UNIVERSITÄT DUISBURG ESSEN

Lehrstuhl für Energiewirtschaft
Prof. Dr. Christoph Weber

EWL

Stephan Spiecker, Philip Vogel, Christoph Weber, Carlo Obersteiner

INVESTMENT PLANNING OF INTERCONNECTORS UNDER CONSIDERATION OF WIND POWER EXTENSIONS IN EUROPE

8th International Workshop on Large-Scale Integration of Wind Power into Power Systems as well as on Transmission Networks for Offshore Wind Farms

14-15 October 2009

Bremen, Germany

Agenda

- Why investment in interconnectors?
- Evaluation of line investments
- The European electricity market model E2M2s
- The European „Supergird“-Scenario for line investment
- Results
- Outlook

Advantages of meshed electricity markets

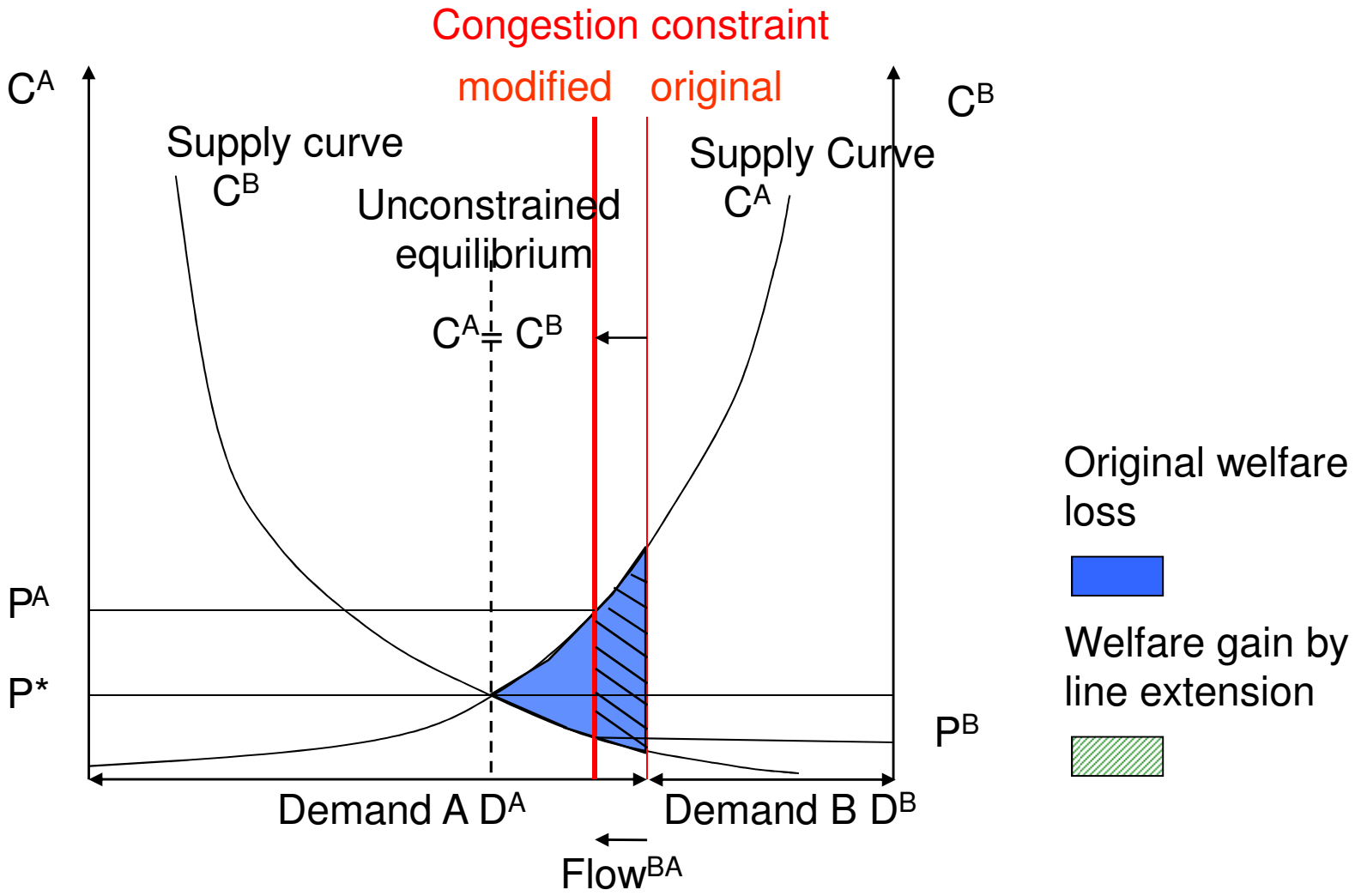
- Increased trade and physical flows of electricity
- Reduced production costs of electricity in connected countries
- Insurance against demand volatility und reduced reserve requirements
- Reduction of additional national power plant capacities
- Higher competition on national electricity markets
- Balancing of fluctuative wind production
- Absorption of extreme wind and demand peaks

