, ii) smart meters are installed, iii) a different kind of wind turbines and solar panels is partially used, iv) a novel function describing this volatile system, is introduced. The new function, in turn, depends on three characteristic numbers, which means, that the volatility of this system is characterized by those numbers. Our results suggest that all the present electric energy in Germany can be obtained from controlled wind-solar power. And our results indicate that controlled wind-solar power can in addition produce the energy for transportation, warm water, space heating and in part for process heating, requiring an increase of the electric energy production by a factor of 5. Then, however, a huge number of wind turbines and solar panels is required changing the appearance of German landscapes fundamentally.

15 min. break

AKE 1.5 Tue 12:00 AKE-H16
Sustainable energy for research facilities in Europe — •Johannes Hampp and Michael Düren — Center for international Development and Environmental Research, Justus-Liebig University Giessen

Energy imports from countries with abundant wind and solar resources are considered to take on a key role in the European energy transition. Wind and solar power can be converted to chemical energy carriers like hydrogen and then imported by ship or pipeline for subsequent conversion back to electricity and (waste) heat. Inherent to this supply chain are conversion losses, typically of factor 2-3 of the final electricity provided. A more efficient and economic solution is importing electricity directly using high voltage direct current (HVDC) lines.

We propose a pilot project which could be pushed by the European Scientific Community, e.g. lead by CERN, to overcome the barriers and to secure low-cost and sustainable energy supply for European research institutions. Historically, political and economic barriers hindered such projects, prominently DESERTEC 15 years ago. Recent projects like XLink's Morocco-UK-Link are demonstrating this idea's feasibility and opportunities. In our proposed project, electricity could be imported from renewables out of Algeria or Tunisia via undersea HVDC lines to e.g. southern France, where a suitable power network to CERN and other research centres already exists.

Using techno-economic modelling we provide insights on the infrastructure scale and economics of such a project. We investigate the influence of different demand cases and explore alternative options.

AKE 1.6 Tue 12:15 AKE-H16
A Monte-Carlo assessment of the effects of long-term changes on residential energy supply systems — •Elif Turhan and Patrik Schönfeldt — DLR-Institut für Vernetzte Energiesysteme, Oldenburg, Deutschland

Space heating accounts for approximately one third of the global final energy consumption in both the residential and the commercial building sub-sectors. Including hot water, the 2010 IPCC report on buildings attributes 53% of the total final energy demand of the worldwide building sector to the demand for low temperature heat. At the same time, according to the IEA, the share of renewable energy supply in 2019 only met 11% of the global heat demand, leading to a domination of fossil fuels in this sector, contributing 40% (13.3 Gt) of global CO2 emissions. While these facts underline the need for fast changes, in particular integrating the sectors of heat and electricity, decisions should also include long foresight: Once installed, such systems typically operate for decades.

This contribution presents a risk analyses of long-term changes on the national scale on different energy supply systems at the district scale. For example, the effect on changing capacity of renewable electricity generation on the CO2 emissions caused by the residential energy demand is assessed. To evaluate the uncertain characteristic of the future, a probabilistic scenario space is spanned instead of working with distinct scenarios. This space is then sampled using the Monto Carlo method, resulting in probability density functions for previously defined key performance indicators.

AKE 2: AKE 2

Time: Tuesday 13:30–14:45 Location: AKE-H16

Invited Talk AKE 2.1 Tue 13:30 AKE-H16
Systemstudien von Fusionskraftwerken — •Jorrit Lion — Max-Planck-Institut für Plasmaphysik, Greifswald

AKE 2.2 Tue 14:00 AKE-H16
Techno-socio-economic energy system optimization: A pareto-based approach — •Patrik Schönfeldt — DLR-Institut für Vernetzte Energiesysteme, Oldenburg, Deutschland

To meet the 1.5 °C goal of the Paris agreement, a rapid transition of energy supply is needed. Not only fossil based thermal power plants have to be replaced, but also 89 % of the global heat supply. While this parallel transition might be challenging, it also offers the chance to lift the potential of mutual benefits, i.e., the electricity sector can benefit from the integration as the sector coupling can provide flexibility. In this context, automatic optimisation routines can aid finding solutions that are not just feasible but also meet other demands, such as affordability. However, different stakeholders often have deviating, sometimes even contradicting demands for qualities of energy systems. Even affordability might be read in different ways. Also, we find ourselves in a situation where physics and regulations might not overlap.

This contribution presents an approach designed to explore the space of optimal solutions, facilitating informed decisions, including the weighting of various design goals, late in the planning process. The contribution also gives examples, where the energy system model has to deviate from the actual physical system. The Energetisches Nachbarschaftsquartier (ENaQ) serves as a case study for this approach. Its boundary conditions are shortly outlined and example results are assessed.

