# Electricity Market Flexibility

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29th May 2014

Prepared for Restructured Electricity Market Conference
The Van Horne Institute, University of Calgary

# The Challenge

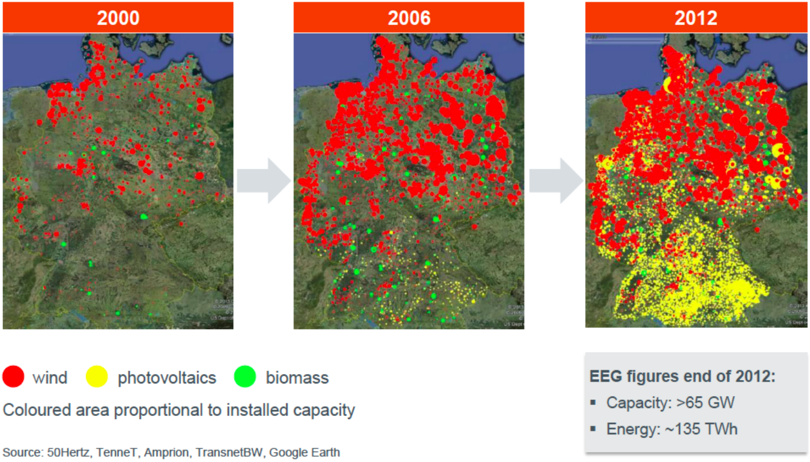



Figure : Wind, photovoltaics and biomass in Germany (Schucht, 2014)

# The Fundamental Issue

- Feed in and withdrawal must balance at all time
  - within certain limits
  - respecting grid capacity constraints
- Balancing requires adjusting
  - consumption of electricity and/or
  - generation of electricity
- How can this be done in an economically efficient manner?
  - decentralised by individual consumers and generators
  - centralised by system operator or others (regulation, rationing)

# Analytical Framework

- Take current markets in Europe as starting point and discuss possible development or reform of these
  - do not consider fundamentally different models
- Disregard
  - network issues: transmission capacity, interconnection
  - market expansion and integration: market coupling
  - as if electricity is generated and consumed at a single point and trade takes place in an all-encompassing market
- Concentrate on short-term issues (taking capacities as given), but touch on long-term issues (investment and disinvestment)

# Transaction Costs

- In theory, trade could take place continuously in real time
- In practice, impossible due to costs associated with
  - receiving and processing (price and other relevant) information
  - making bids and offers, setting prices, writing contracts
  - metering, settling contracts, handling payments
  - adjusting consumption and generation
- Implications
  - transactions conducted before actual delivery
  - time divided into discrete market time periods
  - contracts covering multiple market time periods
  - contracts with flexible volumes
  - deviations (imbalances) between contracted and actual trade
  - rationing (by system operator or others)

# Transaction Cost Diversity

- The importance of transaction costs differ between
  - consumption technologies
  - generation technologies
  - storage availabilities
  - agents of different size and diversification
- Therefore, contracting possibilities should differ with respect to
  - time between transaction and exercise of contract
  - length of market time period
  - duration of contracts (number of contract periods)
  - fixed versus flexible volume
  - rationing in specified contingencies

# Time Between Transaction and Exercise

- In spot markets, gate closure typically 12-36 hours in advance in day-ahead markets and 1-2 hours or less in intraday markets
  - mostly dictated by system-operation considerations
- A shorter time time between transaction and exercise
  - allows for better optimisation of consumption and generation to real time costs and benefits
  - reduces liquidity when gate closure approaches
- Do larger volumes of renewables require a shortening of time between transaction and exercise?
  - wind and sunshine generally predicted with relatively high levels of accuracy, even hours beforehand
  - but exeptions occur
  - so, perhaps gate closure should be revisited

# Forecasting

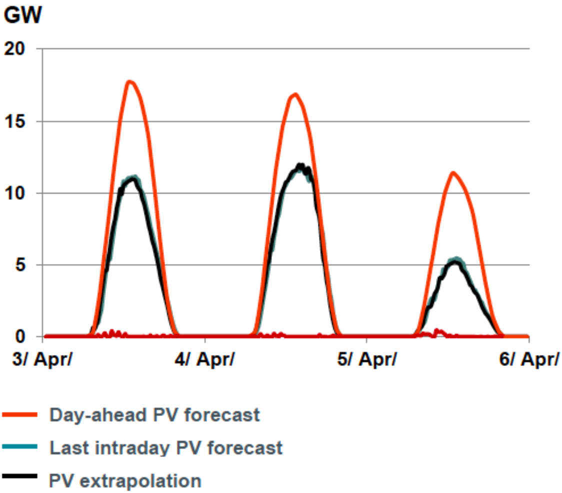



Figure : Photovoltaic forecasts, Germany April 2013 (Schucht, 2014)

