Bad Honnef Physics School

Energy Science – an interdisciplinary challenge

September 1-6, 2019

Abstracts of the lectures:

Dr. Tim **Bongers** (Amprion)

Electricity grids - Fundamentals and Challenges in Power System Planning and Operation

Electricity grids transport the electrical energy from renewable energy sources, fossil and nuclear power plants to the customers such as households or industries. They are the backbone for a secure, economic and sustainable supply of electrical energy. The rising share of renewable energy sources, the decommissioning of fossil und nuclear power plants, additional electrical applications such as electric vehicles, heat pumps or power-to-gas units are some of the challenges, which need to be tackled for the future design of electricity grids. This lecture provides an insight into the fundamentals of electricity grids and addresses the challenges in planning and operation of grids.

PD Dr. Gunther **Brunklaus** (Helmholtz-Institut Münster)

Energy storage in batteries

In the lecture Batteries for Energy Storage fundamental battery components, materials concepts and state-of-the-art energy storage solutions as well as selected currently explored battery systems will be presented in detail. In particular, available benefits and challenges of presently commercially available batteries will be discussed, including portable and stationary energy storage devices. In addition, an outlook on future perspectives, novel battery systems for contemporary applications and materials design strategies will be provided, including relevant aspects of the German ‘Energiewende’, fostering the curiosity of young talents for this vibrant research area.

Prof. Christoph **Buchal** (Universität zu Köln, Forschungszentrum Jülich)

Introduction: Energy-Facts and resulting Challenges

We present an overview of the basic energy facts. These simple facts will lead to an understanding of the fascinating interplay between the development of mankind and food production, energy supply, scientific progress, industrialization, mobility, globalization, growing energy and materials use and the related emissions. Understanding the four great Industrial Revolutions and their overwhelming impact, we try to explain the present phase of revolutionary transitions and the general paradoxical chaos of national and international developments, contradictory scientific disputes and societal clashes. Some promising developments are outlined.

Dr. Pablo **Cuéllar** (BAM, Berlin)

Wind energy challenges. An offshore perspective and some possible solutions

This talk provides a brief introduction on general engineering challenges for the offshore (marine) wind energy production, focusing on material, structural and hydromechanical aspects.

The talk begins with a broad overview on general trends for offshore wind-farms, with insights on some characteristic structural features and their associated loads. Then, some particular open issues for the foundation of the offshore wind turbines into the seabed are introduced. Here, different research approaches are discussed, from experimental investigations to coupled computational analysis at micro- and macroscopic scales.

In the second part of the seminar, both the hydromechanical Wave–Tower interaction and some general aspects of the windfarm aerodynamics (wake analysis) are discussed. Some modelling possibilities in the frame of CFD (computational fluid dynamics) are introduced and the relevance of such analyses for a proper windfarm layout optimization is pointed out.

Summing up, this seminar aims to show that: i) Numerical analysis of the turbine's interaction with wind/waves and with the seabed is both useful and affordable. ii) Simplified models can provide an insight into windfarm aerodynamics. iii) Turbulent wake analysis is very relevant for the windfarm layout.

Dr. Peter **Hefele** (Konrad-Adenauer Stiftung, Berlin)

Strategies for meeting the energy demand: The example of Asia

Access to energy is key to any kind of human development. This goes, in particular, true for the Region Asia-Pacific, which comprises more than half of the global population, a rising middle class and economic powerhouses such as China, Japan, India and South-East Asia.

Energy production in the region is still largely based on fossil sources, in particular coal. Considered as cheap, it comes with tremendous negative side effects in terms of pollution and rapidly rising greenhouse gas emissions.

Thus a global "Energiewende" can only be successful if a rapid and sustainable transformation of the current energy systems happens in Asia, too.

The presentation will look into the status quo of Asia´s energy production and distribution. It will also consider Asia´s role in global energy markets. The focus will be set less on technologies but rather on policy frameworks, regulation and energy economics. Asia is also a good example that further steps of regional integration of energy markets are urgent to rebalance demand and supply and to optimize existing systems.

The presentation will finally analyse the situation of main countries in terms of energy policy concepts, evaluate progress made towards a sustainable energy system transformation and its perspectives on mitigating climate change.

There are plenty of opportunities for closer cooperation between Germany, Europa and the Asia-Pacific. This is not limited to the exchange solely of technology. New comprehensive concepts such as sustainable solutions for urbanisation also provide an interesting new field of exchange for politics, science and business.

