FTI·CL Energy

Impact of the wind production profiles on electricity prices in 2030

CEEM-Dauphine - workshop on renewables and electricity prices: modeling approaches

1/06/2015

Outline

- Who we are and what we do
- Research question
- Power market model
- Background assumptions
- Results

FTI·CL Energy

Who we are and what we do

FTI Consulting in an international multidisciplinary consulting firm

FTI Consulting activity

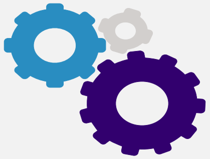
- FTI Consulting offers solutions specific to challenges and opportunities faced by companies worldwide

PORTEE INTERNATIONALE

Avec plus de 4,200 professionnels dans 24 pays sur les 6 continents, notre expertise s'étend sur la plupart des hubs sociaux, politiques et économiques du globe.

PROFESSIONNELS EXPERIMENTES

Nous sommes des conseillés reconnus avec des expertises variées et des références exceptionnelles de clients internationaux.



EXPERTISE

Nous combinons une importante expertise et une connaissance industrielle unique pour adresser les challenges court terme et long terme.

FTI Consulting facts

1,300+
clients served

3 Nobel Laureates

700+
Industry experts

1982
Year founded

AMCF Association of Management Consulting Firms

2012 Award for Business Strategy

FTI Consulting was recognized for helping The E.W. Scripps Company reinvent its newspaper operating model

$2bn
enterprise value

FCN
publicly traded - NYSE

FTI-CL Energy is a European center for energy consulting, in particular in the electricity sector

Market design

- International experience in a number of electricity markets
  - Centralized markets (Italy, Spain, Greece, Ireland, US)
  - Decentralized markets (Germany, Nord Pool, France, UK)
  - Capacity mechanisms (Germany, Nord Pool, France, UK)

Modelling

- Modelling of European power markets
  - Energy price forecasts
  - Impact analysis of market reforms
  - Evaluation of assets
  - Competition analysis
  - European databases

Integrated vision

- European Target Model
- Cross-border trading rules
- Competition analysis
- State Aid
- Contractual disputes

Examples of clients

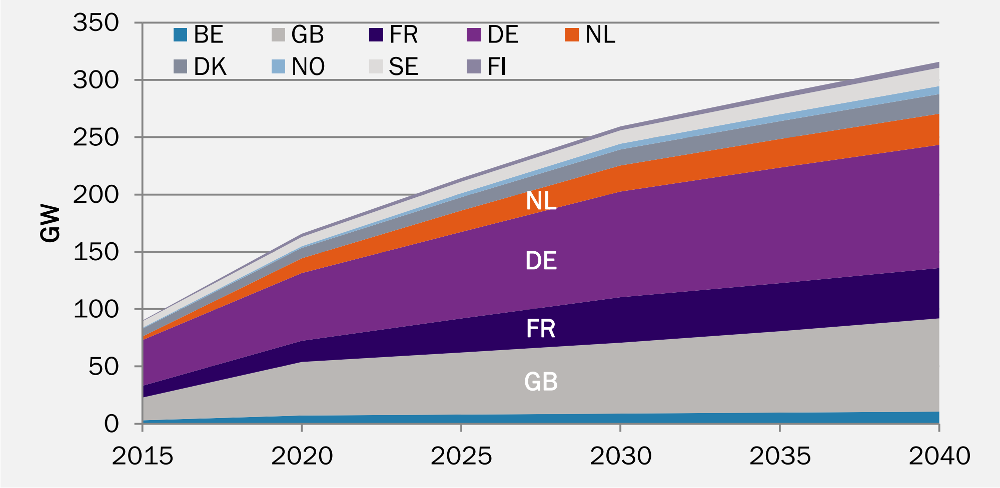
gasNatural fenosa
EDF
ofgem
GDF SUEZ
centrica
GAZPROM
Friends of ETS
edp
direct energie
eurelectric ELECTRICITY FOR EUROPE
nationalgrid
CER Commission for Energy Regulation
An Coimisiún um Rialáil Fuinnimh
MACQUARIE
قطر للغاز QATARGAS
هيئة تنظيم الكهرباء - عمان AUTHORITY FOR ELECTRICITY REGULATION, OMAN
endesa

