Impact assessment on European x-border Electricity Balancing Market

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Background

- A study under the EC DGENER Framework Contract commissioned on January 2012
- In support of ACER's invitation by EC (18/01/2012) to develop the FG for the x-border Balancing Market
- Mott MacDonald, Sweco, Imperial College team
- Completed finally in March 2013 mainly due to severe delays in obtaining the Nordic balancing data

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Purpose

- Understand the operational & market impacts of the various policy options and models of integration
- Identify potential implementation challenges, barriers and minimum pre-requisites
- Evaluate the likely costs & roadmap of implementation for the various models of integration
- Quantify the benefits of exchanging Balancing Energy and assessing the benefits of Sharing Reserve Services on a cross-border
- Extensive consultations with the industry (9 TSOs, major stakeholders & institutions)

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Quantitative assessment

- Five approaches to quantification of benefits:
  - Stacking model: Exchange of surpluses only, retention of “Margins” and full CMO on historical (2011) data UK – France
  - Time-series/regression analysis of the relationship between balancing prices and market indices for Great Britain, France where trading of balancing energy has been introduced;
  - Comparison of balancing costs for the five Nordic countries between an integrated balancing market and a hypothetical individual country basis (using 2011 historical data)
  - Exchanges of Balancing Energy between two hypothetical systems with varying penetration levels of intermittent generation
  - Exchanging Balancing Reserves for Europe-wide “2030” system with high penetration of intermittent generation

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Data acquisition & processing

- GB: 350 BMU 5 pairs of bids/offers + technical constraints for each ½ hour = 150 million data points for a single year of operation (2011)
- Semi-complete dataset for France
  - Incomplete bid offer data
  - Adequate for econometric analysis
- Nordic TSOs very reluctant to release balancing data, eventually did so in September 2012 after considerable pressure from ACER / EC

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Exchanges of Balancing Energy UK – France

- A non-linear optimisation algorithm has been applied to determine the least cost mix of offers and bids submitted by Balancing Service Providers (BSPs) in each country that resolved each system imbalance for every Settlement Period
- For the welfare gains a “stand alone” base case assuming no internal congestion and no interconnections with other parties
- For the coupled system scenarios the optimiser was finding the least cost solution to system imbalances drawing upon all offers/bids, subject to not breaching the available interconnector capacity (for both directions) at each settlement period
- No netting of imbalance volumes

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Data inputs

- BSP unit level:
  - Bid / Offer Prices including capacity steps for every PTU in 2011
  - Unit level generation constraints
  - Generation schedules (FPN)
- System level:
  - Net Imbalance Volumes
  - Available interconnector transmission capacity
- Exchange rates
- Assumptions: Power plant start-up costs not included. Plant ramp profiles were not known. Downward regulation was assumed to be delivered only by plants that were in operation. i.e. plant de-loading. DSR side of the market was not modelled.

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Three Scenarios

- **Full CMO (Unconstrained trade)**
- **Exchanges of Surpluses**
  - exclude 2200MW of lowest cost offers in UK from trade (domestic use only)
  - exclude 1500MW of lowest cost offers in France from trade (domestic use)
  - exclude 1000 MW of most beneficial bids in UK from trade (domestic use)
  - exclude 1000 MW of most beneficial bids in France from trade (domestic use)
- **CMO with "Margins"**
  - exclude 2200MW of most expensive offers in UK from trade (domestic use)
  - exclude 1500MW of most expensive offers in France from trade (domestic use)
  - exclude 1000 MW of least beneficial bids in UK from trade (domestic use)
  - exclude 1000 MW of least beneficial bids in France from trade (domestic use)