# Market Time Period

- Minimum market time period typically one hour
  - (shorter in balancing markets)
- A shorter market time period
  - allows for more frequent price adjustments to reflect underlying market conditions
  - reduces deviations from average volume within period
  - increases number of transactions
- Do larger volumes of renewables increase variation in market conditions within current market time periods?
  - most variation between and within days, not within the hour
  - but increasing variation within the hour also
  - so, perhaps market time period should be revisited

# Hourly Changes in Residual Demand

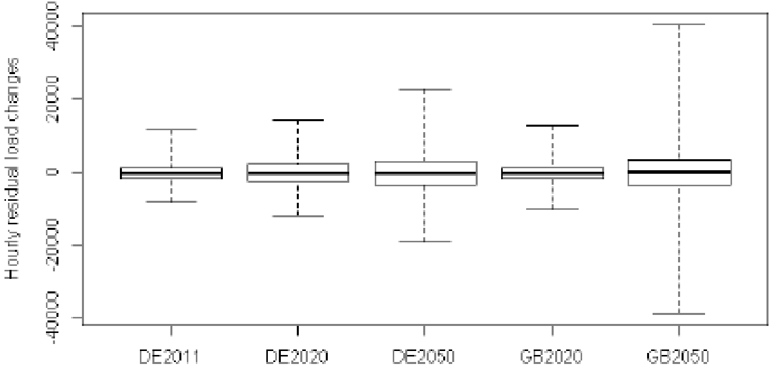



Figure : Actual and model simulations (Bertsch et al, 2013)

# Variations in Frequency

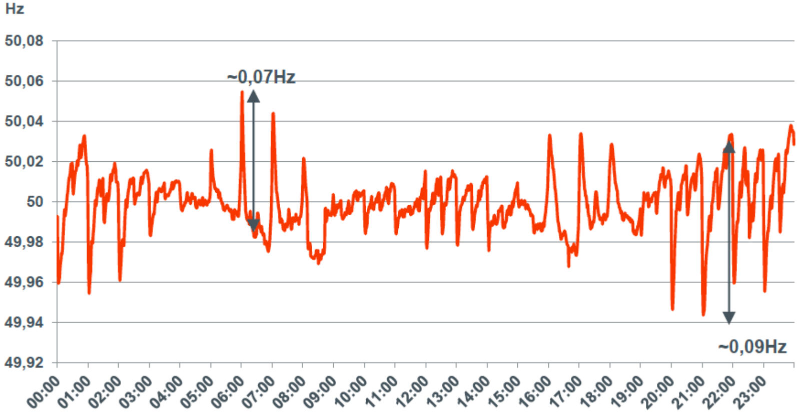



Figure : Average 4th quarter 2013, 50Hertz control area (Schucht, 2014)

