Arbeitskreis Energie (AKE)

Hardo Bruhns
Meliesallee 5
40597 Düsseldorf
ake@bruhns.info

The programme of the Energy Working Group (Arbeitskreis Energie, AKE) presents a wide range of energy technologies based on geological, chemical and physical research in conjunction with engineering developments. Furthermore, the evening talk of the conference – presented by M. Winter – is thematically associated to the AKE programme. The sequence of sessions is imposed to some extent by constraints in the availability of the speakers.

The relevance of the German "Energiewende" is increasingly being put into context by the rapid international evolution of energy generation and use. In particular renewable energies push the role of electricity as the future key energy vector both for stationary applications and for the mobility sector. Wind (AKE 6) and photovoltaic generation (AKE 2) dominate; both are areas with continuing substantial developments. However, their strongly fluctuating power output imposes a reconsideration of the classical electricity systems (AKE 7). In this context the development of batteries and fuel cells (AKE 1) and of chemical storage and sector coupling (AKE 8) is pursued actively in order to mitigate the temporal imbalance between generation and demand.

While the global market for electrical individual mobility is rapidly evolving (AKE 1), alternative combustion fuels are considered for improving the environmental balance of air traffic (AKE 9).The German regulatory mechanisms for supporting the mass market of clean energy technologies are discussed in the session (AKE3).

CO_2 sequestration and storage is discussed for mitigating the atmospheric green-house effect. If it shall play a role, then huge volumes for safe geological CO_2 storage will be needed (AKE 10). Fusion research is pursued in a future perspective for clean and safe electricity generation (AKE 4). It would massively reduce the need of dealing with long-term storage of nuclear waste which, together with the associated decommissioning, continues to be a most relevant issue for current fission reactor technology (AKE 5) as are the safety and security aspects (AKE 11, a joint AKE/AGA session).

Übersicht der Hauptvorträge und Fachsitzungen

(Hörsaal S Aula)

Hauptvorträge

AKE 1.1	Mo	9:00– 9:30	S Aula	**Energy Density, Lifetime and Safety - Not Only an Issue of Lithium Ion Batteries** — •Martin Winter, Falko Schappacher, Markus Börner, Alex Friesen
AKE 1.2	Mo	9:30–10:00	S Aula	**Fuel Cells - A complement and an Alternative to Batteries on the Path to Application** — •K. Andreas Friedrich
AKE 2.1	Mo	11:00–11:30	S Aula	**Roadmap and roadblocks for multi-junction device technology based on metal halide perovskites** — •Eva Unger
AKE 3.1	Mo	16:45–17:15	S Aula	**Die Defizite der Energiewende** — •Manuel Frondel
AKE 4.1	Mo	17:15–17:45	S Aula	**Fusion Research - recent progress and perspectives** — •Antonius Donné
AKE 5.1	Di	8:30– 9:00	S Aula	**Research for the safe management of nuclear waste** — •Dirk Bosbach
AKE 6.1	Di	9:00– 9:30	S Aula	**Smarte Rotoren für kosteneffiziente Windenergieanlagen** — •Jan Tessmer
AKE 6.2	Di	9:30–10:00	S Aula	**Beiträge der Windphysik zum Ausbau der Windenergienutzung** — •Martin Kühn
AKE 7.2	Di	10:15–10:45	S Aula	**Surplus electricity and storage under conditions of intermittent supply** — •Friedrich Wagner
AKE 8.1	Di	11:00–11:30	S Aula	**Power to Gas Konzepte für die Energiewende** — •Frank Graf
AKE 8.2	Di	11:30–12:00	S Aula	**Sektorenkopplung als Teil der Energieversorgung von morgen** — •René Schoof

AKE 9.1	Di	16:45–17:15	S 8	**Verändern alternative Treibstoffe die Emissionen des Luftverkehrs und seine Klimawirkung?** — •Christiane Voigt
AKE 10.1	Di	17:15–17:45	S 8	**Geological CO_2 storage - concepts and state of knowledge** — •Axel Liebscher
AKE 11.1	Mi	16:45–17:15	S Aula	**Nuclear Power and Nuclear Safety Post Fukushima** — •Christoph Pistner, Matthias Englert
AKE 11.2	Mi	17:15–17:45	S Aula	**Safeguards and Non-Proliferation experience from an IAEA perspective** — •Tariq Rauf
AKE 11.3	Mi	17:45–18:15	S Aula	**Civil Nuclear Power - The Cyber Security Perspective** — •Guido Gluschke