AKE 2.3 Tue 14:15 AKE-H16
Space-charge-mediated phenomena at oxide interfaces for electrochemical water splitting — •Felix Gunkel[1], Moritz Weber[1], Lisa Heymann[1], Anton Kaus[1], and Christoph Baeumer[2] — [1]PGI-7, FZ Jülich — [2]Twente University

Complex oxides have evolved as a major class of functional energy materials applied in a wide range of energy conversion and storage appraoches which harvest the ability to precisely tailor and combine oxides on the nanoscale. Heterogeneous interfaces of oxides enable the exchange of ionic and electronic defect species between the neighboring materials, giving rise to electronic-ionic charge transfer and space charge formation. Such space charge regions typically possess distinctly different material properties as compared to the bulk and allow tailoring and tuning of ionic-electronic properties by intentional design of interfaces. Here, we will discuss how dedicated design and understanding of interfacial space charge phenomena can be used to tailor electronic and ionic charge transport along and across electrochemically active oxide interfaces and surfaces, with particular focus on the role of space charge at solid-liquid interfaces operating in alkaline water splitting. As will be shown the dedicated control of the surface band structure of oxide catalysts via space charge can be used to mediate activity for oxygen evolution reaction, while the mass transport across the interface is responsible for the degradation and limited lifetime of the catalysts. In this way, the control of space charge and electronic structure can be used to realize hybrid catalysts that attempt to break classical scaling relations of electrochemical activity and stability.

AKE 2.4 Tue 14:30 AKE-H16
Investigating potential climatic side-effects of a large-scale deployment of photoelectrochemical devices for carbon dioxide removal — •Moritz Adam[1], Thomas Kleinen[2], and Kira Rehfeld[1,3] — [1]Institut für Umweltphysik, Heidelberg, Germany — [2]Max-Planck-Institut für Meteorologie, Hamburg, Germany — [3]Geo- und Umweltforschungszentrum, Tübingen, Germany

Integrated assessments of economy and climate favour CO_2 removal from the atmosphere to reach ambitious temperature-stabilization targets by 2100. However, most of the proposed approaches are in conflict with planetary boundaries and they may come with unintended climatic side-effects. Draw-down of CO_2 by photoelectrochemical (PEC) reduction is a recent and promising approach (May & Rehfeld, ESD 10, 1-7 (2019)). If adjusted for high solar-to-carbon efficiencies, PEC devices would require comparably little land for achieving annual CO_2 abstraction rates compatible with limiting global warming to 2°C or below. Yet, their climatic side-effects are unknown. Here, we discuss our work towards investigating potential impacts of PEC CO_2 removal on climate and carbon cycle in simulations with a comprehensive Earth System Model. We plan to compare potential side-effects for localized and delocalized PEC deployment. We expect delocalized setups to have only little impact on climate and to minimize carbon emissions due to land use change, while localized setups might alter circulation patterns and could impact carbon stocks significantly. Still, PEC devices remain costly and in development, leaving emission reductions as the only appropriate measure for stabilizing anthropogenic warming.

AKE 3: AKE 3

Time: Wednesday 14:00–15:15 Location: AKE-H16

Invited Talk AKE 3.1 Wed 14:00 AKE-H16
The perspective of plasma conversion within the Power-to-X initiative — •Ursel Fantz[1], Ante Hecimovic[1], and David Rauner[2] — [1]Max-Planck-Institut für Plasmaphysik, Boltzmannstr. 2, 85748 Garching — [2]AG Experimentelle Plasmaphysik, Universität Augsburg, Universitätsstr. 1, 86159 Augsburg

The Power-to-X initiative refers to various technologies for storing or using surplus electricity of variable renewable energies such as solar energy, wind energy and hydropower to convert the power into gas, heat or liquids. Using plasma technology for conversion of low energy molecules into value-added chemicals (following the Power-to-Gas route) is a promising approach: plasmas provide a fast response time and high throughput, are tolerant against impurities and operate different gases in a wide parameter range. Various plasma reactor concepts for formation of syngas, hydrogen, and ammonia are presently under investigation at the technology readiness level of about three to four. Within the plasma activities embedded in the Research Field “Energy” of the Helmholtz Association an atmospheric plasma torch is investigated. Its goal is to established the plasma route and develop a prototype reactor. A near future milestone is the performance comparison of plasma CO_2 conversion into CO including the gas separation process with low temperature and high temperature electrolysis. These facets of the plasma technology and its perspective to contribute to the PtX route will be highlighted in the presentation.