# Ramping

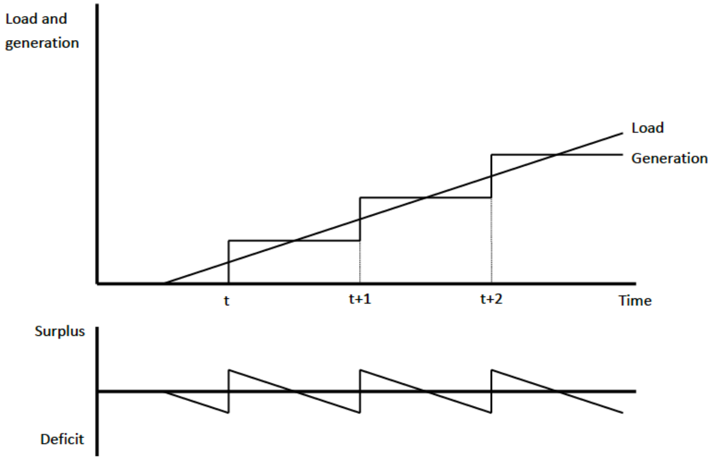



Figure : Imbalances with ramping at market time period change

# More Rapid Increase in Demand

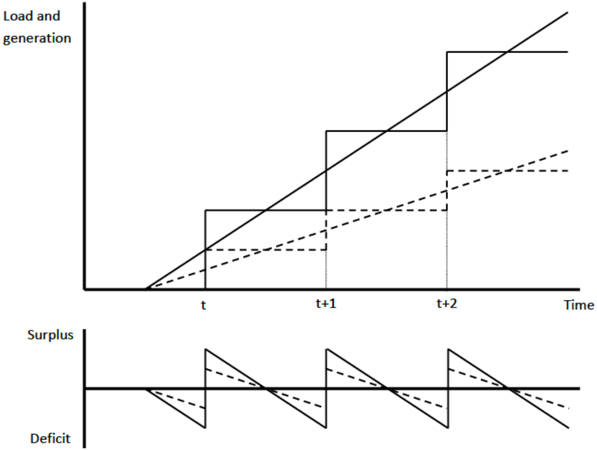



Figure : Imbalances for different demand growth rates

# Market Time Period

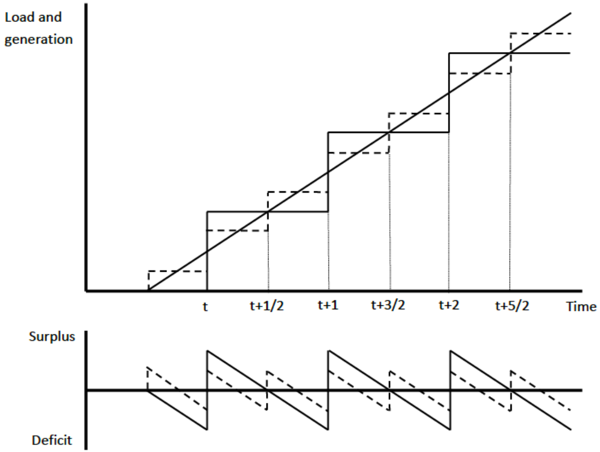
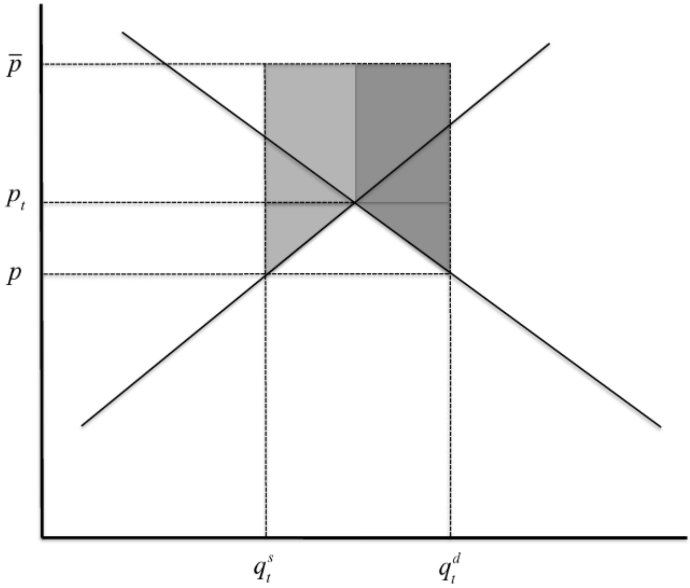



Figure : Imbalances for differant market time period durations

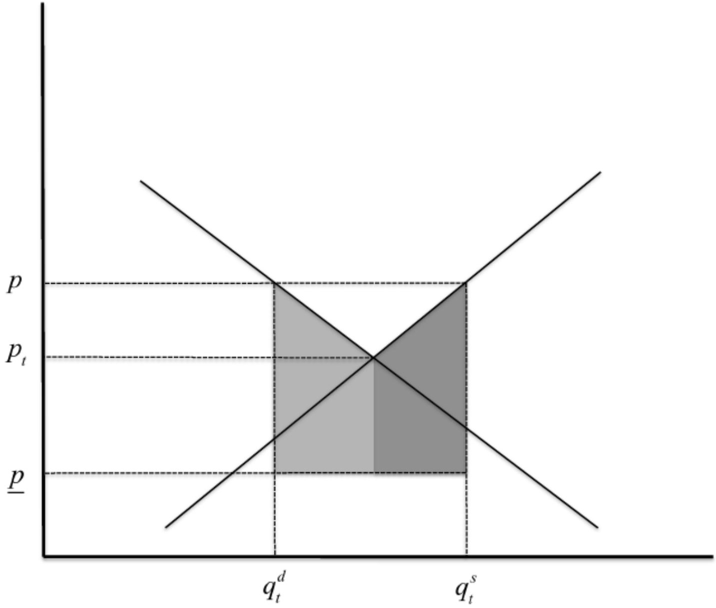
# A Simple Model

- Inverse demand and supply at time $t$: $q_t^d(p)$ and $q_t^s(p)$
- Market open for $t \in \left[0, \overline{T}\right]$, divided into $N$ trade periods of length $T = \frac{\overline{T}}{N}$
- Bids and offers for each trade period made before $t = 0$, based on expected demand and supply
- Each trade period cleared independently: trade period price $p$
- Imbalances costly
  - excess demand $q_t^d(p) - q_t^s(p) > 0$ covered at unit cost $\overline{p} > p$
  - excess supply $q_t^d(p) - q_t^d(p) < 0$ disposed of at value $\underline{p} < p$

# Excess Demand



# Excess Supply



# Results

- If $\left\{q_t^d, q_t^s\right\}$ is identically and independently distributed over time, expected loss from imbalances is independent of length of trade period, $T$, and hence number of trade periods.
- If demand is price inelastic and increasing (or decreasing) over time, while supply is price elastic but constant over time, expected loss from imbalances is increasing and convex in $T$.
- If transaction costs are proportional to number of trade periods, then optimal duration of trade period is decreasing in growth rate of demand and cost of sourcing power to cover excess demand, but increasing in cost of contracting, price elasticity of supply and value at which excess supply may be disposed of.