Fachsitzungen

AKE 1.1–1.2	Mo	9:00–10:00	S Aula	**Electrochemical Storage: Batteries and Fuel Cells**
AKE 2.1–2.4	Mo	11:00–12:15	S Aula	**Renewable Energy: Photovoltaics**
AKE 3.1–3.1	Mo	16:45–17:15	S Aula	**Economics of Energy Supply and Use**
AKE 4.1–4.1	Mo	17:15–17:45	S Aula	**Future Perspectives: Fusion Energy Research**
AKE 5.1–5.1	Di	8:30– 9:00	S Aula	**Nuclear Decomissioning and Storage**
AKE 6.1–6.2	Di	9:00–10:00	S Aula	**Renewable Energy: Wind Energy**
AKE 7.1–7.2	Di	10:00–10:45	S Aula	**Renewable Energy: Aspects of Intermittent Generation**
AKE 8.1–8.5	Di	11:00–13:00	S Aula	**Sector Coupling, Chemical Conversion and Storage of Renewable Energy**
AKE 9.1–9.1	Di	16:45–17:15	S 8	**Alternative Fuels for Air Traffic**
AKE 10.1–10.1	Di	17:15–17:45	S 8	**Future Perspectives: CO_2-Storage**
AKE 11.1–11.3	Mi	16:45–18:15	S Aula	**Nuclear Energy and Security (Joint Session AKE-AGA)**

Mitgliederversammlung Arbeitskreis Energie

The annual members' meeting of the AKE (with elections of the AKE chairman and board) will be held during the AKE spring meeting in Bad Honnef on April 6 / 7, 2016.

AKE 1: Electrochemical Storage: Batteries and Fuel Cells

Zeit: Montag 9:00–10:00 Raum: S Aula

Hauptvortrag AKE 1.1 Mo 9:00 S Aula

Energy Density, Lifetime and Safety - Not Only an Issue of Lithium Ion Batteries — •Martin Winter[1,2], Falko Schappacher[1], Markus Börner[1], and Alex Friesen[1] — [1]MEET Battery Research Center, Westfälische Wilhelms-Universität Münster, Corrensstraße 46, 48149 Münster, Germany — [2]Helmholtz Institute Münster (HI MS), IEK-12, Forschungszentrum Jülich GmbH, Corrensstraße 46, 48149 Münster, Germany

Lithium ion batteries (LIBs) became the most important rechargeable electrochemical energy-storage system for portable consumer electronics devices and are presently advancing to a key technology for enabling the broad commercial launch of electric vehicles (EV). For a broad acceptance of this technology and a market breakthrough of EVs several issues have to be addressed to overcome customers' objections against this technology. The cruising range and hence the energy density (Wh/L) and specific energy (Wh/kg), respectively, is a most crucial parameter. Different cell chemistries are discussed as alternative for LIB to increase the energy density, but the advantages and disadvantages (e.g. energy density, lifetime and safety) of these so-called Post-LIB systems and other alternatives with respect to LIBs and advanced LIBs have to be compared carefully.

In this presentation, we will highlight the most recent findings in view of practically realizable specific energies and energy densities of various battery chemistriesas well as the safety and aging characteristics of LIBs and will compare it with state of the art technologies.

Hauptvortrag AKE 1.2 Mo 9:30 S Aula

Fuel Cells - A complement and an Alternative to Batteries on the Path to Application — •K. Andreas Friedrich — German Aerospace Center (DLR), Institute of Engineering Thermodynamics, Pfaffenwaldring 38-40, Stuttgart 70569, Germany

Fuel cells are acknowledged as essential parts of the necessary transition of the energy system as required by the commitments to climate protection in the frame of COP21 and COP22. Fuel cell development has reached an advanced maturity stage as demonstrated by the first series cars from Asian manufacturers, the approaching commercialization of stationary systems in Europe as well as the successful market penetration of residential fuel cell systems in Japan. With the advancement of fuel cell application in cars a concurrent built-up of a hydrogen refueling infrastructure is needed. The first hydrogen infrastructure areas are located in California, Germany and Japan. In order to achieve a global reach, however, much more efforts worldwide are needed. In this presentation an overview over the state-of-art of fuel cells, with a focus on polymer electrolyte membrane (PEMFC) and solid oxide fuel cells (SOFC) is given accompanied by a critical assessment of achievements and challenges. The advantages and disadvantages in comparison to other technologies, in particular batteries, is discussed. The system design of a hybrid fuel cell with a battery exhibits many beneficial properties that will be described. Finally, some applications are highlighted, e.g. propulsion of aircraft, in which fuel cells are a necessity to achieve the requirements.

AKE 2: Renewable Energy: Photovoltaics

Zeit: Montag 11:00–12:15 Raum: S Aula

Hauptvortrag AKE 2.1 Mo 11:00 S Aula

Roadmap and roadblocks for multi-junction device technology based on metal halide perovskites — •Eva Unger — Department of Chemistry, Lund University, Lund, Sweden — Helmholtz Center Berlin for Materials and Energy, Berlin, Germany

Solar cells based on metal-halide perovskite semiconductors inspire high hopes for efficient low-cost solar cell technology. These materials are promising to realize efficient tandem solar cell technology compatible with conventional solar cell technology based on silicon. Multijunction solar cell devices with efficiencies exceeding 30% could be achieved by boosting silicon solar panels with a device based on absorber materials with optical band gaps of about 1.7 eV. In this respect, the ease of tuning the optical properties of metal halide perovskite materials and the possibility to achieve highly efficient devices entirely by solution-based deposition methods make this class of evolving semiconductors an ideal case to develop low-cost and scalable multi-junction device technology. This talk will give an overview over the state of the art and current performance metrics of metal-halide perovskite device technology. Close to the ideal band gap for absorbers for tandem solar cell stacks of 1.7 eV, the onset of photo-induced halide migration becomes limiting to the open circuit voltage indicating an intriguing but potentially hampering intrinsic properties of metal halide perovskites to their application in solar energy conversion devices.