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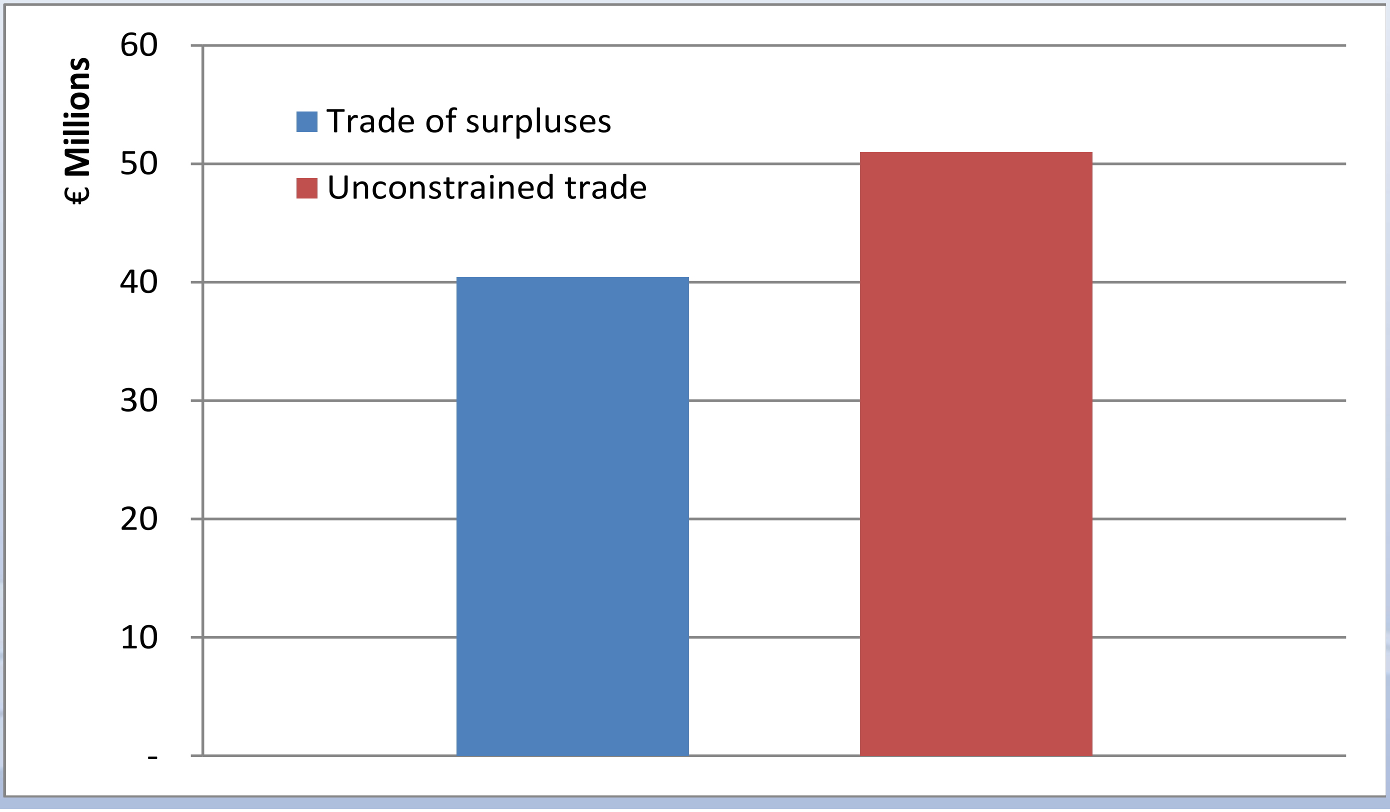
Results

- Annual benefit of €52 million to two countries (€ 40 mil “surpluses”)



Trading pattern:
UK importing lower cost offers from France (upward regulation)
France exporting surplus energy to the UK (downward regulation)

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Econometric Analysis

- Based on previously successfully applied methodology (Skytte 1999)
- Data covering the period from April 2005 to December 2011 for France and from June 2008 to March 2012 for UK
  - XB balancing started in December 2010
  - Prices were adjusted for inflation
- Model differentiated between periods when the system was short and when the system was long
- The results verified the theoretical hypothesis that the XB balancing mechanism would bring the balancing prices closer to the day-ahead prices.

Analysis of Nordic Balancing Markets

- Historic data (2011) to compare welfare gains vis-à-vis the costs for balancing a hypothetical "stand alone" case.
- Data inputs (8.5 mil data records):

- NOIS bid data. The bid data consisted of quantities, prices, region of origin, whether it was flagged as a special bid and whether it was cleared by the market
- Nord pool spot regulating volumes. The dataset consisted of the cleared regulating volumes per region, price of the regulating power
- Scheduled and actual exchange per cross-border interconnector from Nord Pool Spot. The scheduled flow was the market cleared exchange from Nord Pool Spot and Nord Pool Elbas
- Energinet.dk planned and observed trade. Svenska Kraftnät planned and observed cross-border exchange