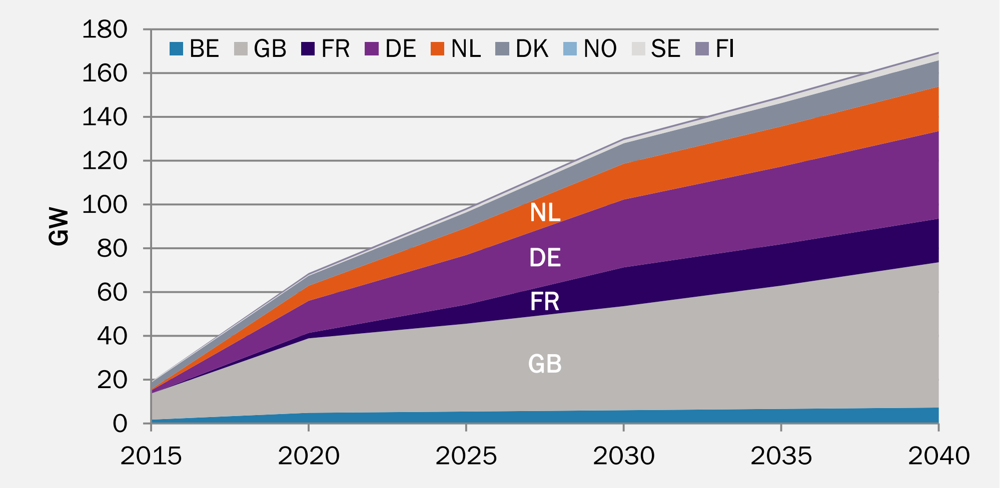
Research question

When modelling future power markets, detailed view on wind power production profiles are critical

Wind power production key assumptions

- Achieving European renewable objectives will require substantial wind capacity in the next decades.
- We have reasonable estimates of the expected wind utilisation factors ranging from 20% for onshore to over 35% for offshore wind.
- However, the way electricity markets will function in the future will largely depend on the variation of wind production and its correlation between different countries
- Detailed modelling therefore requires a concise view on wind future production profiles and their correlation
- This is particularly important for valuation of
  - Peaking plants
  - Storages
  - interconnectors


Total expected wind capacity

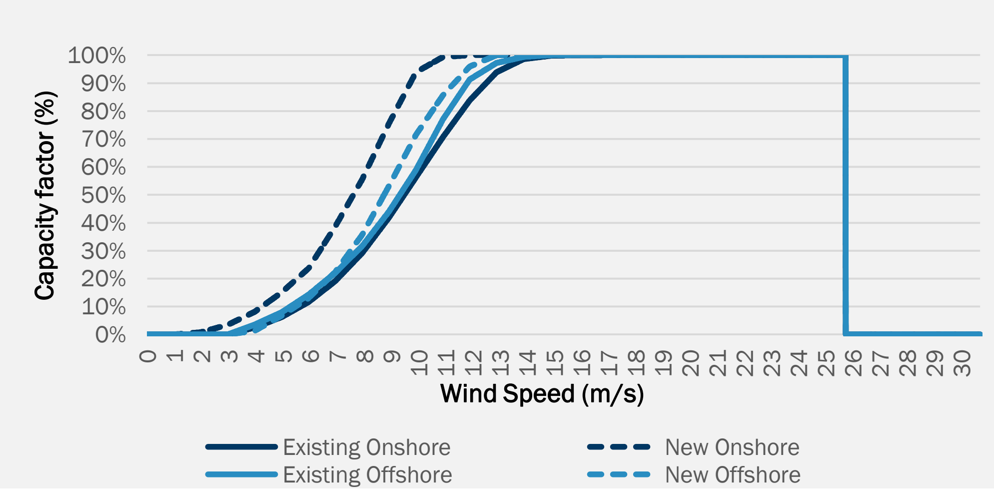

Expected offshore capacity

There are two broad approaches to model wind production profiles

Wind production approach

- Use historical hourly wind production data reported by national TSOs to construct the hourly utilization factors.
- Modify the obtained country-specific wind utilization factors to reflect future changes due to change in the offshore/onshore mix and due to diversification of the production sources.
- Apply the obtained future hourly utilization factors to the expected installed wind capacity by country in any given year.

