

**Franz Hubert**

## **Network based Energy Systems**

### **Syllabus**

**Content:** The purpose of this lecture is to familiarize students with the basic notions and tools of the analysis of energy markets and strategic behavior in these markets with an emphasis on electric power and gas. The lecture consist of three parts and is accompanied by a tutorial.

In the first part we put the gas and power industries into the broader picture of energy markets. We describe some important basics of the international energy industry: major energy sources and markets, their interconnections, historical perspective on prices and production to reserve ratios, resource & environmental problems, etc.

In the second part we focus on electric power. We look at the sector from three angles: power generation, transmission, and 'reliability management'; with two issues in mind: the use of existing asset and the investment into new assets.

Firstly, we address each of these issues from an operations research view, explaining the various problems which have to be solved in order to achieve an efficient power supply. Secondly, we suggest how the efficient solutions can be implemented using decentralized markets, if these were perfectly competitive. Thirdly, we look at some problems which result from market power using non-cooperative game theory. With market power, the market participants will act strategically and try to 'game' the rules to their advantage.

In the third part, we will look at the international pipeline system for natural gas, and discuss how investment and regulation can shape the power structure. In this part we will be using notions from cooperative game theory.

**Organization:** 4 hours lectures and tutorial per week (4sws). Home assignments will be discussed in tutorials

**Prerequisites:** Basic knowledge of microeconomics (optimization theory), game theory and industrial organization.

**Examination:** there is a written examination (90 min) counting for 6 ETCS at the end.

## Topics

### Part I

#### Energy markets: the big picture

Primary energy: production & reserves, consumption, prices and elasticities, moving energy around, international trade flows, fuel storage, major players, energy and the environment, energy security, regulation/taxes/subsidies.

### Part II

#### Basics of power systems

Value chain, generation technology & fuel mix, transmission technology, lack of storage, economics of scale, network economics, reliability and the value of lost load, reorganizing power markets.

#### Generation

Sunk cost, operating cost and the merit order, load duration, peak load, optimal dispatch, investment.

Designing a decentralized market for power, bidding formats, 'power only' versus separate markets for capacity.

Strategic bidding, supply function equilibria, long term contracts, investment in generation capacity.

#### Transmission

Transmission: losses and constraints, the loop flow problem, nodal pricing and congestion rents, transmission rights, investment.

Designing Markets for transmission rights, physical versus financial rights, regulated access, cost regulation for transmission services.

The competitive effects of transmission capacities, nodal versus zonal pricing, market coupling and coordination of re-dispatch, investment in transmission capacity.

#### Reliability

Intertemporal constraints and inter-dispatch management, unit commitment, balancing services, reserve capacity.

Designing markets for auxiliary services and reserve capacity.

### Part III

#### Basics of the gas sector

Value chain, sources and transport systems, LNG / pipeline gas, international gas trade, economics of scale & network economics.

#### Pipelines

Pipelines and market power, strategic investment in gas pipelines.

#### Building a European market for gas

Access to bottleneck facilities, market efficiency and market power.

## Literature

There is an excellent textbook for the part on electric power:

Biggar, Darryl R. & Hesamzadeh, Mohammad Reza (2014): *The Economics of Electricity Markets*, IEEE Press/Wiley

Also useful (in this order) are:

Kirschen, Daniel & Strbac Goran (2004): *Fundamentals of Power System Economics*, John Wiley & Sons

Stoft, Steven (2002): *Power System Economics*, Wiley-Interscience, John Wiley & Sons

Additional articles will be given during the lecture.