AKE 2.2 Mo 11:30 S Aula

Highly Stable and Efficient Perovskite Solar Cells Via Multication Engineering — •Michael Saliba, Anders Hageldt, and Michael Graetzel — EPFL, Lausanne, Switzerland

Perovskites have emerged as low-cost, high efficiency photovoltaics with certified efficiencies of 22.1%. The perovskites used for solar cells have an ABX3 structure where the cation A is methylammonium (MA), formamidinium (FA), or Cs; the metal B is Pb; and the halide X is Br or I. Unfortunately, single-cation perovskites often suffer from phase, temperature or humidity instabilities. This is particularly noteworthy for CsPbX3 and FAPbX3 showing a photoinactive yellow phase at room temperature instead of the more desired photoactive black phase.

Here, we investigate triple cation (with Cs, MA, FA) perovskites resulting in significantly improved reproducibility and stability. We then use multiple cation engineering as a strategy to integrate the seemingly too small Rb (that never shows a black phase as a single-cation perovskite) to study novel multication perovskites.

One composition containing Rb, Cs, MA and FA resulted in a stabilized efficiency of 21.6%. The open-circuit voltage of 1.24 volts at a band gap of 1.63 eV leads to a very small loss-in-potential of 0.39 V, versus 0.4 V for commercial silicon cells. Polymer-coated cells maintained 95% of their initial performance at 85°C for 500 hours under full solar illumination and maximum power point tracking.(1)

(1) Saliba et al., Incorporation of rubidium cations into perovskite solar cells improves photovoltaic performance. Science (2016).

AKE 2.3 Mo 11:45 S Aula

Growth-control of the ordered double-perovskite stucture in $(Pr_{0.5}Ba_{0.5})CoO_{3-\delta}$ thin films — •Gunkel Felix[1], Hausner Clemens[2], David N. Müller[2], Daniel Bick[1], Lei Jin[3], Chunlin Jia[3], Theo Schneller[1], Ilia Valov[2], and Dittmann Regina[2] — [1]Institute of Electronic Materials (IWE2), RWTH Aachen University — [2]Peter Grünberg Institut, Forschungszentrum Jülich GmbH — [3]Ernst Ruska-Centre for Microscopy and Spectroscopy with Electrons, Jülich

The complex oxide compound $(Pr_{0.5}Ba_{0.5})CoO_{3-\delta}$ (PBCO) is considered an efficient catalytic oxide for oxygen evolution half-reaction (OER) taking place during water splitting operation. We discuss structural and electrical properties of epitaxial PBCO thin films serving a model systems for exploring the atomistic processes during OER. PBCO thin films are synthesized in a disordered and in an ordered double-perovskite crystal structure by controlling the growth temperature during pulsed laser deposition. The thin films are fabricated with defined surface morphologies and crystal orientation. During the growth process, the transition from disordered to ordered phase can be monitored directly by means of electron diffraction (RHEED). The epitaxial thin films show catalytic activity comparable to their porous counter parts fabricated by chemical routes, making them ideal model templates for systematic studies. The ability to control the ordered double-perovskite phase of PBCO bears the potential to force the formation of structural oxygen vacancies within the lattice with atomic precision and to tailor active sites for OER on the nanoscale.

AKE 2.4 Mo 12:00 S Aula

Influence of the pH value of the dye on the electrical prop-

erties of dye sensitized solar cells prepared with anthocyans — •Irén Juhász Junger[1], Sarah Vanessa Homburg[1], Hubert Meissner[1], Thomas Grethe[2], Anne Schwarz-Pfeiffer[2], Johannes Fiedler[1], Andreas Hermann[1], Tomasz Blachowicz[3], and Andrea Ehrmann[1] — [1]Bielefeld University of Applied Sciences, Faculty of Engineering and Mathematics, Bielefeld (Germany) — [2]Niederrhein University of Applied Sciences, Research Institute for Textile and Clothing (FTB), Mönchengladbach (Germany) — [3]Silesian University of Technology, Institute of Physics - Center for Science and Education, Gliwice (Poland)

In recent years the harvesting of renewable energies became of great importance. This led to a rapid development of dye-sensitized solar cells which can be produced from cheap, low-purity materials. The best electrical properties are provided by cells prepared using synthetical, ruthenium based dyes. Unfortunately, most of them are toxic and expensive. The anthocyans extracted for example from hibiscus flowers yield a cheap and eco-friendly alternative to the toxic dyes, however, with a loss of solar cell efficiency. Our aim is to improve the conversion efficiency and the stability of solar cells prepared with anthocyans by changing the pH value of the dye. In order to find the optimal pH value, its influence on the solar cell properties is investigated.

