3rd International Conference on Energy and Environment: bringing together Economics and Engineering

Faculty of Economics of Porto / Portugal

ICEE Conference

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Keynote Speakers

HENRIK LUND
M.Sc. Eng. PhD. Dr. Techn. Henrik Lund is Professor in Energy Planning at Aalborg University in Denmark and Editor-in-Chief of Elsevier International Journal of Energy. Prof. Lund was head of department from 1995 to 2002 and has served as head of several large research projects in Denmark as well as in Europe. Prof. Lund holds a PhD in “Implementation of sustainable energy systems” (1990) and a senior doctoral degree in “Choice Awareness and Renewable Energy Systems” (2009). Prof. Lund has more than 25 years of research experience and involvement in Danish Energy Planning and Policy making. Among others, Prof. Lund has been involved in the making of the Danish Society of Engineers proposal for a future 100% Renewable Energy Plan for Denmark. Prof. Lund was awarded a gold medal by the International Energy Foundation (IEF) for “Best Research Paper Award” within the area “Energy Policies & Economics” in 1998. And Prof. Lund is the main developer of the energy system analysis model EnergyPLAN, which is used by various researchers and energy planners around the world. Prof. Lund has contributed to more than 200 books and articles and is the author of the book “Renewable Energy Systems: The Choice and Modelling of 100% Renewable Solutions” (Academic Press, Elsevier 2014).

LUC HENS
Graduated as a biologist and received his Ph.D. in Biology from the Vrije Universiteit Brussel (VUB), Belgium. Until 2010 he was a professor and Chair of the human ecology department. He also lectures at the Technical University in Sofia (Bulgaria), at the National and Kapodistrian University of Athens (Greece), and at Leiden University (Holland). He was a senior scientific advisor at the “Vlaamse Instelling voor Technologisch Onderzoek” (VITO), which is Belgium’s biggest environmental research organization. He is currently retrained as an emeritus professor. Professor Hens’ specific area of research concerns the elucidation of interdisciplinary instruments for sustainable development. In this framework, he acted as the promoter of over 10 research projects on environmental management in ports in Vietnam and Cambodia. Luc Hans acts as an expert in environmental policy on several councils in Belgium. He is the European editor for the “International Journal of Environment Development and Sustainability”.
Sustainability.

JORGE VASCONCELOS
Chairman of NEWES, New Energy Solutions. Consultant to several international organizations and national authorities. Invited Professor at the Technical University of Lisbon, MIP/Portugal Program Chairman of AEEEN (Associação Portuguesa de Economia da Energia - IEEE Affiliate)

First chairman of the Portuguese Energy Regulatory Authority, Founder and first chairman of the Council of European Energy Regulators. Co-founder of the Ibero-American Association of Energy Regulatory Authorities (ARNAE). Former Professor and member of the Executive Committee of the Florence School of Regulation. Prior to the regulatory experience, he was in industry and at several European universities. Among many other functions, member of the European Commission Advisory Group on the Energy Roadmap 2050 and Chairman of the Green Tax Reform Commission set up by the Portuguese Government in 2014.

Author and editor of several books and articles. Graduated in power systems from Porto University and got the Dr.-Ing. degree from the University of Erlangen-Nuremberg.

REINHARD HAAAS
Energy Economics Group, Institute of Energy Systems and Electric Drives, Vienna University of Technology

Reinhard Haas is university professor of Energy Economics at Vienna University of Technology in Austria. He teaches Energy Economics, Regulation and Competition in Energy markets, and Energy Modeling.

His current research focus is on (i) evaluation and modeling of dissemination strategies for renewables; (ii) modeling pathways to sustainable energy systems; (iii) liberalization vs. regulation of energy markets; (iv) energy policy strategies.

He works in these fields since more than 20 years and has published more than 60 papers in reviewed international journals. Moreover, he has coordinated and coordinated projects for Austrian institutions as well as the European Commission and the International Energy Agency.