→ Positive welfare effects by interconnector investment

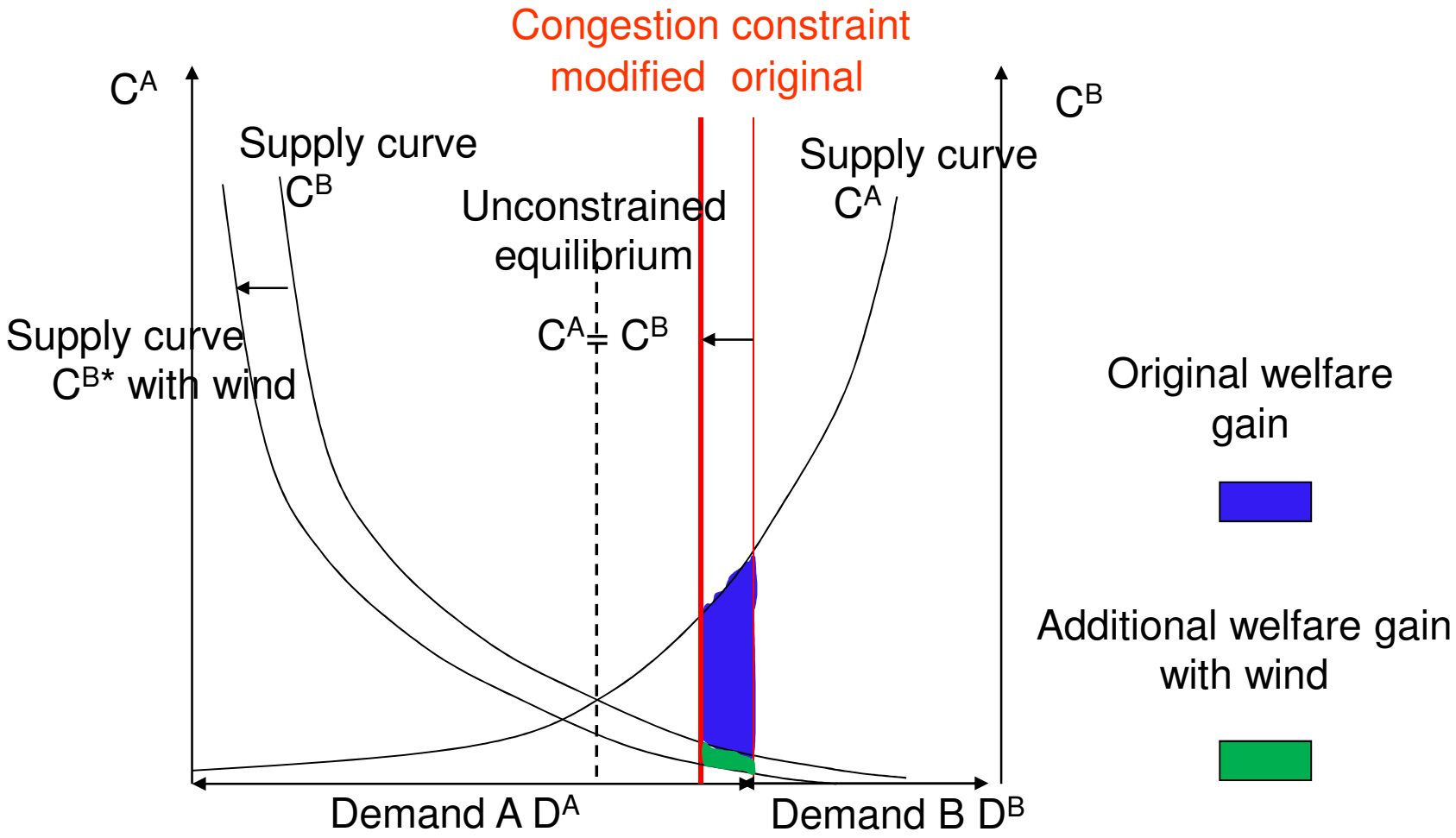
Measures for assessing benefits

- **congestion rent of the new link** depending on the transmitted energy which feasible and the price difference between the two markets (1. benefit)
  - → Measure of direct (potential) TSO benefit
- the **convergence of prices** of all relevant markets to indicate the direct benefit for the consumer & producers (2. benefit)
  - Indication of societal benefit
  - But if prices converge at higher level no indication of consumer benefit
  - Prices are marginal measures, therefore assessment of integral benefit difficult
- the **prices** without additional capacity to be **compared** with the results with additional capacity
  - Similar to previous measure
  - Could be even increasing for area with so far lower price level
- the **system cost** without additional capacity to be **compared** with the results with additional capacity
  - Measure of integral societal benefit
  - to be compared with costs of line extension
  - → If difference is positive, then extension is overall beneficial for societies

Extension of cross border capacities



Welfare gain and wind production (I)



Welfare gain and wind production (II)

- Caused by technical restrictions not all types of power plants can react on fluctuating energy production of RES-E
  - Gas and hydro power plants are flexible
  - Coal and nuclear power plants are less flexible
- National electricity markets differ in their level of flexibility
  - Organically evolved power plant capacities
  - Geographic differences, e.g. availability of places for technologies
- Connection of flexible and less flexible electricity systems can reduce integration costs of wind energy
  - Reduction of high start-up costs / expensive shutdowns
  - Reduction of power plant capacities that operate in part load efficiency

Challenges with evaluating interconnector investments

- The European electricity market is already meshed
- Changes at one point may influence other parts of the system

→ The European electricity market has to be analyzed as a whole