AKE 3: Economics of Energy Supply and Use

Zeit: Montag 16:45–17:15 Raum: S Aula

Hauptvortrag AKE 3.1 Mo 16:45 S Aula

Die Defizite der Energiewende — •Manuel Frondel — RWI Essen

Der Anteil der erneuerbaren Energietechnologien am deutschen Strommix lag Ende 2015 bei rund 30%. Das bedeutet gegenüber dem Anteil von weniger als 7% im Jahr 2000, in dem das Erneuerbaren-Energien-Gesetz (EEG) zur Förderung der Erneuerbaren eingeführt wurde, mehr als eine Vervierfachung. In keinem anderen Land der Welt wurde der Anteil der Erneuerbaren derart vorangetrieben. Doch was weltweit große Beachtung findet, hat einen sehr hohen Preis: Die Kosten für den Ausbau der erneuerbaren Energien in Deutschland nehmen stetig zu und liegen mittlerweile bei deutlich über 20 Mrd. Euro jährlich. Während viele armutsgefährdete Haushalte unter diesen Lasten zu leiden haben, wird immer mehr überschüssiger grüner Strom produziert, der wegen fehlenden Stromnetzen keine Abnehmer mehr findet. Um dies zu vermeiden und den künftigen Kostenanstieg für die Verbraucher zu dämpfen, sollte der weitere Ausbau der Erneuerbaren gedrosselt und mit dem Tempo des Netzausbaus in Deutschland synchronisiert werden.

AKE 4: Future Perspectives: Fusion Energy Research

Zeit: Montag 17:15–17:45 Raum: S Aula

Hauptvortrag AKE 4.1 Mo 17:15 S Aula

Fusion Research - recent progress and perspectives — •Antonius Donné — EUROfusion, Garching, Germany

The European roadmap to the realisation of fusion electricity to the grid breaks the quest into eight missions. For each mission, it reviews the current status of research, identifies open issues, and proposes a research and development programme.

A long-term perspective on fusion is mandatory since Europe has a leading position in this field and major expectations have grown in other ITER parties on fusion as a sustainable and secure energy source. China, for example, is launching an aggressive programme aimed at fusion electricity production well before 2050. Europe can keep the pace only if it focuses its effort and pursues a pragmatic approach to fusion energy. With this objective, the present roadmap has been elaborated.

ITER is the key facility of the roadmap as it is expected to achieve most of the important milestones on the path to fusion power. The Fusion Roadmap is tightly connected to the ITER schedule and the vast majority of resources in Horizon 2020 are dedicated to ITER and its accompanying experiments. Parallel to the ITER exploitation in the 2030s, the construction of the demonstration power plant DEMO needs to be prepared. DEMO will for the first time supply fusion electricity to the grid. The design, construction and operation of DEMO require full involvement of industry to ensure that, after a successful DEMO operation, industry can take responsibility for commercial fusion power.

AKE 5: Nuclear Decomissioning and Storage

Zeit: Dienstag 8:30–9:00 Raum: S Aula

Hauptvortrag AKE 5.1 Di 8:30 S Aula

Research for the safe management of nuclear waste — •Dirk Bosbach — Forschungszentrum Jülich, Germany

The safe management of radioactive waste arising from electricity production is one of the great challenges of our times. Technologies for the decommissioning of nuclear facilities and for the safe management of the associated waste have been developed in recent decades. Current R&D activities are focusing on optimization regarding e.g. radiation exposure of personal, economic aspects, etc. Some special waste streams arising from the decommissioning of nuclear installations have not been in the focus of R&D activities in the past, e.g. radioactively contaminated toxic metals such as beryllium, cadmium or mercury, spent ion-exchange resins, radioactively contaminated NAPL and decontamination fluids, wastes containing asbestos, PCB, etc. and mixed wastes with elevated concentrations of chemotoxic/hazardous constituents. Although the expected volumes of various of these special waste streams will be comparatively small, there are specific challenges linked to their safe management, for example, due to their associated chemotoxicity, potential releases of radionuclides, their incompatibility to established conventional treatment and conditioning techniques, analytical challenges regarding the adequate determination of radioactive and chemotoxic inventories, etc. The presentation will provide an overview of current R&D activities at Forschungszentrum Jülich on waste treatment and waste form development regarding some special wastes.

AKE 6: Renewable Energy: Wind Energy

Zeit: Dienstag 9:00–10:00 Raum: S Aula

Hauptvortrag AKE 6.1 Di 9:00 S Aula

Smarte Rotoren für kosteneffiziente Windenergieanlagen — •Jan Tessmer — DLR - Deutsches Zentrum für Luft- und Raumfahrt

Weltweit waren Ende 2015 Windenergieanlagen mit ca. 430 GW Gesamtleistung installiert, davon über 43 GW in Deutschland mit einem Anteil von rund 14 % an der Bruttostromerzeugung. Wesentlichen Vorteile von Windenergie sind niedrige Stromerzeugungskosten, globale Einsetzbarkeit und gute Regelbarkeit (Systemdienstleistungen).

