ICEE 2019

16-17 May 2019

4th International Conference on Energy and Environment: bringing together Engineering and Economics

Welcome | Bem Vindos!

It is a great pleasure to welcome you to the 4th International Conference on Energy & Environment: bringing together Engineering and Economics, ICEEE, in Guimarães, Portugal, May 16 - 17, 2019.

The conference is organized by the School of Engineering, University of Minho and the School of Economics and Management, University of Porto.

ICEEE brings together leading academic scientists, researchers and scholars from the energy and environment science community to discuss and exchange ideas and results on engineering and economics.

Programme - Full version available

Associated Journals

Selected papers are planned to be published in scientific journals.

Programme - Full version available

Weather report: Expected Temperatures for May 16 and 17, max 20C-min 7C (info: www.ipma.pt)
MARKET DESIGN FOR A SUSTAINABLE AND DEMOCRATIC ELECTRICITY SYSTEM

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Guimaraes, May 2019
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
6. Storing every peak?
7. Subsidizing renewables?
8. Conclusions
1. INTRODUCTION

Motivation:

* Climate change $\rightarrow$ Paris agreements
* Targets for renewables
* Europe: The clean energy package $\rightarrow$ energy communities
* It is not possible to force variable renewables into the system
* A strong desire of some customers to participate in electricity supply
Electricity generation EU-28

![Graph showing electricity generation trends for EU-28 from 1990 to 2020. The graph compares different energy sources: coal, oil products, gas, nuclear energy, and renewable energy. The values for 2017 and 2018 are preliminary.](image-url)
Ranking: Electricity generation from RES in EU-28

Percentage

- AT
- SE
- PT
- DK
- ES

%
Electricity generation: Austria vs Portugal

Austria

- Hydro: 63%
- Wind: 15%
- Convent: 15%
- Biomass: 6%
- Solar: 1%

Portugal

- Hydro: 38%
- Wind: 27%
- Convent: 27%
- Biomass: 6%
- Solar: 2%
Strategic decision by European Council in 2014

- 20% Greenhouse Gas Emissions
- 20% Renewable Energy
- 20% Energy Efficiency
- 10% Interconnection

≤ - 40% Greenhouse Gas Emissions
≥ 27% Renewable Energy
≥ 27%* Energy Efficiency
15% Interconnection

* To be reviewed by 2020, having in mind an EU level of 30%
Energy Union Strategy

Energy efficiency

Energy security, solidarity and trust

A fully integrated energy market

Decarbonizing the economy

Research, innovation & competitiveness

#EnergyUnion
Structure of the Package

Enabling Framework

Energy Union Governance

Energy Efficiency

Renewables
- Revised Renewable Energy Directive

Electricity Market Design
- Regulation and Directive on internal electricity market; Regulation on risk-preparedness, ACER regulation

Innovative

Inter-connected

Socially fair

Inclusive

Safe for all

Digital

Investment-friendly
How prices come about: Three periods of market design

- **before liberalisation**
- **after liberalisation:** old thinking
- **after liberalisation:** new thinking

### Price, costs (EUR/MWh)

- **Short-term marginal costs**
- **Average costs**
- **Long-term marginal costs**
- **Scarcity prices**
- **Excess prices**

### Time
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

• hourly resolution of residual load over a year in scenarios with large quantities of variable renewables;

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

• Integration of flexibility/elasticity in a dynamic framework for price calculation;
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 THE ELECTRICITY SYSTEM AND PRICES IN ELECTRICITY MARKETS
Example: prices without and with PV

Price = System marginal costs

Price with PV!

Supply curve w/o PV

PV

Demand $D_t$

Supply curve w/ PV
Supply and Demand

RES Production > Demand

RES Production < Demand

Supply and Demand
Key term of the future: Residual load (base load is “dead”)

Residual load = Load – non-flexible generation

Under coverage
Excess electricity

GW

0 20 40 60 80 100 120 140 160

hours of a week

Excess electricity
Deviation from STMC-pricing in spot markets

These price spreads provide incentives for new flexible solutions!!!!
The CO2-Price

- Textmasterformate durch Klicken bearbeiten
- Zweite Ebene
- Dritte Ebene
- Vierte Ebene
- Fünfte Ebene

The graph shows the CO2-Price in EUR/ton CO2 from January 2004 to May 2019. The red circle highlights a specific period of interest.
Development of electricity prices in Europe up to 2016 (1)

AT, DE, FR, CZ, PL

One market

Italy

Nordpool
Development of electricity prices in Europe up to 2018 (2)
Classified residual load over a year

Under coverage

Surplus due to excess generation

2016

2030
Classified residual load

How to cover
Cold - dark – Lull?
There are two extreme positions:

By a regulated capacity payment with STMC pricing?

or

By competition between supply-side and demand-side technologies and behaviour (incl. Storages, grid and other flexibility options) with correct scarcity pricing signals?
4 THE 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.