→ Relevant parts of the system has to be modeled in detail

- Resulting challenges
  - Data availability
  - Technical differences of production technologies
  - Intertemporal dimension
  - Stochastic of fluctuating production
  - Level of detail for system components
  - Computing power for calculation

→ Trade-off between different challenges

Uncertainties for evaluation

- Economical constraints
  - Fuel prices
  - Demand development
  - Capital costs
- Energy policy
  - CO_2 prices
  - Subsidy for RES-E
  - Nuclear phase-out
- Naturally constraints
  - Wind in-feed
  - Water inflow

→ Uncertainties can be anticpated by different scenarios

European Electricity Market Model E2M2s

- Model of **European countries**
- Includes **electricity and district heating markets**
- **Variable degree of detail**:
  - whole of Europe or
  - European regions or/and
  - several regions within one country
- **High temporal resolution**:
  - Electricity is not storable
    → Individual hours have to be considered
  - Hydro storages and other technologies require modelling of full years
    → **Typical days and typical hours** as approach
- **Stochastic modelling of wind and water fluctuations**
  - Increasing share of wind power production in European System
  - Fluctuating wind power induces additional load flows
  - Changes in hydrological conditions have also to be foreseen

E2M2^S - Methodology

- Minimization of system costs
  - Corresponds to market outcomes in workable competition
- Dynamic recursive optimization for modelling years
  - Optimal operation of conventional units with start-up costs etc.
  - Optimal use of hydro reservoir
  - Optimal CHP operation
  - Optimal investment
- Cost components taken into account
  - Fuel cost
  - Other variable cost (e.g. desulphurization)
  - CO_2 cost
  - Investment cost
  - Other fixed cost (e.g. staff, insurance)

E2M2^S: RES-E availability – stochastic scenarios

1. Wind power availability
   - Wind speed data from several measurement points per country, hourly time series for three years available
   - Typical power curve for wind turbines
   - Calibration on annual total wind generation