Eines der wichtigsten Ziele der Forschung und Entwicklung ist eine weitere Kostenreduktion. Hierfür sind weitere Entwicklungen in der Anlagentechnik notwendig. Gewichtsreduktion und längere Lebensdauer durch neue Bauweisen und Werkstoffe unter Berücksichtigung genauerer Kenntnisse der Systemparameter bezüglich Elastizität und Strukturdynamik sind wesentliche Treiber bei der Kostenreduktion. Der Beitrag beleuchtet daher vertieft die Erforschung innovativer Rotorblatttechnologien im Rahmen aktueller Forschungsvorhaben.

Neue Methoden vom Designprozess bis zur automatisierten Produktion, das Verhalten neuer Komponenten im System der Gesamtwindenergieanlage und die Auswirkungen auf Akzeptanzkriterien (z.B. Lärm)müssen verifiziert und validiert werden bevor sie im industriellen Betrieb eingesetzt werden können. Der vom BMWi und dem Land Niedersachsen geförderte Aufbau einer Forschungsplattform (DFWind) wird in den kommenden Jahren eine Infrastruktur bereitstellen, die neben der phänomenologischen Untersuchung zwei hintereinander stehender Windturbinen sowie ihres Umfeldes auch die Erprobung und Qualifikation neuer Technologien und Methoden erlauben wird.

Hauptvortrag AKE 6.2 Di 9:30 S Aula

Beiträge der Windphysik zum Ausbau der Windenergienutzung — •Martin Kühn — ForWind - CvO Universität Oldenburg

In der Weiterentwicklung der Windenergie stellen sich eine Vielzahl spezifischer Fragen auch an die Physik. Diese reichen von den räumlichen und zeitlichen Eigenschaften des Kraftstoffs »Wind«, über die Energiewandlung im Konverter bis zu energiemeteorologischen und systemdynamischen Aspekten der Netzintegration.

Kürzlich wurde vor diesem Hintergrund das »Forschungslabor für Turbulenz und Windenergiesysteme« (WindLab) der Universität Oldenburg eröffnet. Es dient der Erforschung turbulenter atmosphärischer Strömungen und deren Zusammenspiel mit Windenergiesystemen, d.h. Windparks, Windenergieanlagen und deren Komponenten. ForscherInnen aus Physik, Meteorologie und Ingenieurwesen untersuchen grundlagenorientiert und angewandt die bisher nur lückenhaft verstandenen Turbulenzeigenschaften und -interaktionen auf unterschiedlichsten räumlichen Skalen vom Rotorblatt über einzelne Windenergieanlagen bis zu großen Windparkverbünden.

Die Forschungsprogrammatik gliedert sich in drei Schwerpunkte, in denen methodisch neuartige Lösungsansätze erarbeitet werden: Beschreibung und Modellierung der Windturbulenz, Simulationen und Experimente zur Interaktionen von Turbulenz und Windenergiesystemen und turbulenzkompensierende Regelungsverfahren.

Resultierend sind wesentliche Beiträge zur Reduktion der durch Windturbulenz verursachten Kosten für Nutzung und Netzintegration von Windenergie zu erwarten.

AKE 7: Renewable Energy: Aspects of Intermittent Generation

Zeit: Dienstag 10:00–10:45 Raum: S Aula

AKE 7.1 Di 10:00 S Aula

Verbesserung der Wetterprognose im Hinblick auf wetterabhängige erneuerbare Energieträger — •Stefan Declair und Roland Potthast — Deutscher Wetterdienst, Sektion Datenassimilation, Frankfurter Straße 135, 63067 Offenbach, Deutschland

Die stetig wachsende Anzahl an wetterabhängigen regenerativen Energien in Deutschland bewegt die Energiewende auf eine Zeit zu, in der die Vorhersagequalität für Windenergie und Photovoltaik eine gewisse Schwelle nicht mehr unterschreiten darf, um Netzstabilität zu gewährleisten. Die zugrundeliegende Wetterprognose ist ein tragender Pfeiler für die Leistungsprognose. Das Kollaborationsprojekt EWeLiNE zwischen dem Deutschen Wetterdienstes (DWD), dem Fraunhofer-Institut für Windenergie und Energiesystemtechnik (IWES) sowie den Übertragungsnetzbetreibern TenneT, 50Hertz und Amprion schlägt den Bogen zwischen Meteorologie und Energiewirtschaft.

Kernaspekt des Projektes auf Seiten des DWD ist die gesamten Wettermodellkette mit dem Ziel der Verbesserung der Wetterprognose mit Fokus auf die energierelevanten Variablen Globalstrahlung und Windgeschwindigkeit in 100m Höhe. Dieser Beitrag beleuchtet die wichtigsten Projektergebnisse beginnend bei der Datenassimilation und Ensemblegenerieung über die Modellphysik bis hin zu postprozessierenden Maßnahmen wie Model Output Statistics.