# Contract Duration and Fixed versus Flexible Volumes

- Many market participants hold contracts with long duration on time-invariant terms, often with flexible volumes
  - (small) consumers
  - generators on special terms (feed-in tariffs)
- Shorter durations and less volume flexibility would
  - increase sensitivity to market prices
  - reduce variation in actual volumes
  - induce more active participation in short-term markets
  - raise transaction costs
- Do larger volumes of renewables require contracts with shorter duration or less volume flexibility?
  - metering
  - (contracts for) curtailment of renewable electricity

# Rationing

- Rationing (balancing) of feed in and withdrawal warranted
  - imbalances within (minimum) contract period
  - (unplanned) deviations from contracted volumes
- Examples
  - automatic frequency control
  - restrictions on ramping
  - activation of operating reserves
  - demand-side management
  - blackouts
- Do larger volumes of renewables increase need for rationing?
  - ramping restrictions on renewable generation
  - demand-side management
  - operating reserves

# Demand-Side Management

- Under current market conditions, net benefits from demand-side management negative for most consumers
- Demand-side management may be
  - automated ("smart" meters, "intelligent" devices)
  - delegated (supplier or distributor, interruptible contracts)
- Do larger volumes of renewables increase incentives for demand side management?
  - variations in prices
  - (risk of non-delivery)
  - may require developing new market instruments, as well as investment in relevant infrastructure

# Operating Reserves

- Operating reserves to cover deviations between actual and planned volumes (in relevant contingencies)
  - primary, secondary, tertiary control
  - demand-side versus supply-side reserves
- Do larger volumes of renewable electricity increase the need for operating reserves?
  - yes, if deviations between actual and planned volumes increase in (some) relevant contingencies
  - if so, what kind of reserves?

# Investment in Flexibility

- Nature of variation (volatility) in renewable generation
  - frequency
  - amplitude
  - distribution
- Impacts on the need for
  - flexibility of resources (reaction time)
  - total amount of resources (difference between max and min)
  - cost structure of resources (fixed versus variable costs)
- Market-based incentives
  - number of operating hours (residual load duration)
  - price in operating hours (caps)
  - fixed payments (availability)

# Residual Load Duration

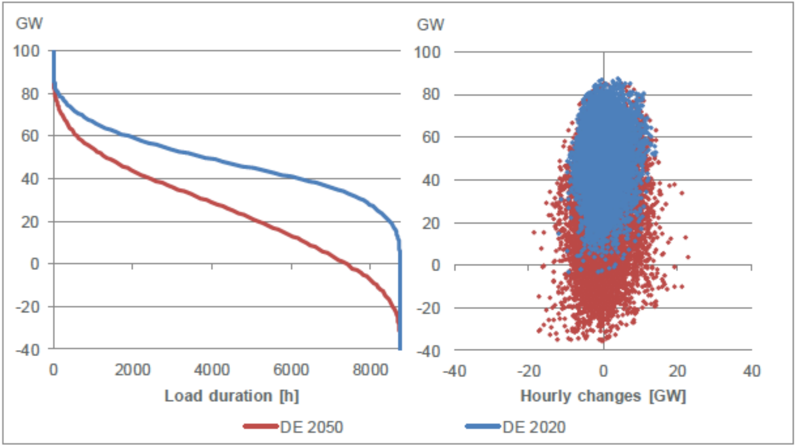



Figure : Model simulation (Bertsch et al, 2012)

# Conclusion

- Not obvious that larger volumes of renewables warrant fundamental changes to markets
  - risk of increased complexity
- However, may be need for further developing these markets and the extent to which they are utilised
  - direct participation
  - indirect participation (demand-side management)
- Problems mainly due to renewables being introduced too fast for other adjustments to take place
  - divestment of inflexible, and investment in flexible, consumption and generation capacity
  - (infrastructure)
- Reason to believe that, given time, markets will deliver required adjustments and flexibility

# References


- Bertsch, Joachim, Christian Growitsch, Stefan Lorenczik and Stephan Nagl (2012), Flexibility options in European electricity markets in high RES-E scenarios - Study on behalf of the International Energy Agency (IEA), Institute of Energy Economics, University of Cologne.
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