   → Currently three scenarios per time step, from almost no wind to full power

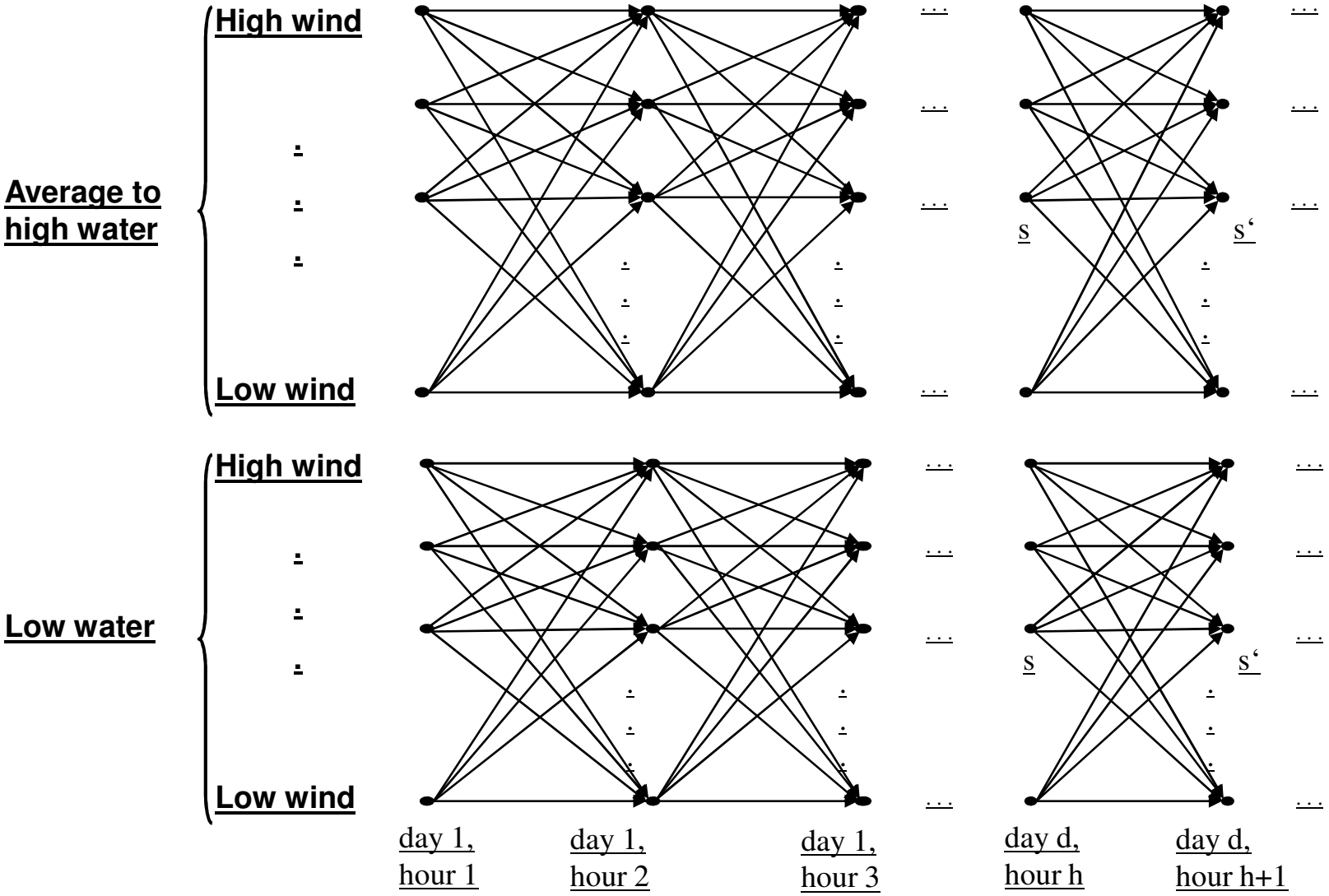
   - Transition probabilities derived from wind speed data:

     e.g. with some likeliness after full wind there will be very little wind
2. Hydro availability
   - In the case of hydro storage plants especially the long-term fluctuations are relevant
   - Fluctuations of 20 % or more may occur between one year and another
   - Cases with low water inflow are most critical

   → Currently two scenarios corresponding to rather low and just above medium water inflow