Hauptvortrag AKE 7.2 Di 10:15 S Aula

Surplus electricity and storage under conditions of intermittent supply — •Friedrich Wagner — Max Planck Institut für Plasmaphysik, Greifswald, Germany

Data from the German electricity system for the years 2010, 2012, 2013, and 2015 are used and scaled up to a 100% supply by intermittent renewable energy sources (iRES). In the average, 330 GW wind and PV power are required to meet a 100% target. A back-up system is necessary with the power of 89% of peak load. Surplus electricity accrues at high power levels. Curtailing surplus power to a large extent is found to be uneconomic. Demand-side-management will suffer from the strong day-to-day variation of available surplus energy. A day storage is ineffective because of the day-night correlation of surplus power during winter. A seasonal storage loses its character when transformation losses are considered because it can contribute only after periods with excessive surplus production. The capacities to be installed stress the difficulty to base heat supply and mobility also on iRES generated electricity in the future. As the German energy transition replaces one CO2-free electricity supply system by another one no major reduction in CO2 emission can be expected till the last nuclear reactor will be switched off. The German GHG emission targets for 2020 and beyond may be in jeopardy.

AKE 8: Sector Coupling, Chemical Conversion and Storage of Renewable Energy

Zeit: Dienstag 11:00–13:00 Raum: S Aula

Hauptvortrag AKE 8.1 Di 11:00 S Aula

Power to Gas Konzepte für die Energiewende — •Frank Graf — DVGW-Forschungsstelle am Engler-Bunte-Institut des Karlsruher Instituts für Technologie (KIT), Engler-Bunte-Ring 1 - 7, 76131 Karlsruhe

Ein zukünftig auf Windkraft und Solarenergie basierendes Energiesystem kommt ohne verschiedene Speichermöglichkeiten nicht aus. Power to Gas kann deshalb mittel- und langfristig einen wichtigen Beitrag zum Gelingen der Energiewende leisten. Die Speicher- und Verteilstruktur für Erdgas ist in Deutschland hervorragend ausgebaut und sehr gut als Speicherinfrastruktur für elektrische Energie geeignet. Die derzeit betriebenen Poren- und Kavernenspeicher für Erdgas in Deutschland haben ein Arbeitsgasvolumen von 24,1 Mrd. m3, was etwa einer chemischen Speicherleistung von 265 TWh entspricht. Neben Transport und Speicherung von großen Mengen an elektrischer Energie mit Hilfe der bestehenden Erdgasinfrastruktur kann über PtG-Prozesse auch regenerativer Kraftstoff erzeugt werden. Außerdem kann der Wärmemarkt mit einem Gas aus erneuerbaren Quellen versorgen werden.

In den letzten Jahren wurden umfangreiche Forschungs- und Entwicklungsarbeiten durchgeführt und erste Praxiserfahrungen an mehreren Demonstrationsanlagen gesammelt. Im Beitrag werden die verschiedenen Aspekte erörtert.

Hauptvortrag AKE 8.2 Di 11:30 S Aula

Sektorenkopplung als Teil der Energieversorgung von morgen — •René Schoof — Energy Storage Technology, Uniper Energy Storage GmbH, Ruhralleee 80, 45136 Essen

In einer künftigen Energieversorgung, die zunehmend auf erneuerbaren Energien aus Wind und Sonne basiert, wird es immer wichtiger, diese planbar bereitzustellen und zu transportieren. Neben Netzausbau und Speichertechnologien kann die Kopplung verschiedenster Sektoren wie Wärme, Gas, Mobilität, Industrie usw. einen wesentlichen Beitrag zum Gelingen dieser Systemtransformation beitragen. Darüber hinaus ist die Sektorenkopplung der Garant für das Erreichen einer CO2-neutralen Energienutzung zur Einhaltung der Klimaziele im Sinne von COP21.

Eingeladener Vortrag AKE 8.3 Di 12:00 S Aula

Was kann Sektorenkopplung leisten? Eine modellgestützte Analyse von Technologien und ihrer Potenziale — •Hans Christian Gils — Deutsches Zentrum für Luft- und Raumfahrt (DLR), Institut für Technische Thermodynamik, Stuttgart

Eine stärkere Verknüpfung von Strom-, Wärme-, Verkehrs- und Gassektor kann einen wesentlichen Beitrag zum Gelingen der Energiewende leisten. So können beispielsweise durch ein gesteuertes Laden von Elektrofahrzeugen, sowie einen optimierten Betrieb von Wärmepumpen und Kraft-Wärme-Kopplungs-Anlagen der Bedarf nach regelbaren Kraftwerken gesenkt, und Erzeugungsspitzen aus Windkraft- und Photovoltaikanlagen in höherem Maße genutzt werden. Im Zentrum des Vortrags steht die Analyse des wirtschaftlichen Potenzials verschiedener Sektorenkopplungstechnologien in einem überwiegend auf fluktuierenden Quellen basierenden Energieversorgungssystem in Deutschland. Die Untersuchungen stützen sich auf die Anwendung des DLR-Energiesystemmodells REMix, und behandeln auch die Frage, wie die Sektorenkopplung mit anderen Technologieoptionen, z.B. einem erweiterten Stromnetzausbau und dem Import regelbaren erneuerbaren Stroms, wechselwirkt.

