

AKE 1: Innovative Contributions for the Energy System Transformation

Time: Tuesday 11:00–12:45

Location: KH 01.022

Invited Talk

AKE 1.1 (6) Tue 11:00 KH 01.022

Unterwasserpumpspeicher in den Braunkohletagebauen des Rheinischen Reviers – die Lösung zur bezahlbaren Grundlastenergieversorgung der deutschen Industrie — ●HORST SCHMIDT-BÖCKING¹, H. RISSE², G. LUTHER³, U. SCHÖLER⁴, J. SCHWISTER⁵, L. MÜLLER⁶, T. BENDER⁶, A. GARG⁶, H. LAMBERTZ⁷ und M. DÜREN⁸ — ¹Institut für Kernphysik, Goethe Universität Frankfurt — ²RWTH Aachen — ³Universität des Saarlandes, Saarbrücken — ⁴Früher Ruhrgas Essen — ⁵Techn. Beigeordneter a.D. Stadt Kerpen — ⁶University of Applied Sciences, Mainz — ⁷Kreistagsabgeordneter im Rhein-Erft-Kreis — ⁸Justus-Liebig-Universität Gießen

Die Energiewende in Deutschland kann gelingen, wenn man der Industrie zu jeder Zeit auch in Flauten bezahlbare elektrische Energie in ausreichender Menge zur Verfügung steht und die Überschüsse insbesondere aus PV am Tage verwertet werden können. Dazu braucht man sehr große Energiespeicher. Zur Zeit scheint man das Kurzzeit-Speicherproblem fast nur mit elektrochemischen Speichern lösen zu wollen. Die bewährte Technologie von Pumpspeichern wird kaum im Betracht gezogen, da es angeblich keine Möglichkeiten mehr gäbe, in Deutschland wegen fehlender Topographie und geltenden Umweltauflagen solche Speicher in ausreichender Größe zu errichten.

In den mehr als 400 m tiefen Braunkohletagebauen kann man riesige Pumpspeicher (sogenannte Unterwasserpumpspeicher) errichten, die so groß sind, dass sie selbst zu Kosten von weniger als 6 Cent/kWh die Grundlastversorgung für die Industrie sichern können. Dort könnten „unsichtbare“ Unterwasserpumpspeicher erbaut werden, von weit mehr als 100 GWh Speicherkapazität (ein Zyklus), die man sofort ohne Flutung des Sees in Betrieb nehmen kann. Deutschland besitzt heute ca. 38 GWh Pumpspeicher und weniger als 3 GWh ins Stromnetz integrierte elektrochemische Speicher. Der Ausbau an elektrochemischen Speichern (vor allem Li-Ionenbatterien) wird stark zu nehmen. Diese Speicher werden aber vor allem im privaten Bereich und in der Mobilität (unter 100 kWh) und im mittleren Speicherbereich (< 300 MWh) zum Einsatz kommen und werden ohne Zweifel wichtige Speicherkomponenten in der Energiewende sein. Sie unersetzbar, da sie extrem hohe Leistungen (etliche 10 GW) bereitstellen können.

Im Vortrag wird das Funktions- und Aufbauprinzip dieser Speicher vorgestellt und deren Wirtschaftlichkeit im Vergleich zu anderen Speicherkonzepten beschrieben.

AKE 1.2 (5) Tue 11:30 KH 01.022

Meeting Future Energy Needs - A regulatory view on a sustainability path — ●JÖRG COSFELD — University of Applied Sciences Düsseldorf, Düsseldorf 40476, Germany

Sustainability demands the cessation of all greenhouse gas emissions to prevent catastrophic climate tipping points. Humanity cannot afford to gamble against these abrupt and irreversible scenarios, which necessitate urgent global political and economic action. This work summarizes carbon dioxide emissions from the energy sector, examining the role of fossil fuels and future expectations. While addressing the challenges of anthropogenic climate change across political, economic, and scientific domains, it highlights the complexity of finding comprehensive solutions.

Rising global energy demands, particularly in electricity generation (40%) and transportation (30%), require solutions that curb emissions. This study explores regulatory frameworks, focusing on the stagnation of American fuel economy progress. From 1975, American Automotive Manufacturers (AAM) improved engine efficiency, enabling greater travel distances per fuel load. However, between 1985 and 2010, due to the lack of updates to Corporate Average Fuel Economy (CAFE) standards, AAM shifted toward heavier vehicles, halting fuel economy improvements.

This work details regulatory gaps and compares fuel efficiency standards in Europe, North America, and Asia-Pacific. It also provides an outlook on under-regulated sectors requiring scientific and regulatory attention.

AKE 1.3 (4) Tue 11:45 KH 01.022

The Role of Regulatory Frameworks in Reducing Carbon Emissions: Insights from the Energy and Lighting Sectors — ●JÖRG COSFELD — University of Applied Sciences Düsseldorf, Düsseldorf 40476, Germany

Sustainability requires the cessation of carbon dioxide and other greenhouse gas emissions to prevent irreversible and abrupt climate tipping points. This work provides a concise summary of carbon dioxide emissions from the US energy sector and evaluates its greenhouse gas (GHG) abatement potential by 2030. Feasible solutions in a mid-range scenario suggest a reduction of up to 3.0 gigatons of CO₂-equivalent emissions at costs below 50 USD per ton. Key opportunities lie in energy efficiency improvements and advanced technologies, particularly in buildings, appliances, and power generation, offering both environmental and economic benefits.