→ Use of recombining trees for reduction of complexity

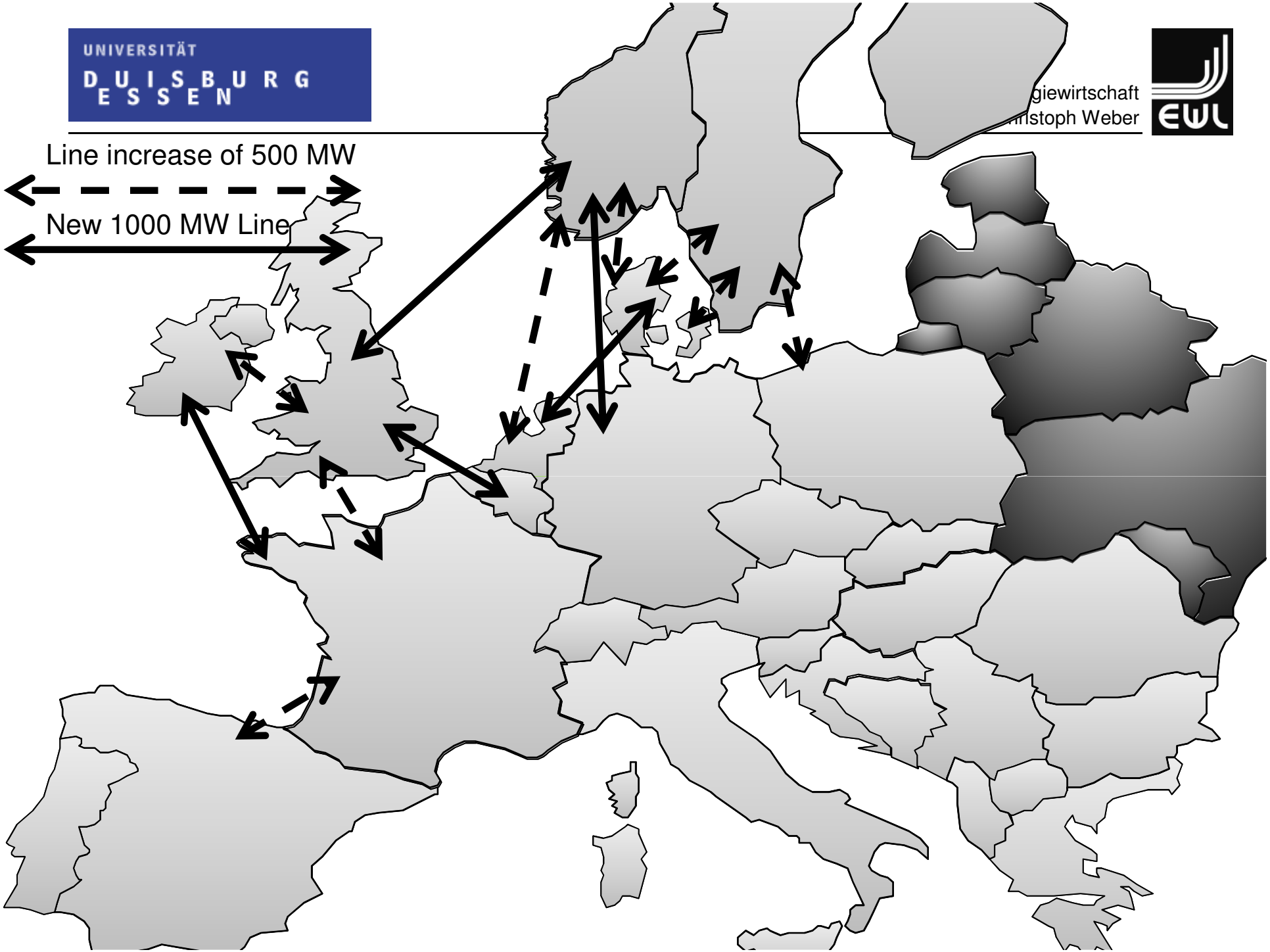
E2M2^{S}: RES-E availability – stochastic scenarios



The Supergrid

- In Europe investments in wind energy appear to a large extent
- Especially in the North Sea large amounts of wind turbines are planed
- Therefore lots of politicians, researcher and stakeholder of the power markets ask for line investment between the northern european countries
- From an economic point of view these investments are only beneficial if total welfare is higher than necessary investment costs

