



# Load-flow based market coupling with large-scale wind power in Europe

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# Overview

- Introduction and motivation
- Modelling of European electricity system
  - i. Optimisation of power plant operation
  - ii. Representation of load-flow based market coupling
- Application case
- Results
- Summary



# Introduction

- Anticipated higher utilisation of limited cross-border interconnectors due to increasing:
  - i. International electricity trade
  - ii. Intermittent generation from renewable energy sources like wind power
- Largest part of European interconnectors: Auction based allocation of available interconnection capacities
- No correspondence between commercial planned transactions and physical flows within meshed electricity networks:
  - i. Possible requirements to adapt market outcomes to technical restrictions
  - ii. Available interconnector capacities may not be optimally utilized
- Incentive to consider international distribution of load flows during market clearing process:
- Improved coordination of European electricity trade with load-flow based market coupling



# Motivation

- Objective to analyse the impacts of load-flow based market coupling on European electricity markets:
  - i. System operation costs
  - ii. Electricity prices
  - iii. International electricity exchanges
- Application of optimisation model taking into account:
  - i. Zonal representation of European electricity markets and of available cross-border interconnectors
  - ii. Chronological order of scheduling processes



# Modelling of the European electricity system I

## Optimisation of power plant operation I

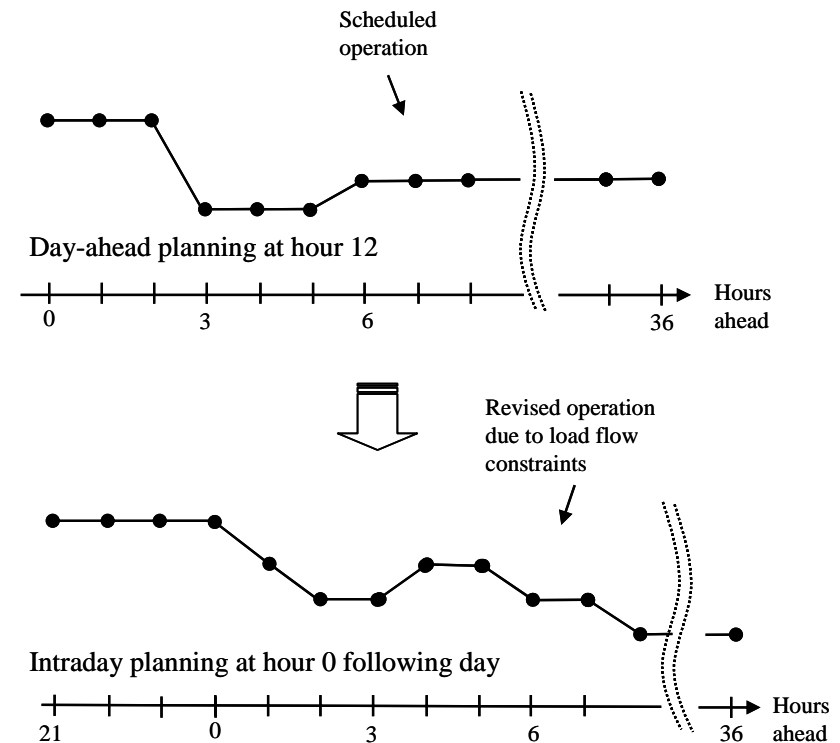
- Wilmar Planning Tool: Bottom-up stochastic optimisation model of unit commitment and dispatch
- Coverage of electricity demand in hourly time resolution
- Objective: Minimisation of system operation costs
- Inclusion of balance equations describing following markets:
  - i. Day-ahead market: Cleared at 12 o'clock for the following day
  - ii. Intraday market: Balancing deviations between power production agreed upon the day-ahead market and required redispatch in order to fulfil load flow restrictions
  - iii. Markets for different kinds of reserve power
  - iv. Heat markets to consider the operation of CHP
- Consideration of restrictions of unit commitment and dispatch as well as of electrical load flows



# Modelling of the European electricity system II

## Optimisation of power plant operation II

- Rolling planning covering a whole year:
  1. At noon: Day-ahead scheduling of power plant operation and international electricity exchange
  2. Intraday rescheduling of power plant operation under consideration of international load flow restrictions
- Unit commitment and dispatch taking into account intertemporal restrictions between planning periods