Hristina **Cigarida** (GWI, Essen)

Combined heat and power units

The growing demand for less polluting forms of energy has led to a rapid interest in the combined heat and power (CHP) technologies, for which this lecture is aimed at. The first part will introduce the CHP systems and their basic operating principles, the main technologies that are deployed in these systems with their advantages and disadvantages as well as their diverse applications by presenting various examples. The second part will mainly focus on micro-CHP units, specifically fuel cell micro-CHP units, as systems that are expected to play a major role in curbing the CO_2 emissions. Additionally, the possibilities of coupling CHP systems with renewable energies and their future perspectives will be discussed.

Dr. Stephanus **Lintker** (EnergyAgency.NRW, Düsseldorf)

Global aspects of energy consumption

The growth in energy consumption is very often a direct link to a growing economy and the development of a better live.

What are the key figures in energy consumption? What are the perspectives and the development for some parts of our world? Can energy consumption be managed?

Several examples – diverse country focuses – and national strategies are part of the presentation and the basis for a following exchange.

The varieties in the development of energy consumption, the link to climate change, the development in the energy mix and some national strategies behind are aspects in the lecture.

One answer is today already clear: There is a need for the next generation of scientists and engineers to pay attention to energy consumption!

Ludger **Mohrbach** (VGB PowerTech e.V.)

NUCLEAR ENERGY AND CLIMATE

In 2017, about 85% of the world's primary energy supply was based on burning hydro-carbons, with each kg of atomic carbon producing about 2.7 kg of CO_2, practically all of which was and is deposited in the atmosphere.

The carbon dioxide concentration has exceeded 400 ppm in 2016, up from about 280 ppm in the pre-industrialized era, producing (together with the other anthropogenic greenhouse gases, all together being about half as effective as CO_2) a medium average global temperature rise of already one Kelvin. In business-as-usual scenarios, climate models predict an unbearable total positive temperature change of between 3.3 and 4.1 Kelvin until 2100, with economic development and population growth being the main drivers. If all countries would keep their reduction promises of the Paris Convention of globally 50%, warming would still come out at 2.4 to 2.7 Kelvin. It would require at least another reduction by a factor of two to reach "acceptable" 2 Kelvin. In order to limit global warming to 1.3 to 1.5 Kelvin as deemed desirable by the Paris Convention, practically an early total decarboni-sation of all world-wide energy consumption would be necessary.

About half of the global primary energy supply in that timeframe may altogether be required for power generation, today about 450 nuclear power plants provide about 11% of the world-

wide electric energy supply. They represent about 4% of the global primary energy supply, second on the list of carbon-free energy sources only to hydropower (7%) and roughly comparable to all other renewables together (including traditional biomass burning).

Thus, nuclear saves today already more than 2.3 Gt/a of CO_2 emissions compared to coal/ gas, this corresponds to approx. 6% of all anthropogenic CO_2 emissions. The (domestic part of the) German share of greenhouse gas emissions corresponds to only slightly more than 2%.

Prof. Juliet **Newson** (University of Reykjavik, Island)

Geothermal energy: Iceland's wealth – a model for Europe?

This lecture is a broad introduction to magmatic and non-magmatic geothermal systems, discussing conceptual models of these systems; i.e. the heat and mass flow, chemistry, permeability structure, and boundary conditions. The energy extraction process for steam flash plants, and binary plants is described, and some direct use applications. Special attention is given to low temperature electricity generation, and also to use of geothermal energy for heating and cooling for cities. We discuss the environmental impact of geothermal development, briefly touch on issues of regulation and social acceptance and give a short description of the direction of EU funded research in geothermal energy.

Prof. Dirk **Pleiter** (Forschungszentrum Jülich)

Energy efficient information technology

Information technology has become a major sink for electrical energy at a global scale. As the costs for this energy has become a major driver of total-costs-of-ownership of IT equipment, significant efforts are being made to improve power and energy efficiency. In this talk we will discuss basic aspects of power and energy efficiency in context of IT hardware technology as well as the status quo with focus on high-performance computing and analyse major constraints resulting from the underlying technologies. On this basis we will review a broad set of strategies for improving energy efficiency. We will conclude with a discussion of the most promising steps forward.