AKE 8.4 Di 12:30 S Aula

Direct CO_2-Methanation of flue gas emitted by conventional power plants — •Johannes Israel[1], Fabian Rachow[1], Carola Schwiertz[1], Evgenia Charlafti[2], Klaus Mueller[1], and Dieter Schmeisser[1] — [1]BTU Cottbus - Senftenberg, Konrad-Wachsmann-Allee 17, 03046 Cottbus — [2]TU Berlin, Ackerstraße 76, 13355 Berlin

The catalytic conversion of CO_2 with H_2 into CH_4 is possible by the Sabatier reaction $CO_2 + 4H_2 \rightarrow CH_4 + 2H_2$. Using excess energy from renewable electricity generation, this approach offers an opportunity for recycling of CO_2 as synthetic natural gas.

In a new concept, we investigate the performance of the Sabatier reaction as direct methanation of flue gas, emitted by conventional power plants. We investigate the Sabatier process in an upscaled system, with a maximum input flow rate of 45 Nm^3/h Gas. The performance is investigated in a simulated composition of flue gas and under real conditions at a lignite power plant in Schwarze Pumpe, Brandenburg, Germany.

We can achieve a CO_2-conversion of up to 90%, with approx. 100% selectivity towards CH_4. Under flue gas conditions and at a certain limit of gas flow the system is operated at an autothermal running modus, a steady state equilibrium of exothermic heat production and thermal flow that needs neither external annealing nor cooling.

AKE 8.5 Di 12:45 S Aula

Synthesis of Methanol from CO_2 for Power-to-Liquid applications — •Fabian Rachow, Moritz Hagendorf, Klaus Müller, and Dieter Schmeisser — Brandenburgische Technische Universität Cottbus - Senftenberg, Angewandte Physik-Sensorik, Konrad-Wachsmann-Allee 17, 03046 Cottbus, Germany

The direct synthesis of methanol [$CO_2 + 3H_2 \rightleftharpoons CH_3OH + H_2O$] represent a possibility to reduce the global CO_2-emission by recycling the CO_2 and also to store excess energy from renewable energy sources into a common fuel or chemical feedstock (Power-to-Liquid). For an acceptable conversion rate of CO_2 a catalyst is needed, together with high temperatures (>200°C) and high pressure (50-200bar). Methanol is normally produced form synthesis gas, a mixture of CO and H_2. By directly using CO_2 for the exothermic reaction, we avoid the conversion of CO_2 to CO by the reversed water gas shift reaction. We also present new concepts for the conversion from CO_2-rich flue gases, eliminating the need for a separation of the CO_2. The concept is backed up by measurements in laboratory scale. Here we use a $Cu - ZnO$ catalyst on a ZrO_2 substrate prepared by impregnation and compare the results with commercially available catalysts. We achieved a conversion of around 7% and a selectivity of 60% at a temperature of 240°C and 45bar. The reaction is thermodynamically limited with a maximum conversion rate of 15% at 250°C and 50bar. The conversion and the selectivity towards methanol is highly influenced by the catalyst used, the temperature, the pressure as well as the flow rate of the reactants.

AKE 9: Alternative Fuels for Air Traffic

Zeit: Dienstag 16:45–17:15 Raum: S 8

Hauptvortrag AKE 9.1 Di 16:45 S 8

Verändern alternative Treibstoffe die Emissionen des Luftverkehrs und seine Klimawirkung? — •Christiane Voigt — Deutsches Zentrum für Luft- und Raumfahrt (DLR), Oberpfaffenhofen, Deutschland — Johannes Gutenberg-Universität, Mainz, Deutschland

Hohe Wachstumsraten im Luftverkehr erfordern eine umfassende Kenntnis der Wirkung des Luftverkehrs auf die Atmosphäre und das Klima. Aktuelle Prognosen erwarten eine Verdopplung der CO2 Emissionen des Luftverkehrs bis 2050, daher setzten internationale Luftverkehrsorganisationen (IATA, ACARE) ambitionierte Ziele, die Emissionen des Luftverkehrs deutlich zu reduzieren. Nationale Luftfahrtbehörden streben z.B. mit dem "Biofuel Flightpath" eine Erhöhung des Anteils an alternativen Treibstoffen im Luftverkehr an. Alternative Treibstoffe besitzen einen niedrigeren Aromatengehalt, welcher die Verbrennungsprozesse im Triebwerk modifiziert und somit einen Effekt auf die Emissionen haben kann. Die Emissionen alternativer Treibstoffe im Luftverkehr und ihre Wirkung auf Atmosphäre und Klima sind bislang jedoch wenig untersucht und daher das Ziel aktueller Forschung. Der Vortrag zeigt neue Ergebnisse von Flugzeugmessungen im Abgasstrahl von Jets, die mit Bio- oder synthetischen Treibstoffen betankt wurden. Die Partikel und Spurengas-Emissionen alternativer Treibstoffe wurden im Abstand von 100 m hinter voranfliegenen Test-Flugzeugen gemessen und quantifiziert. Ihre Wirkung auf die Bildung und Lebensdauer von Kondensstreifen wird untersucht und das Klima-Potenzial alternativer Treibstoffe wird diskutiert.