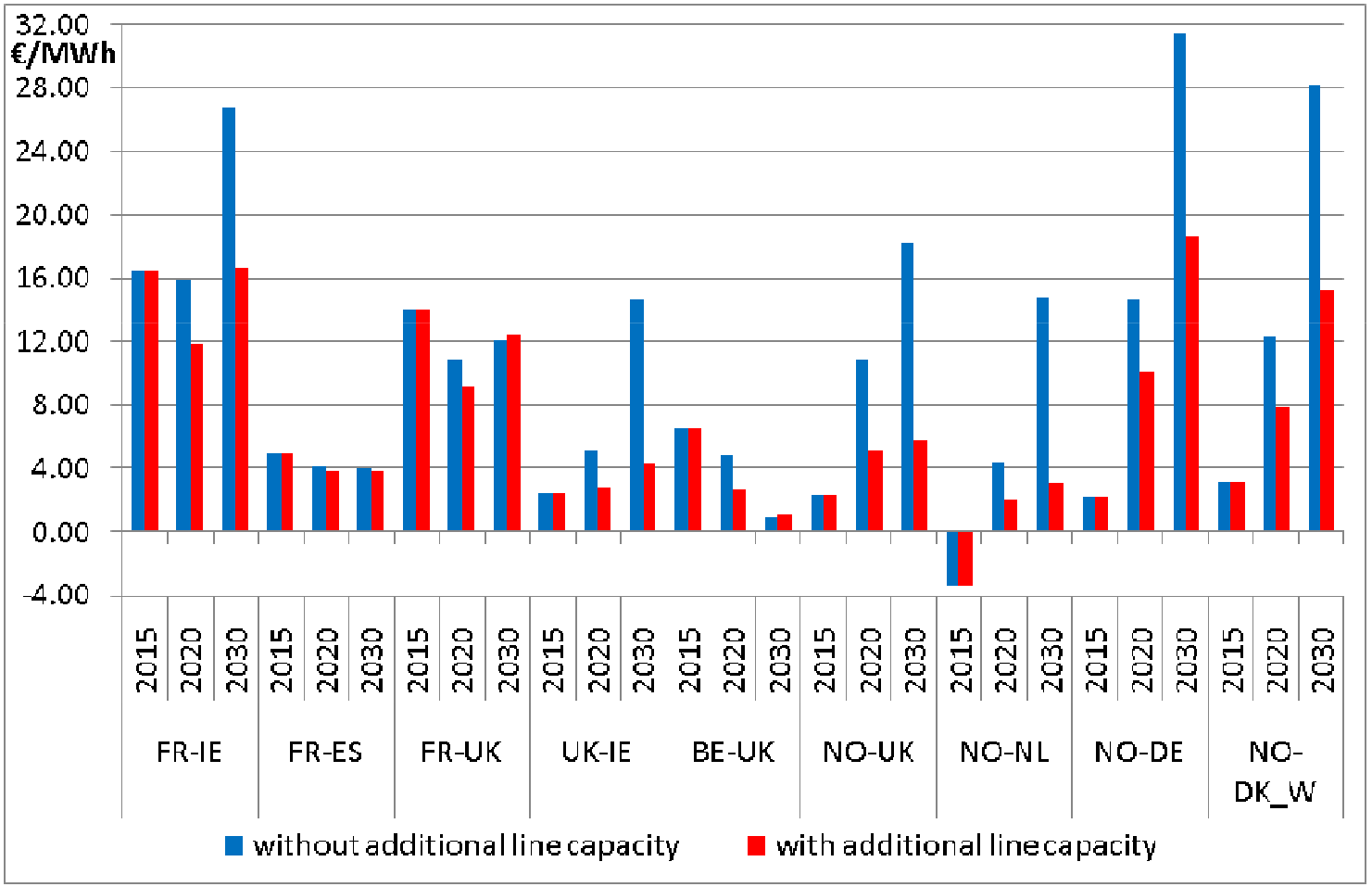
→ In the following case study welfare gain of a Supergrid-Scenario is evaluated