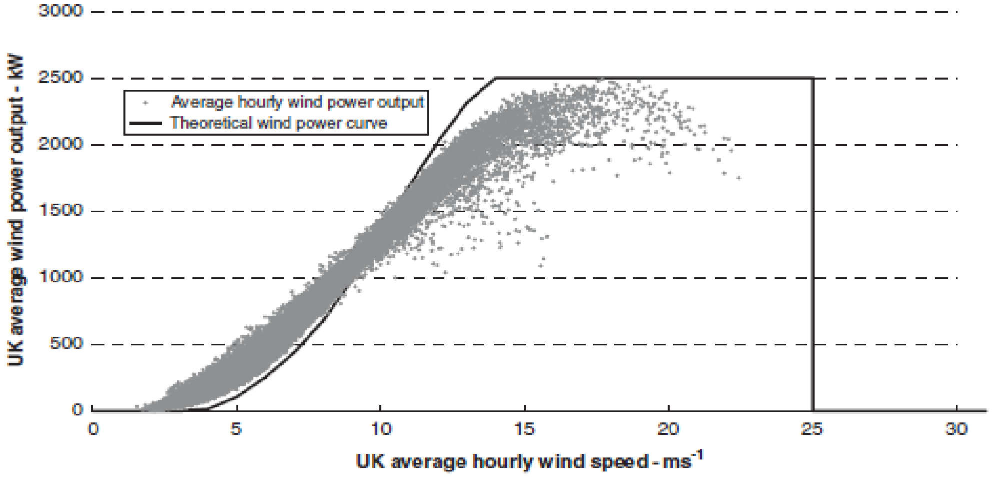
Wind production build curves used



Wind speed approach

- Use historical wind speed data reported by various weather stations in GB and the rest of the EU (3hrs granularity).
- Pre-treat wind speed data to account for volatility and layer effect.
- Use the wind turbine power curves to convert pre-treated wind speed into power production separately for existing and new onshore and offshore.
- Academic literature suggests that such approach can result in biased production profiles.

Average UK wind speed vs average power output



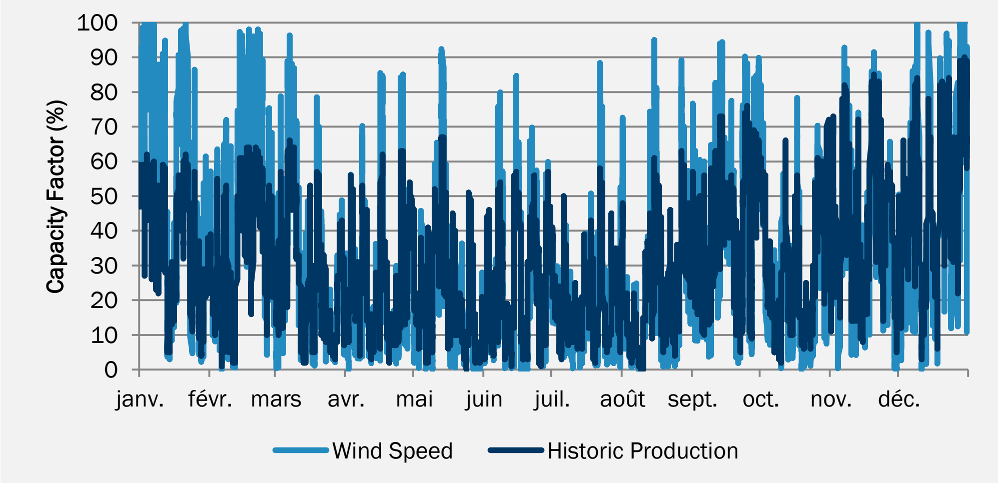
Source: Graham Sinden, 2005, Characteristics of the UK wind resource: Long-term patterns and relationship to electricity demand, Energy Policy

Using the “wind speeds” approach results in a very volatile profile with heavier tails