AKE 10: Future Perspectives: CO_2-Storage

Zeit: Dienstag 17:15–17:45 Raum: S 8

Hauptvortrag AKE 10.1 Di 17:15 S 8

Geological CO_2 storage - concepts and state of knowledge — •Axel Liebscher — Deutsches GeoForschungsZentrum, Potsdam, Germany

The German national climate targets aim at 80-95% reduction of greenhouse gas emissions by 2050. To reach these targets, additional and intensified measures for greenhouse gas reduction are necessary, which have to cover all emission sources and sectors. To limit global warming to significantly <2°C by end of the century so-called negative emissions are necessary in the second half of the century in all likelihood.

Long-term geological storage of CO_2, captured at emission sources, is an essential measure within the portfolio of emission reduction technologies. In combination with biomass it is the only currently available technique that allows for negative emissions in climate relevant quantities. Currently, 15 industrial scale projects store 30 Mt of CO_2 per year worldwide. The longest operating CO_2 stoarge project is "Sleipner" off-shore Norway, which stores 1 Mt of CO_2 per year since 1996. In Germany, experiences on geological CO_2 storage has been gained at the pilot site Ketzin, where $\sim$ 67 kt of CO_2 have been stored between 2008 and 2013. Storage reservoirs are typically porous rocks (either depleted hydrocarbon reservoirs or saline aquifers) at $>$ 1000 m depth that are overlain by impermeable cap rocks. Crucial to any storage project is a site-specific monitoring concept, based on geochemical and geophysical methods. With such a system, surveilance of the storage system, detection of even small amounts of CO_2 and sound prediction of long-term behaviour is possible.

AKE 11: Nuclear Energy and Security (Joint Session AKE-AGA)

Zeit: Mittwoch 16:45–18:15 Raum: S Aula

Hauptvortrag AKE 11.1 Mi 16:45 S Aula

Nuclear Power and Nuclear Safety Post Fukushima — •Christoph Pistner and Matthias Englert — Öko-Institut e.V., Rheinstraße 95, 64295 Darmstadt

On March 11, 2011, the second "major accident" in a civilian nuclear power plant after Chernobyl took place in Fukushima Dai-ichi. A major earthquake and resulting tsunami lead to a core melt in three reactors and the following relocation of more than 100.000 residents. But still, worldwide there are 450 nuclear reactors operational today. Safety checks like the EU-Stresstest took place after Fukushima and possibilities for optimization have been identified basically everywhere. Fukushima emphasized the importance of taking natural events more thoroughly into account and led to the implementation of additional safety equipment. But still, events from internal and external causes continue to happen frequently. In addition to these "conventional" safety problems, also other threats gain in importance. Besides the danger of terrorist attacks on nuclear facilities, also the deterioration of the institutional environment due to a military or economic crisis has to be taken into account. Thus, nuclear power remains to be a technology with the inherent potential for catastrophic accidents.

Hauptvortrag AKE 11.2 Mi 17:15 S Aula

Safeguards and Non-Proliferation experience from an IAEA perspective — •Tariq Rauf — formerly IAEA, Head Verification and Security Policy, Vienna

The International Atomic Energy Agency (IAEA) has been implementing nuclear safeguards for more than half a century covering peaceful nuclear activities. IAEA safeguards are implemented in States pursuant to legal authority from the IAEA Statute and bilateral, regional and international nuclear non-proliferation treaties and agreements; and are set of technical measures that allow the IAEA to independently verify a State's legal commitment not to divert nuclear material from peaceful nuclear activities to nuclear weapons or other nuclear explosive devices. In 1991, the IAEA safeguards system suffered a massive shock when it was discovered that Iraq was running an heretofore undetected parallel undeclared nuclear (weapon acquisition) programme. As a result, the IAEA safeguards system was strengthened based on a combination of expanded information and technical measures through the Additional Protocol (to safeguards agreements). Further challenges to the IAEA safeguards system came during 1992 through 2015, from the DPRK, Iran, Libya, South Korea and Syria. This presentation describes the structure and technical elements of safeguards, including implementation in high-priority cases.

Hauptvortrag AKE 11.3 Mi 17:45 S Aula

Civil Nuclear Power - The Cyber Security Perspective — •Guido Gluschke — Institute for Security and Safety at the Brandenburg University of Applied Sciences, Potsdam, Germany

The talk will discuss the situation at nuclear facilities in the digital age. It will elaborate on the cyber-related challenges of the safety and security domains. Furthermore, the talk will introduce the concept of design basis threat which represents the IAEA methodology for risk treatment in terms of physical protection and will have a look how cyber fits into this model. Finally, some international initiatives on cyber security will be presented.