Line increase of 500 MW
New 1000 MW Line

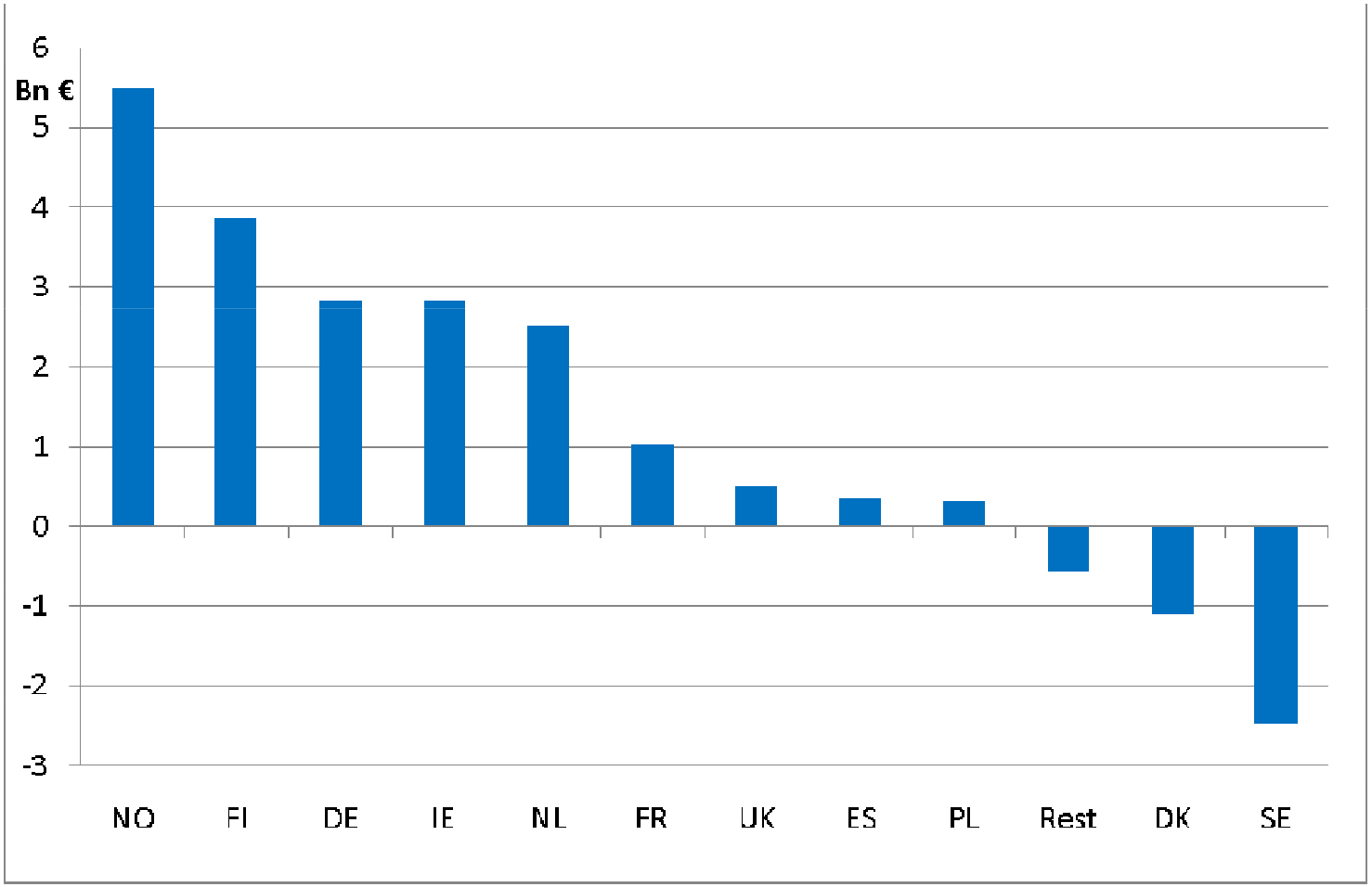
Scenario Parameters

- CO_2 Price 2008 25 €/t CO_2 increase until 2015 to 60 €/t CO_2
- Interest rate for investment of 7% real
- Moderate development of RES-E (calculated by Green-X)
- New lines online in 2020
- Calculation in five year steps until 2030, subsequent perpetuity is assumed
- All cost reductions are discounted to 2020