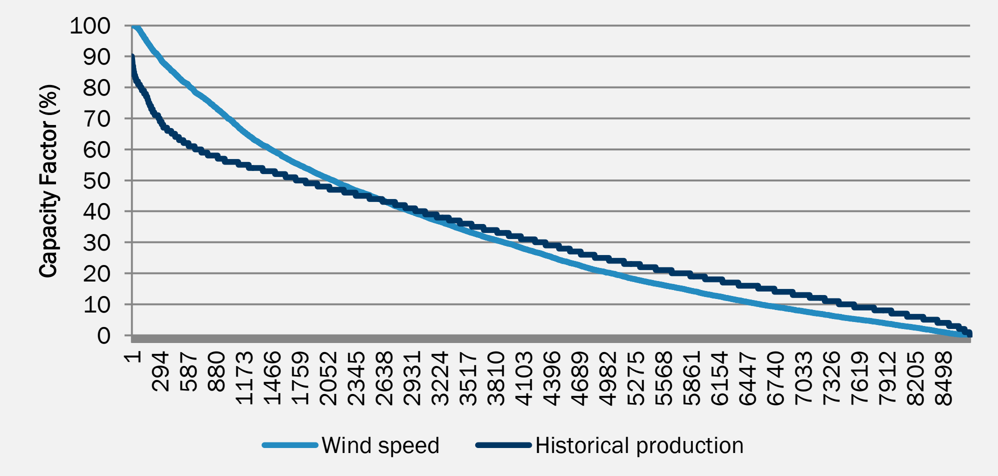
Wind power production profile comparison

- By construction, power production profile obtained from wind speed data and power production profile built from historic production data **have the same average utilization factor.**
- **However, the two methodologies give different hourly results.**
  - **Wind speed based profile provides peakier hourly output** than actual production data. This could be due to outages of turbines or turbines cut off at too high wind speeds
  - **Wind speed based profile provides lower minimum** in low wind periods, likely due modelling limitation of the hub height.
- The results are consistent with the academic literature. While aggregated historic production method provides a low volatile profile, wind speed method provides a too volatile profile.

Historical and constructed wind production in GB, 2012



Duration curves of historical and constructed GB wind production, 2012



A hybrid approach allows using the best of the two worlds

Historical wind production data

- **Pros**
  - Relies on actual production data and does not suffer from the issues of conversion of speed to production
  - Easy to implement
- **Cons**
  - Needs to be rescaled to account for the change in the number of sources, e.g. shift to the off-shore sources

Production constructed from wind speed data

- **Pros**
  - Allows constructing wind production data from multiple sources
  - Potentially allows sampling from a longer historical data
- **Cons**
  - The wind-to-power conversion using the wind power curves has well documented accuracy issues

Hybrid approach

- Use wind speed data from a representative number of weather stations
- Pre-treat wind speed data to account for additional wind volatility and layer effect
- Use calibrated power curves to better match historical wind data with constructed profiles.

We analyse the impact of each wind production modelling approach on power prices

Power market model

Our model covers the power markets of the North-West Europe and calculates prices in each price zone