AKE 3.2 Wed 14:30 AKE-H16
Konzentrierende Solarsysteme mit IR-PV-Modul für solare Photobioreaktoren der nächsten Generation — •Markus Sauerborn und Joachim Göttsche — Solar-Institut Jülich, FH Aachen, D-52428 Jülich

Am Solar-Institut Jülich werden in Kooperation mit Instituten der Mikrobiologie solare Photobioreaktoranlagen der nächsten Generation entwickelt. Mit der aktuellen Entwicklung sollen kombinierten Versorgungssysteme für Mikroalgenkulturen für verschiedene Nutzungskonzepte ausgelegt und energetisch optimiert werden. Allgemein vielversprechend ist hier, dass aus Zivilisationsabwässern effektiv Nährstoffe gewonnen werden können, um so Nährstoffkreisläufe zu forcieren oder besondere Schadstoffbelastungen zu vermeiden. Für die in den Projekten vorliegenden Rahmenbedingungen wurden jeweils geeignete Bestrahlungssysteme konzipiert. Während im Projekt AlgNutrient eine Solaranlage für eine PBR-Tankanlage und mit Upscaling-Ziel zur Großanlage konstruiert wurde, stand in AlgaeSolarBoxes als Vorgabe eine containerbasierte mobile Kleinanlage im Fokus der Entwicklung. Abgeschlossenen solaren Bioreaktoren wirken mit ihrer optimierten Lichtaufnahme als Strahlfalle. So wird auch die von der Photosynthese nicht verwertbare IR-Strahlung verstärkt absorbiert und durch reduzierte Abstrahlung entsteht Stauwärme. Ein neuartiges IR-PV-Modul nutzt spektrale Aufspaltung des Solarstrahls und verwertet den selektierten IR-Anteile des Sonnenlichtes durch geeignete PV-Zellen. Das Gesamtsystem erhöht damit die Gesamtenergieeffizienz und wird energetisch autarker.

AKE 3.3 Wed 14:45 AKE-H16

Broadband dielectric spectroscopy on lithium-salt-based and choline-chloride-based DESs — •Arthur Schulz, Peter Lunkenheimer, and Alois Loidl — University Augsburg, Experimental Physics V, Augsburg, Bavaria

We have performed broadband dielectric spectroscopy (BDS) on three Lithium-salt-based deep eutectic solvents (DESs) - systems where the only cation is Li+ - covering a broad temperature and frequency range that extends from the low-viscosity liquid around room temperature down to the glassy state approaching the glass-transition temperature. We observe a relaxational process that can be ascribed to dipolar reorientational dynamics and exhibits the clear signatures of glassy freezing. We find that the temperature dependence of the ionic dc conductivity and its room-temperature value also are governed by the glassy dynamics of these systems, depending, e.g., on the glass-transition temperature and fragility. Compared to previously investigated systems, containing the same hydrogen-bond donors and choline chloride instead of a lithium salt, both the reorientational and ionic dynamics are significantly reduced due to variations of the glass-transition temperature and the higher ionic potential of the lithium ions. Additionally, we analyzed a range of deep eutectic systems composed of choline chloride and a carboxylic acid (e.g., maline, for which a relatively high room-temperature conductivity was reported) using BDS. The nature of the observed dynamic processes, as well as the evidence for and strength of their coupling are compared to previously investigated choline-chloride-based DESs.

AKE 3.4 Wed 15:00 AKE-H16

Multiphysical Simulation of a PEMFC — •Fabian Gumpert[1], Lara Kefer[1], Susanne Thiel[2], Maik Eichelbaum[2], and Jan Lohbreier[1] — [1]Technische Hochschule Nürnberg, Applied Mathematics, Physics and Humanities, Germany — [2]Technische Hochschule Nürnberg, Applied Chemistry, Germany

Proton Exchange Membrane Fuel Cells (PEMFC) excel through their high power density and dynamic behavior making them promising candidates for future mobile sources of energy. In a fuel cell hydrogen and oxygen combine in a redox reaction to water thereby releasing electrical energy. But many parameters which determine the performance and lifetime of the PEMFC are experimentally difficult to access. Finite-element-method (FEM) simulations are utilized to solve coupled differential equations to numerically study these parameters.

First of all, voltage-current curves which are commonly used to describe the properties of power sources are modelled. The numerical results show good qualitative agreement with experimental data. This is also true for the computed temperature distribution in the PEMFC, which was compared with data from a laboratory-sized setup. For the performance of the fuel cell it is critical that the relative humidity of the membrane stays in a specific range. Only when the water content is sufficient the polymer membrane is permeable for hydrogen ions. As indicated above, this parameter is hardly measurable; it can only be investigated with the use of multiphysical simulations. We combine exterior experimental data and numerical models of the interior to draw conclusions about the water content within the fuel cell.