The higher the excess capacities, the lower is the share of RES.

strive to retain system resource adequacy by correct price signals.
5 Flexible coverage of residual load

Very high prices (2000 EUR/MWh!)

Load reduction due to Demand response to prices

Load reduction due to Demand-side management technical (e.g. cycling)

Flexible power plants

Extension Transmission grid

Capacity without ensured payments

Storages
Comparison

Capacity without ensured payments

Flexible power plants

Security margin

Capacity with ensured payments
6. Storing every peak?

Under coverage

Excess capacity

High excess capacity at very few hours!

e.g. 20% less capacity stored → 1% less electricity stored!
The costs of storage

\[
C = \frac{IC \cdot \alpha + C_{OM}}{\eta_{STO}} + C_{E} \left[ \frac{EUR}{kWh} \right] T
\]

Key factors:
- \( T \) (Fullloadhours)!
- \( C_{E} \) (electricity price)
Impact of fullloadhours

At 500 h/a: four times the costs of 2000 h/a!

Price spread
Spotmarkt

H2

Pump storage
Battery

EUR/kWh

0

0.1

0.2

0.3

0.4

0.5

0.6

0

500

1000

1500

2000

2500

3000

3500

4000

4500

Hours/year
Decreasing full-load hours of storages

Under coverage

Hours/year

excess generation

Residual load

Storage 1

Storage 2

FLH Storage 1

FLH Storage 2

0 1000 2000 3000 4000 5000 6000 7000 8000

0 2000 4000 6000 8000

-4000 -6000 -8000
Range of storage costs 2018

- Battery
- CAES
- PtG-CH4 central
- PtG-H2 central
- Pumped Hydro year
- Pumped Hydro day

Price spread wholesale market 2018

Household electricity price

Range
Minimum
Flexible use of excess electricity

- Load increase by technical Demand-side management (incl. Power-to-heat)
- Shedding of peak power
- Extent of transmission grid
- Storage (if reasonable Fullloadhours)
- Direct marketing

Price very low (-2000 EUR/MWh ???)
Demand for long-term storage

Long-term storage needed

Graph showing the demand for long-term storage with different energy sources and their contributions.
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?

- Electricity to Electrolyser: η=60-70%
- Electrolyser to H₂-Storage: η≈90%
- H₂-Storage to Combined cycle: η=50-60%
- Combined cycle to Electricity: η=27-38%
- Electricity to Electrolyser again
- H₂ to Fuel cell: η=27-38%
- Fuel cell to Electricity

Electricity, H₂, Compressor, Combined cycle
7. IS THE TIME FOR SUBSIDIZING RENEWABLES OVER?

As long there is no price on CO2 ….
Grid parity: PV-costs and household electricity prices

The graph shows the decrease in solar PV costs and an increase in household electricity prices over the years. Grid parity is achieved in 2012, where the cost of solar PV becomes equal to the household electricity price.

- Costs
- Germany
- Grid parity
Assessment of Grid Parity

Grid parity term

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

Savings/revenues

Costs

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>
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<tbody>
<tr>
<td>EnBW He Dreihlt GmbH</td>
<td>900</td>
<td>0.0</td>
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<tr>
<td>DONG Energy Borkum Riffgrund West II GmbH</td>
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<tr>
<td>DONG Energy Northern Energy OWP West GmbH</td>
<td>240</td>
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<tr>
<td>DONG Energy Gode Wind 03 GmbH</td>
<td>110</td>
<td>6.0*</td>
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<tr>
<td>Weighted average</td>
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<td>0.44</td>
</tr>
</tbody>
</table>

Source: Innogy

Bets on:

- Increasing electricity prices
- Decreasing technology costs
- Sector coupling works
Tenant electricity model and Blockchain

Balancing Group/Supplier

PV-System on the roof

Tenant electricity model: Contracted PV-electricity

Customer 1

Customer 2

Customer 3

Meter

Blockchain
New Thinking: Making the electricity system more democratic

*) R. Green
8. CONCLUSIONS

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

• No quick fix, no one size fits all solutions

• Larger market areas favourable

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

• most urgent: exhaust full creativity for flexibility of all market participants incl. decentralised systems (PV …)

• Capacity payments: Any CP will distort the system towards more conv. and less RES capacity

• New key players: Suppliers and prosumagers