This conference is supported by:
On how to integrate large quantities of variable renewables into electricity systems

Reinhard HAAS

Energy Economics Group, TU Wien

Porto, 30 June 2017
CONTENT:

1. Introduction: Motivation
2. Method of approach
3. How variable renewables impact prices in electricity markets
4. The core problem of capacity payments
5. The role of flexibility and sector coupling
6. Balancing groups: A future market design
7. Subsidizing RES: How long?
8. Conclusions
1. INTRODUCTION

Motivation:

* Climate change → Paris agreements
* Phasing out of fossil & nuclear
* Targets for renewables
* Competition & democracy
* It is not possible to squeeze variable renewables into the system by central planning approaches
Introduction: Electricity generation EU-28
EU-28: Electricity generation from „new“ RES

1997: 1 %

2016: 16 % (preliminary)

Source: EUROSTAT, own estimations
Core objective

... to identify the major boundary conditions to integrate even larger amounts of variable renewables into the electricity system

Very important:

Our reflections apply in principle to every electricity system world-wide

.... are based on electricity economic point-of-view
2. METHOD OF APPROACH

• Identification of hourly residual load over a year for various scenarios with large quantities of variable renewables;

• Applying a fundamental model to calculate (static) hourly residual loads and electricity spot market prices;

• Integration of flexibility in a dynamic framework for price calculation;
Elements of electricity markets

- **Long-term:**
  - Bilateral contracts
  - Futures

- **Short-term:**
  - day-ahead and
  - Intraday markets

- **Time of delivery:**
  - Control power,
  - Balancing energy

- **Quantity (TWh):**
  - Years, months
  - Day, hours
  - \(\frac{1}{4}\) hours
Expectation of prices = Short-term marginal costs

(Short-term marginal costs = fuel costs)

due to huge depreciated excess capacities at the beginning of liberalisation!
3 HOW VARIABLE RENEWABLES IMPACT PRICES IN ELECTRICITY MARKETS
Example: prices without and with PV

Price = System marginal costs

Supply curve w/o PV

PV

Supply curve w/ PV

Costs, Price (EUR/MWh)

MW

Demand $D_t$
Supply and Demand

RES Production > Demand

RES Production < Demand

Hours per week

GW
Key term of the future: Residual load
(base load is “dead”)

Residual load = Load – non-flexible generation
Deviation from STMC-pricing in spot markets

Scarcity prices

Electricity price spot market

New price spreads

\[ p_{t1} \]

\[ p_{t2} \]

\[ \rightarrow \text{These price spreads provide incentives for new flexible solutions} \]
Remark: Cold - dark – Lull („Kalte Dunkelflaute“)

Maximum price: ca. 85 EUR/MWh
Given a price pattern, showing excess and scarcity prices it would be attractive for a sufficient number of flexible power plant operators to stay in the market!

REVISED ENERGY-ONLY MARKET
Classified residual load

Under coverage

2013

2030

Surplus due to excess generation
Classified residual load

How to cover Cold - dark – Lull („Kalte Dunkelflaute“) ?
There are two extreme positions:

By Planning including a regulated capacity „market“ with STMC pricing?

or

By a market-based approach ensuring competition between supply-side and demand-side technologies and behaviour (incl. Storages, grid and other flexibility options) with correct scarcity pricing signals?
Cost duration curve

Ensure correct price signals!

Generators stay in the market if:

\[ \sum_{t=1}^{n} (p_{ele_t} \cdot q_{ele_t} - c_{f_t}) > (c_{c_y} + c_{O&M_y}) \]
4 CORE PROBLEMS OF CAPACITY PAYMENTS

All regulatory capacity payments for power plants distort the EOM and lead to wrong price signals for all other options.

Price peaks at times of scarce resource should revive the markets and lead to effective competition.

Capacity payments lead to a rebound: Due to these lower price signals → higher capacity demanded than needed under correct price signals!

Capacity payments → lower quantity of flexibility → lower share of variable RES.
5 THE ROLE OF FLEXIBILITY AND SECTOR COUPLING

FLEXIBLE GENERATION

STORAGES (CENTRAL, DECENTRAL, POWER-TO-HEAT)

GRID EXTENTION

SMART GRIDS

DEMAND-SIDE MANAGEMENT (TECHNICAL)

DEMAND RESPONSE (PRICE SIGNALS)
Market-based coverage of residual load

- Very high prices (2000 EUR/MWh!)
- Transmission grid extension
- Load reduction due to Demand response to prices
- Load reduction due to Demand-side management technical (e.g. cycling)

Flexible power plants

Storages
Capacity payments for residual load

Security marge

Capacity with ensured payments

MW

Hours/year
Comparison

- **Flexible power plants**

- **Security margin**
Specific question: How much storage do we need?

Under coverage

How to use?