# Modelling of the European electricity system III

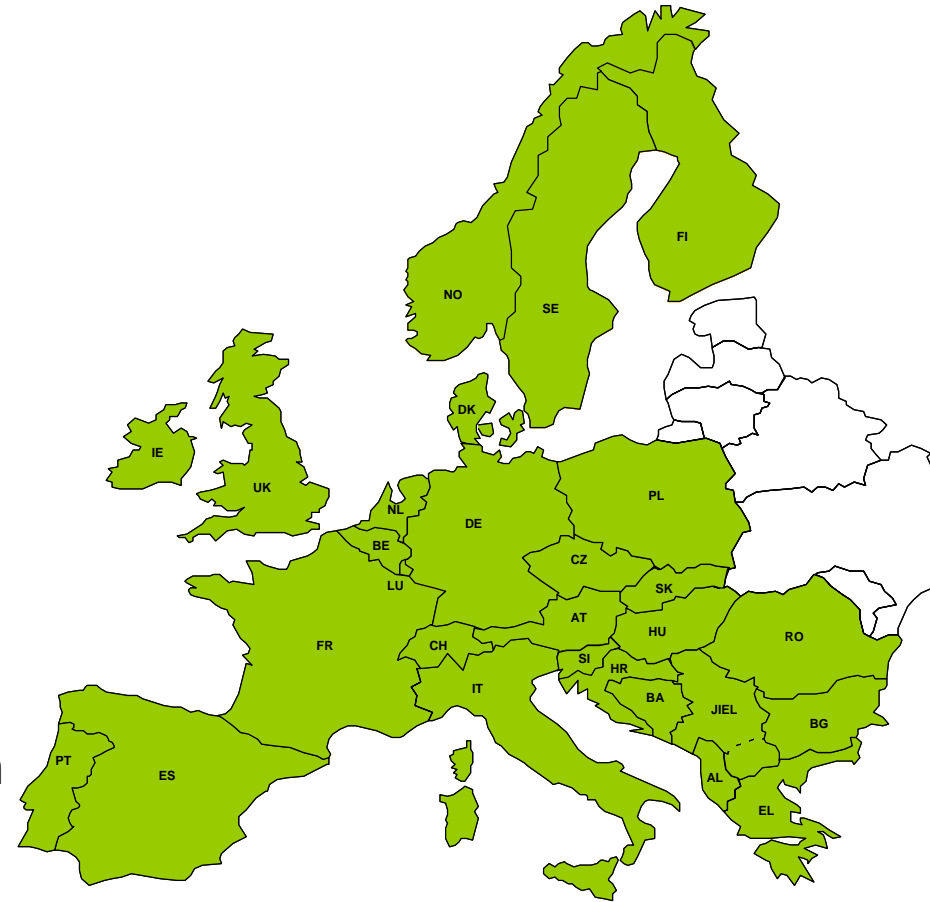
## Representation of load-flow based market coupling

- No load-flow based market coupling (“NTC” case):
  1. Day-ahead market clearing:
    - No consideration of electrical load flow restrictions
    - International exchange limited by Net Transfer Capacities (NTC)
  2. Intraday rescheduling:
    - Representation of zonal physical flows with Power Transmission Distribution Factors (PTDF)
    - International exchange limited by Total Thermal Capacities (TTC)
- Load-flow based market coupling (“MC” case)
  1. Day-ahead market clearing:
    - Representation of zonal physical flows with Power Transmission Distribution Factors (PTDF)
    - International exchange limited by Total Thermal Capacities (TTC)
  2. No intraday rescheduling required
- Comparing both cases gives the theoretical impact of load-flow based market coupling in the whole European power system



# Application case

- Zonal description of EU-27 countries  
(– Malta, – Cyprus, – Baltic countries;  
+ Norway, + Switzerland, + Balkan countries)
- Considered year: 2015
- Fuel and CO<sub>2</sub> emission permit prices based on projections of European Commission
- Derivation of required power plant investments with further electricity market model E2M2s
- Transmission capacities and Power Transmission Distribution Factors supplied by European Wind Integration Study
- Wind power capacities and time-series based on Tradewind data