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Results of Nordic Balancing Markets

- The deviation in the scheduled and observed cross-border exchange was assumed to correspond to the transmitted regulating power
- The results indicate that the cost of “tertiary power” is approximately 8 times greater **(€ 221 million/year)** with a “domestic-only balancing market” compared to the integrated balancing market scheme

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Benefits XB-BE exchanges between systems with intermittent generation

- Two identical systems with energy demand of 450TWh and peak load of 95GW each. We examined the reduction in short-term imbalance volumes arising from different volumes of energy being exchanged and investigated the operating costs savings that may be associated with the exchanging of balancing services cross-border
- Stochastic short-term generation scheduling model over 1 year horizon – the only security requirement is the Value of Lost Load (VoLL) €30,000/MWh
- Four levels of penetration of wind generation: 10%, 15%, 30% and 45% in combination with 0, 2GW, 5GW and 10GW interconnection capacity
- Wind output uncertainty over 4-hour time horizon, standard deviation of forecasting error of wind output 10% to 15% (TSOs assume 15% but this is expected to fall to 10% in the future)

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Results

	10% Wind penetration	15% Wind penetration	30% Wind penetration	45% Wind penetration
0 GW	1.1 – 2.2 GWh/h	1.7 – 3.2 GWh/h	3.4 – 6.4 GWh/h	5.1 – 9.7 GWh/h
2 GW	0.8 – 1.6 GWh/h	1.2 – 2.3 GWh/h	2.6 – 5.2 GWh/h	4.0 – 8.3 GWh/h
5 GW	1.1 – 1.5 GWh/h	1.2 – 2.3 GWh/h	2.4 – 4.7 GWh/h	3.7 – 7.3 GWh/h
10 GW	1.1 – 1.5 GWh/h	1.2 – 2.3 GWh/h	2.4 – 4.6 GWh/h	3.7 – 7.0 GWh/h

	10% Wind penetration	15% Wind penetration	30% Wind penetration	45% Wind penetration
2 GW	82.5 – 158.7	110.5 – 198.9	223.4 – 402.1	265.5 – 477.9
5 GW	90.2 – 162.4	121.4 – 216.2	363.4 – 655.7	424.5 – 764.1
10 GW	90.2 – 162.4	121.5 – 216.4	405.3 – 729.5	574.3 – 1033.7

	10% Wind penetration	15% Wind penetration	30% Wind penetration	45% Wind penetration
Uncertainty costs	350 - 400	600 - 750	1600 - 2100	2900 - 3500

Savings originate from the reduced cost of delivery of balancing services, i.e. lower cost of supplying energy shortfalls.

2 GW / 500 km interconnector approx. € 180m/year

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Benefits of exchanging Balancing Reserves x-border in 2030 EPS

- Grid integration studies using the Imperial Dynamic System Investment Model and considered EU 2030 scenarios. In the scenarios analysed, renewable generation production meets about 45% of the total energy requirements.
- Model minimises the total annual generation operating cost across the technology mix that consists of: (i) marginal variable cost which is a function of the electricity output, (ii) no-load cost which represents efficiency losses due to part load operation and (iii) start-up cost. Generation operating cost is determined by fuel prices and carbon prices
- The model includes requirements for operating reserves, and “frequency response” on the basis of “Single Major Incident”. The amount of RR required is calculated as a function of uncertainty in generation and demand across the time horizons of 4 hours The model captures the fact that the provision of frequency response is more demanding than providing operating reserve and that only a proportion of the headroom created by part-loaded operation will be available for delivery for FCR

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Results

- Model schedules the optimal provision of reserve and response services, taking into account the capabilities and costs of potential providers of these services, including (i) efficiency losses of part loaded plant, (ii) minimum stable generation (iii) ramp rates, (iv) minimum up and down times (v) response slopes. Optimal trade-off between the cost of generating electricity to supply and the cost of procuring sufficient levels of reserve and response. The allocation of spinning and standing reserve is optimized ex-ante to minimise the expected cost of providing these services.
- Integration of Balancing Markets and sharing of reserves could achieve **operational costs savings of the order of € 3bn/year and reduced (up to 40% less) requirements for reserve capacity** (from a level of 120-160 GW to a level 75-95 GW in 2030). This reduction is driven by increased diversity in demand and renewable output and hence reduced in overall uncertainty

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