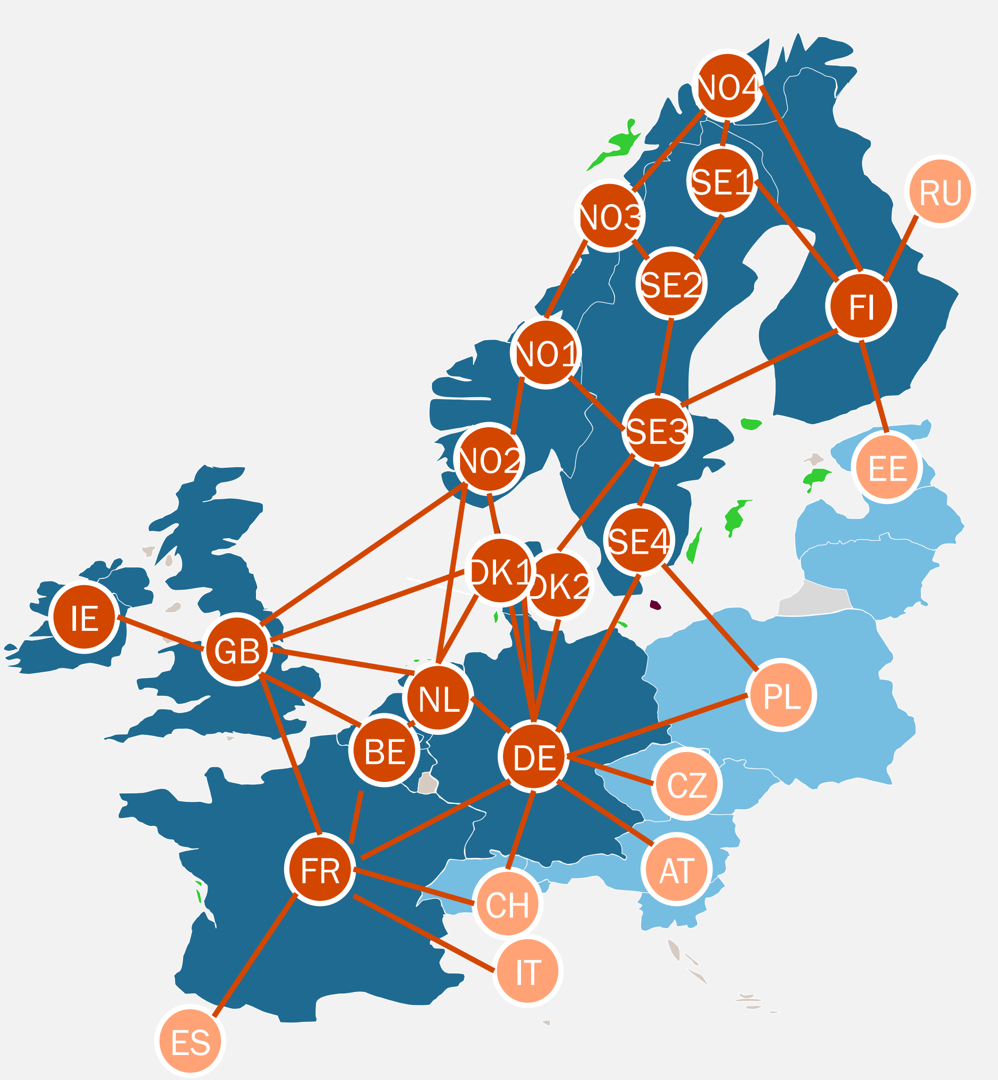
Geographic scope

- The model covers the North-West European Power markets:
  - GB and Ireland
  - France, Germany, Belgium and the Netherlands
  - Denmark, Norway, Sweden and Finland
- The model is set up to model all Nordic zones, however, currently we consider NO and SE each as a single zone