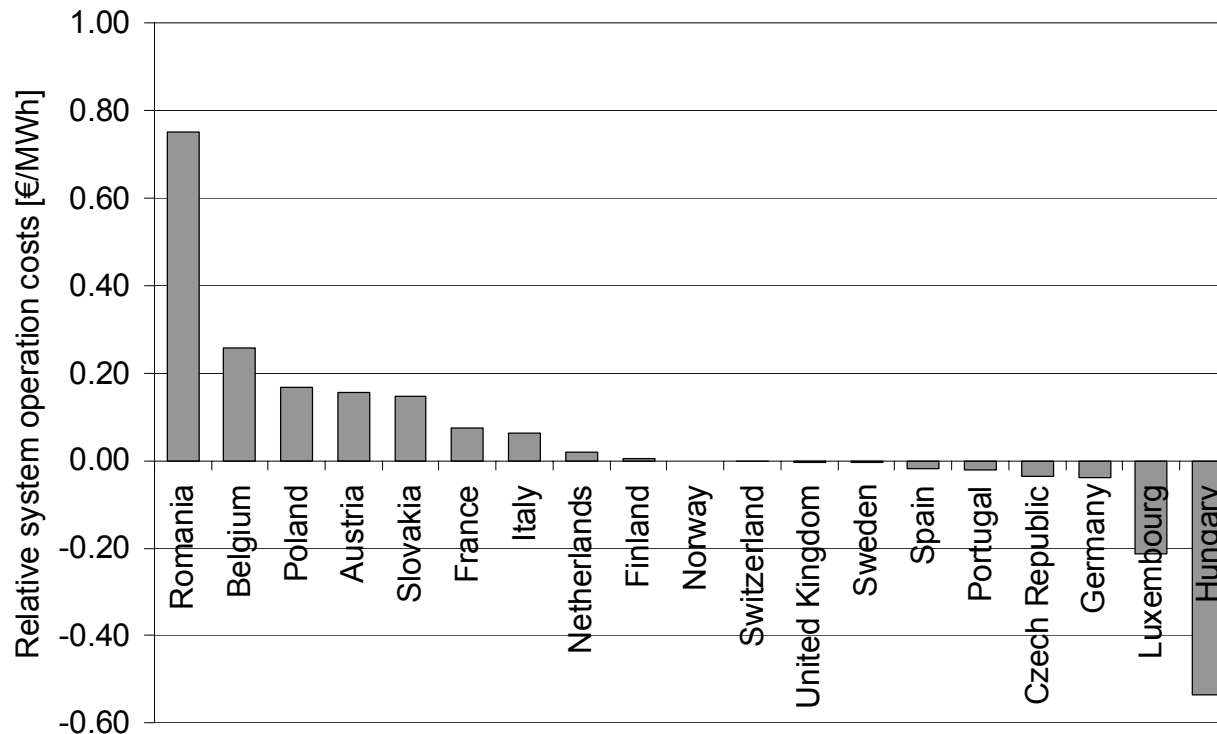




# Results I

## Annual system operation costs

- Absolute difference of relative system operation costs between NTC and MC case in selected countries