Store all?

Hours/year

MW

excess generation
Storing every peak?

Under coverage

Excess capacity

High excess capacity at very few hours!

e.g. 20% less capacity stored → 1% less electricity stored!
Flexible use of excess electricity

Load increase by technical Demand-side management (incl. Power-to-heat)

Shedding of peak power

Extention of transmission grid

Storage (if reasonable Fullloadhours)

Direct marketing

Price very low (-2000 EUR/MWh ???)

Extention of transmission grid

Hours/year
Long-term storage needed
Sector coupling / Sector integration

* In times of surplus generation: How to use excess electricity in meaningful way?

- Heating/Cooling
- Transport

* Vague simplified suggestions, no convincing long-term solutions

* Central (Ptx approaches, e.g. H2) vs decentral (end user level, E.g. Evs, heat pumps for heating) applications

* How to fit use with time of surplus, e.g of PV for heating?
Sector coupling hydrogen: Storage and fuel in transport?

- **Electrolyser**
  - Electricity → H₂
  - η = 60-70%

- **Compressor**
  - η ≈ 90%

- **Combined cycle**
  - η = 50-60%

- **H₂-Storage**
  - η = 27-38%

- **Electricity**
  - G

- **Fuel Cells**
  - H₂ → Electricity

- **Electric Vehicles**
  - H₂ → Electricity

- **Wind Turbines**
  - Electricity
Elements of electricity markets

Long-term:
- Bilateral contracts
- Futures

Short-term:
- day-ahead and
- Intraday markets

Control power, Balancing energy
6. THE CORE ROLE AND RESPONSIBILITY OF BALANCING GROUPS

Balancing group: entity in a control area of an electricity system; it has to ensure that at every moment demand and supply is balanced

E.g. municipal utility of Porto, Vienna, Copenhagen

To meet this target: own generation, storage, flexibility, Trading in long-term, day-ahead and intraday market

Every difference → high costs!
Old thinking

Flexibility options

Storage

Generation

Grid

Supply

Demand
New Thinking: Making the electricity system more democratic
7. IS THE TIME FOR SUBSIDIZING RENEWABLES OVER?
Grid parity: PV-costs and household electricity prices

- Costs
- Germany

Graph showing the decrease in costs over time, indicating grid parity in 2012.
Assessment of Grid Parity

\[ E_{\text{Own}} \times P_{\text{HH}} + E_{\text{Feed-in}} \times P_{\text{feed-in}} > \text{Annuity} \]

Grid parity term

Subsidy still necessary?
Share of own consumption
Bidding Zero for off-shore wind

Tender for wind farms to be constructed between 2021 and 2025:

<table>
<thead>
<tr>
<th>Project</th>
<th>MW</th>
<th>ct/kWh</th>
</tr>
</thead>
<tbody>
<tr>
<td>EnBW He Dreihl GmbH</td>
<td>900</td>
<td>0.0</td>
</tr>
<tr>
<td>DONG Energy Borkum Riffgrund West II GmbH</td>
<td>240</td>
<td>0.0</td>
</tr>
<tr>
<td>Dong Energy Northern Energy OWP West GmbH</td>
<td>240</td>
<td>0.0</td>
</tr>
<tr>
<td>Dong Energy Gode Wind 03 GmbH</td>
<td>110</td>
<td>6.0*</td>
</tr>
<tr>
<td>Weighted average</td>
<td>1,490</td>
<td>0.44</td>
</tr>
</tbody>
</table>

Source: Innogy

Bets on:

- Increasing electricity prices
- Decreasing technology costs
- Sector coupling works
8. CONCLUSIONS

• Sustainable electric system → integration of a broad technology portfolio & demand-side options!

• Larger market areas favourable

• Very important: correct price signals (incl. CO2)

• Most urgent: exhaust full creativity of all market participants incl. decentralised PV systems

• The key: Flexibility (incl. dispatchable var RES)! Currently low economic incentives but activities started → very promising!

• New key player: Balancing group (Supplier), no more the generator
8. CONCLUSIONS

- Capacity payments: Any CP will distort the system towards more conv. and less RES capacity
- calls for capacity markets: a last try of the old generation-focused system to survive
- a pragmatic solution: Strategic reserves which go along with very high penalties (higher than maximum price would be in the EOM) for those suppliers (balancing groups) who make use of them (or to be seen as insurance suppliers can pay)