Prof. Jésus **Rosales Carreon** (University of Utrecht, Netherlands)

Food-water-energy-nexus - how scarce resources interact

Understanding the water-food-energy nexus is paramount if we want to design sustainable cities. Therefore, the linkages between these critical domains require an integrated approach to ensuring water and food security, and energy production in cities worldwide. Food waste reduction has one of the highest priorities in the European Commissions' Circular Economy Action Plan because it has a large potential for resource conservation, and it reduces environmental impact. In this session, we will talk about the food-service sector in Amsterdam. The sector is expected to grow in the city, hence, there is a need to assess the sustainability implications (e.g. CO2 emissions, water use, job creation) of food waste management within the city.

PD Dr. Gabi **Schierning** (IFW, Dresden)

Decentralized energy harvesting by thermoelectrics

The transition to a more sustainable basis for the world's energy supply fuels the research on alternative technologies for the electric power supply by renewable energy sources. Hereby, thermoelectricity – a technology which converts heat fluxes into useable electricity – combines two major sectors of energy demand: electric power supply and heat supply, both equally important for an emission-free future: The heat supply constitutes between a third and a half of total energy demand and greenhouse emissions. For example, the heating and cooling sector accounts for approximately 50% of overall European Union (EU) final energy consumption. Importantly, where heat is produced, waste heat is also produced. In principal, a proportion of the waste heat could be converted by thermoelectricity into useable electricity. In recent years, the substantially improved performance of thermoelectric (TE) materials attracted considerable interest in studying its potential applications. Novel development of the TE materials restrain from the use of scarce elements at still high performance enabling a large-scale use for power generation. The principle feasibility of the TE technique was demonstrated using a variety of different materials and processing technologies, and many different architectures of TE devices were successfully realized. Still, before this technology can be used for broader applications, challenges in the integration of the TE devices need to be overcome. This lecture will first provide an overview of the fundamentals and state-of-the-art and will then discuss problems and advantages of this technology.

Prof. Robert **Schlögl** (MPI, Mülheim a.d. Ruhr)

Chemical energy conversion - potential for the future

Chemical energy conversion CEC uses the science and technology of catalysis[1] to convert free energy from electrons into potential energy of molecular bonds. For fundamental as well as for technical reasons the procedures are wasteful in energy and complex in design. Given the goal to de-fossilize the energy system the critical question arises why CEC should be pursued at all.

The systemic analysis of future sustainable energy systems reveals[2] that all-electric and likely decarbonized energy systems are not possible and that electrical energy storage is not feasible to compensate the spatio-temporal distribution problems of primary renewable electricity.

The analysis will illustrate why the often-used argument to keep CEC to its bare minimum and build a "hydrogen energy system" is a sub-optimal solution. It will be advocated that the copy of biological energy systems with their generation and storage concepts in closed material cycles is indeed the systemic best solution to complement the immediate use of renewable electrical energy for the foreseeable future of the current century.

[1] R. Schlögl, *Angew. Chem. Int. Ed.* **2015**, *54*, 3465-3520.

[2] R. Schlögl, *Angew. Chem. Int. Ed.* **2019**, *58*, 343-348.

Prof. Martina **Schmid** (University of Duisburg-Essen)

Photovoltaics – abundant energy from the sun

The increasing world energy demand is one of the greatest challenges mankind is facing. In search of available energy sources, we find one out there, which provides us basically with unlimited energy: the sun. Constantly, the sun is sending as much energy to earth as 100 million coal or nuclear power plants can generate. One way of transforming light irradiation into electrical energy are photovoltaics.

After a general introduction to energy demand, availability and aspired production, we will look into the working principles and characteristics of photovoltaics. For a broad overview on available technologies the different generations and types of solar cells will be presented. As an outlook, recent research topics will be highlighted, showing the future trends and perspectives.

Prof. Michael **Schreckenberg** (University of Duisburg-Essen)

Future Development of Traffic and Mobility

The analysis of traffic systems using methods of statistical physics during the past twenty-five years gave many new and interesting insights into the complex dynamics of road networks. On the basis of data drawn from various detection devices together with assumptions about psychological features of the driver behaviour a vast number of theories and models were formulated and intensively investigated.

Nowadays many new problems occur. Beside the traffic load itself mainly energetic and environmental aspects dominate the discussions. New techniques like self-driving vehicles, communication with other vehicles and the infrastructure or e-mobility will lead to a complete reorganization of mobility as a whole. But the infrastructure and the traffic management will have serious problems to develop with the same speed. The talk tries to summarize the current status in this field.