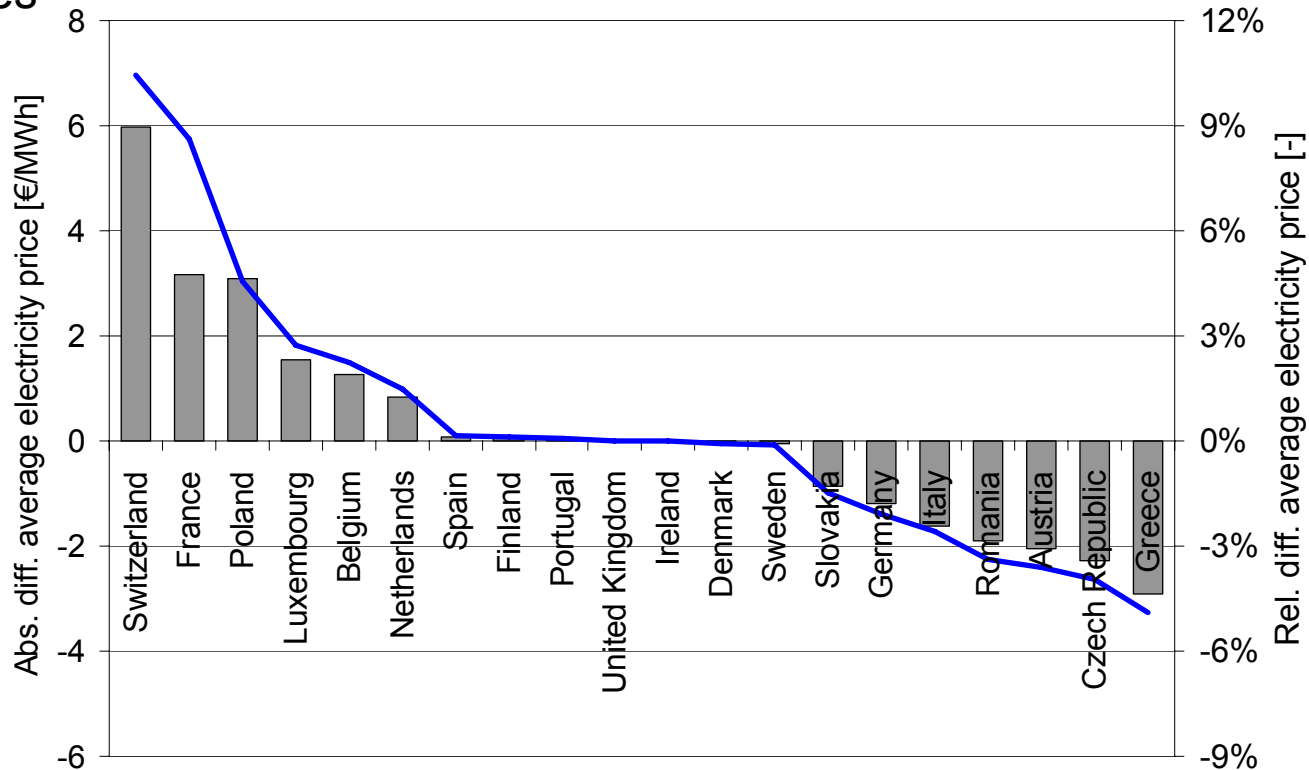


- Absolute reduction in whole European electricity system: 64.6 Mio. €/a (ca. 0.1 %)

# Results II

## Average day-ahead electricity prices

- Absolute and relative price differences between NTC and MC case in selected countries



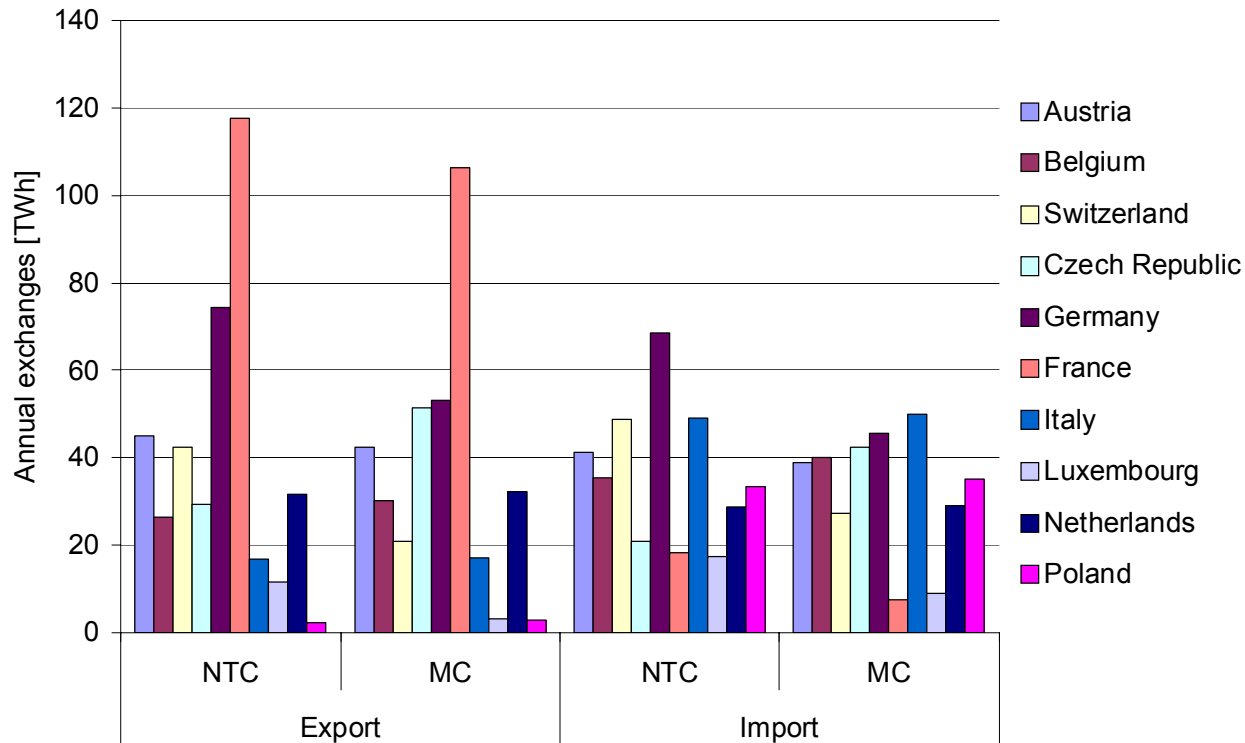
- Reduction in whole European electricity system: 0.79 €/MWh (ca. 1.5 %)