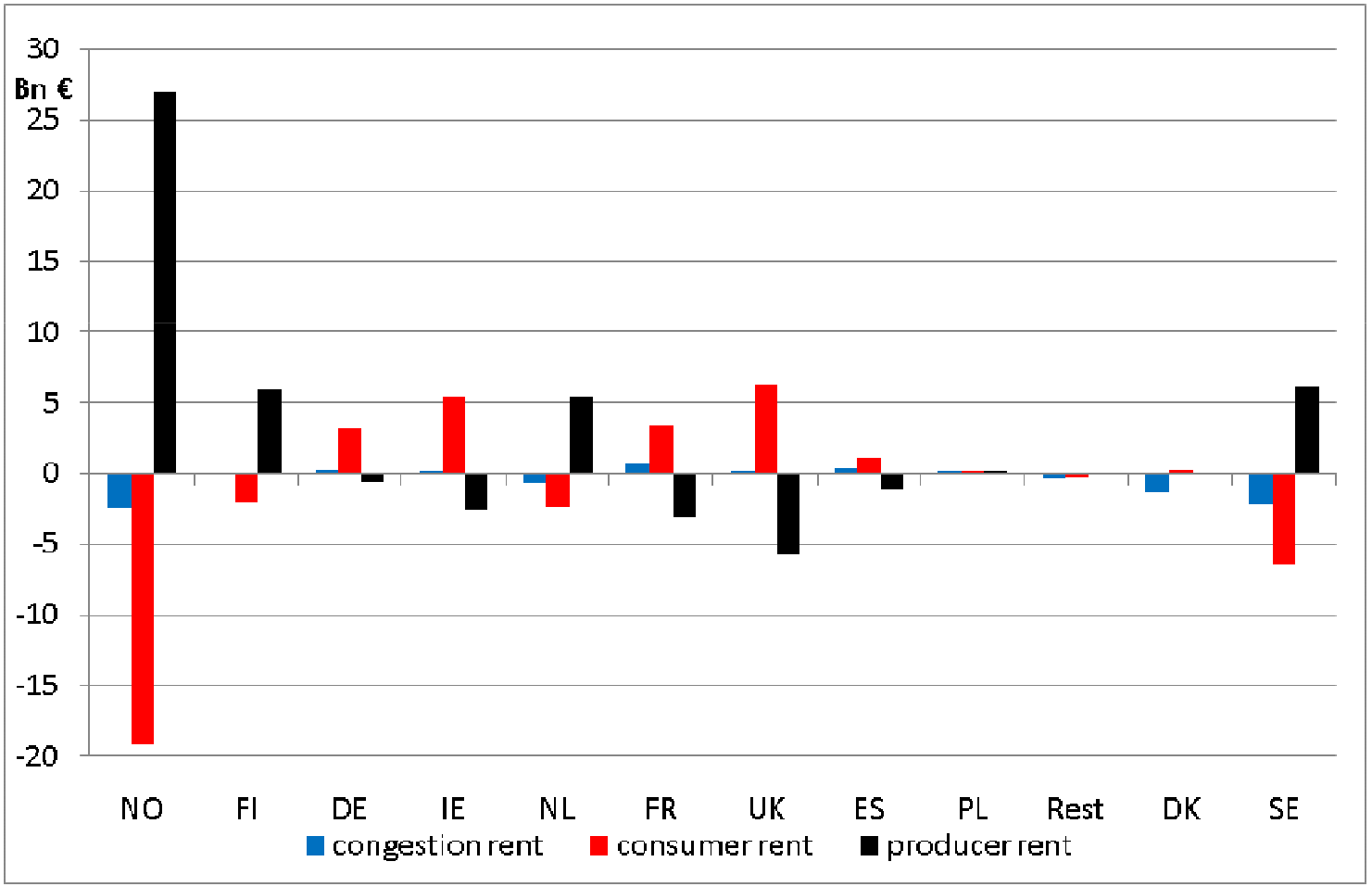
Price convergence at the frontier



Discounted national welfare gain in 2020



Distribution of welfare gain



Intermediate Results

- With additional line capacity prices converge to a higher extent compared to a case without any further line investment

- Line investment increases total welfare by approx . **8.7 bn €**
  - For some countries line investment is advantageous
  - Other countries do not participate on welfare gains or even loose

- Increases in consumer rent are mostly generated at the expense of producers and vice versa

- In most cases TSOs loose with additional line investment
  - The price effect dominates the effect of quantity

Cost estimation for investment

- Assumptions
  - Invest cost of 3 Mio €/km
  - Invest cost within a country are not considered

- Total cost: ca. 8.1 bn €
- Total welfare gain: 15.5 bn €

→ In the selected scenario and under the assumed discount rate an investment in a „Supergrid“ is beneficial from an economic point of view.

Implication of results

- One scenario is not sufficient to evaluate the benefit of line investment
- Timing of investment has influence on profitability
  - Impacts of particular lines should be analyzed
- Focusing on lines with the highest potential benefit is an adequate approach
  - Shadow prices of transmission lines as an economic ranking
- Significant distribution effects are given
  - Political restrictions are probably
  - TSOs have to be compensated for reduction of congestion

Outlook

- Only a European electricity market model allows an adequate analysis of line investment using cost-benefit-analysis

- Several scenarios should be analyzed to consider future uncertainty

- Parameters that influence investment decision
  - CO_2- and fuel prices
  - Changes in power plant structure
  - Increasing demand
  - Hydro inflow
  - Investment in RES-E

- A stochastic approach helps to model the rising volatility in power markets

Thank you for your attention!