The study emphasizes that regulatory frameworks are often better suited for industry sectors than for individual actions, especially in developing countries, where affordability remains a significant barrier. For instance, 5 USD may buy a single LED light but also 10 incandescent bulbs, highlighting the economic trade-offs for low-income households. Comparing US and European regulations, the study discusses the EU ban on incandescent bulbs and Germany's Building Energy Act (GEG), which faced significant public opposition. In conclusion, regulatory frameworks can effectively support climate change mitigation but require careful design to ensure both practicality and applicability, particularly in economically diverse regions.

AKE 1.4 (3) Tue 12:00 KH 01.022

Multiphysics Simulation of 1D MEA in a PEM fuel cell — ●ZAHRA HARATIZAVEH and JAN LOHBREIER — Technische Hochschule Nürnberg Georg Simon Ohm

Abstract: The membrane electrode assembly (MEA) is the key functional unit of low-temperature polymer electrolyte membrane (PEM) fuel cells. It includes a proton-conducting membrane positioned between catalyst layers where hydrogen and oxygen react electrochemically. Gas diffusion layers support this structure by supplying reactants, removing products, and providing electron transport, creating a tightly integrated system in which electrochemical, thermal, and mass-transport processes are closely linked. Water has a significant impact on MEA performance. Ionomer conductivity requires adequate hydration, nevertheless too much liquid water may block gas pathways and delay reactions. Understanding how humidity and transport conditions impact the equilibrium between hydration, gas access, and electrochemical activity is therefore necessary for stable operation. This work focuses on a detailed nonisothermal model used to study how inlet gas relative humidity affects the performance of a hydrogen-fueled PEM MEA. The model incorporates gas-phase species transport, water diffusion and sorption in the ionomer, and the hydration-dependent variation of proton conductivity. Heat generation from electrochemical reactions and Joule heating is included to resolve temperature gradients that develop during operation, coupling thermal effects directly to water content and reaction kinetics. Hydrogen crossover through the membrane is represented to capture cross-diffusion.

AKE 1.5 (1) Tue 12:15 KH 01.022

Comparison of Surrogate Models Trained with Small Data Sets for a Thermoelectric Energy Harvester — ●EUGEN VAMBOLT¹, NIKLAS PÖPEL¹, JOHANNES WIECZOREK², MAHLA MOAZAMIGODARZI², JOHANNES ROTHMAYR², and JAN LOHBREIER¹ — ¹Technische Hochschule Nürnberg Georg Simon Ohm — ²Fraunhofer Institute for Integrated Circuits (IIS) Nürnberg

Energy harvesting technologies can be used to cover the energy consumption of wireless sensor nodes. This enables the use of sensor nodes in locations without a wired power supply. It also eliminates the need to charge or replace batteries, which can quickly become an economic obstacle when a large number of sensors are installed. For energy harvesting technologies to work, there must be a sufficient energy source near the sensor node. For example, temperature differences are essential for the use of thermoelectric generators (TEG) so that electrical energy can be harvested. Locations where such temperature differences can be found typically occur on supply lines or on machines that generate waste heat. The size of the required energy harvesting system depends on the energy consumption of the sensor node and the amount of available ambient energy. The design of a TEG can be optimized for a specific application to meet the energy requirements of the sensor node. To do this, a sensitivity analysis is performed to determine the factors that have the greatest influence on, for example, performance. A surrogate model is usually used in this step, as a large number of

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Overview of Invited Talks and Sessions

(Lecture hall KH 01.022)

Invited Talks

AKE 1.1 Tue 11:00–11:30 KH 01.022 **Unterwasserpumpspeicher in den Braunkohletagebauen des Rheinischen Reviers – die Lösung zur bezahlbaren Grundlastenergieversorgung der deutschen Industrie** — •HORST SCHMIDT-BÖCKING, H. RISSE, G. LUTHER, U. SCHÖLER, J. SCHWISTER, L. MÜLLER, T. BENDER, A. GARG, H. LAMBERTZ, M. DÜREN

Sessions

AKE 1.1–1.6 Tue 11:00–12:45 KH 01.022 **Innovative Contributions for the Energy System Transformation**

predictions have to be calculated. In this thesis, three approaches for surrogate models are investigated and compared with each other.

AKE 1.6 (2) Tue 12:30 KH 01.022

The Inclusive Investigation of Defect Thermodynamics for Cl-Ion Battery Materials using Grand Canonical Diagrams

— •JOHANNES DÖHN¹ and AXEL GROSS^{1,2} — ¹Institute of Theoretical Chemistry, Ulm University, Germany — ²Helmholtz Institute Ulm, Germany

In our contribution we use the example of chloride perovskites to discuss the crucial role of defect thermodynamics for electrode and solid electrolyte materials in Cl-ion batteries. In this regard, the energetic relation between the pristine compound, the formation of defects and the conversion into other materials under varying electrochemical con-

ditions is of great importance, though still underexplored.

Here, we suggest an analysis based on grand canonical approaches which is frequently applied using the concepts of ab initio thermodynamics or the computational hydrogen electrode. Grand canonical diagrams contain in a compact form information on the relative stability of the pristine and defective materials as well as potential decomposition products at varying potentials and loadings. Thus they can help to predict whether topotactic or conversion reactions are to be expected during chlorination/dechlorination. Furthermore, relevant properties as the open circuit voltage or the electrochemical stability window can be read off directly from the diagrams.

We demonstrate that this inclusive investigation of all relevant thermodynamic properties presented here enables a comprehensive and intuitive access to the elucidation of materials properties which can hardly be gained otherwise.