# Results III

## International electricity exchanges I

- Annual scheduled export and import of selected countries



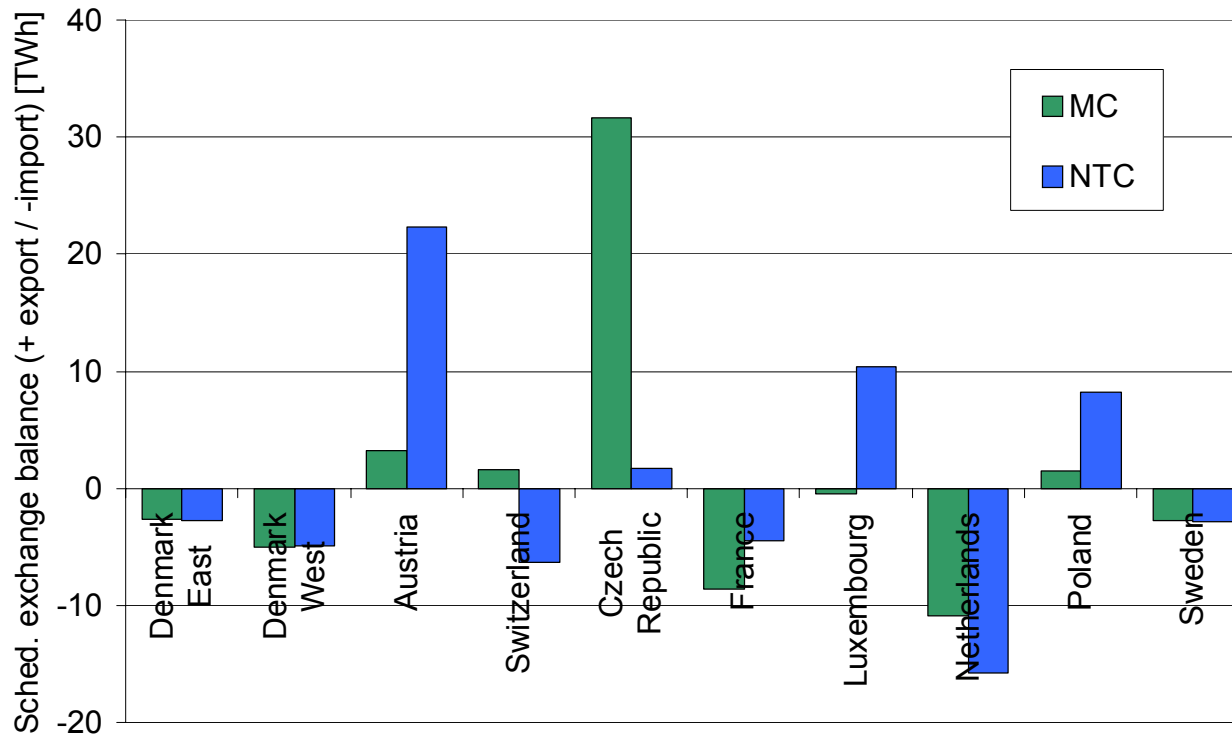
- Scheduled exchange balances remain almost constant
- Less rescheduling of exchanges required with load-flow based market coupling



# Results IV

## International electricity exchanges II

- Example: Annual scheduled electricity balance to and from Germany



- Total scheduled electricity exchange balance of Germany increases from 5.7 TWh to 7.6 TWh with load-flow based market coupling



# Summary

Impacts of load-flow based market coupling on system operation costs and electricity prices:

- Whole European electricity system:
  - i. Reduction of system operation costs of 64.6 Mio. €/a (ca. 0.1 %)
  - ii. Reduction of average day-ahead electricity prices of 0.79 €/MWh (ca. 1.5 %)
- Differentiated impacts on individual countries
  - i. Reduced relative system operation costs: Romania, Belgium, Poland, Austria, Slovakia, France, Italy, Netherlands
  - ii. Reduced day-ahead electricity prices: Switzerland, France, Poland, Luxembourg, Belgium, Netherlands

Impacts of load-flow based market coupling on exchange balances:

- Scheduled exchange balances of individual countries are comparable
- Scheduled exchange balances of individual lines differ considerably

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# Thank you for your attention!

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