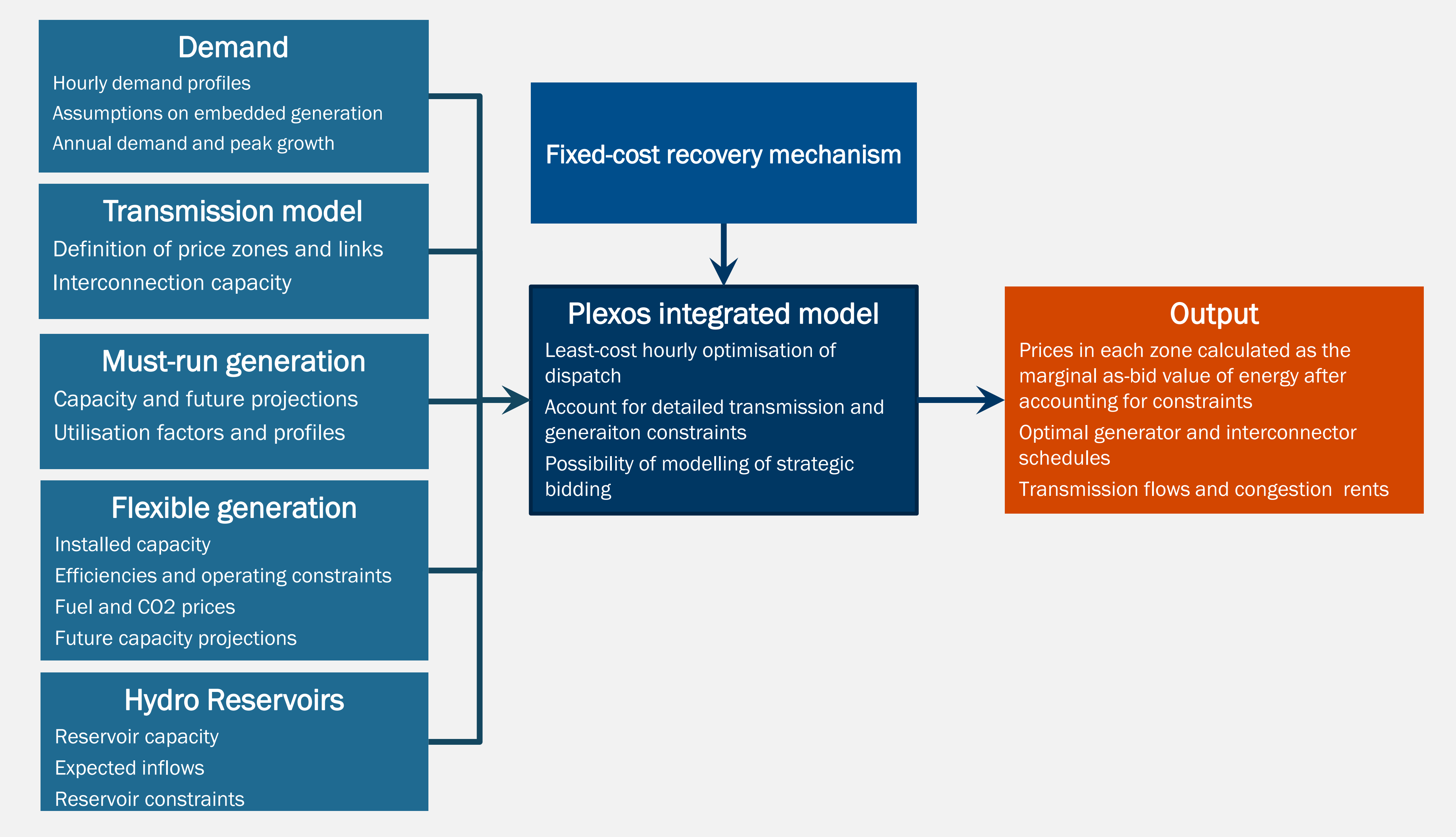
Model structure

- The model constructs supply in each price zone based on individual plants
- Zonal prices are found as the marginal value of energy accounting for generators' bidding strategies
- Takes into account the cross-border transmission and interconnectors and unit-commitment plant constraints
- The model is run on a commercial modelling platform Plexos®
  using data and assumptions constructed by FTI-CL Energy

Model geographic scope



The model outputs are produced using a large amount of data elements and assumptions



Demand

- Hourly demand profiles
- Assumptions on embedded generation
- Annual demand and peak growth

Transmission model

- Definition of price zones and links
- Interconnection capacity

Must-run generation

- Capacity and future projections
- Utilisation factors and profiles

Flexible generation

- Installed capacity
- Efficiencies and operating constraints
- Fuel and CO2 prices
- Future capacity projections

Hydro Reservoirs

- Reservoir capacity
- Expected inflows
- Reservoir constraints

Fixed-cost recovery mechanism

Plexos integrated model

- Least-cost hourly optimisation of dispatch
- Account for detailed transmission and generaiton constraints
- Possibility of modelling of strategic bidding

Output

- Prices in each zone calculated as the marginal as-bid value of energy after accounting for constraints
- Optimal generator and interconnector schedules
- Transmission flows and congestion rents

The model takes a realistic view on the optimisation of the Norwegian hydro system

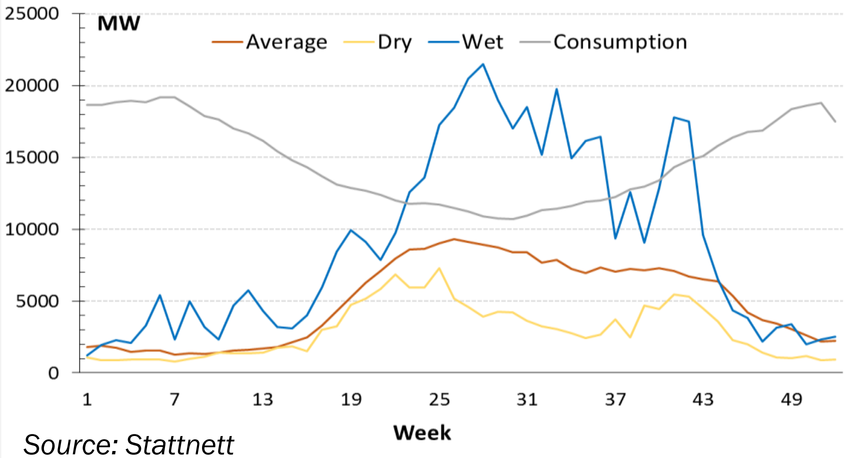
Norwegian hydro

- Norwegian hydro production capacity was split between run-of-the-river and reservoir hydro capacity
  - Run-of the river capacity is modeled as must-run
  - The water use available from the reservoirs is optimised over the year

Reservoir optimisation

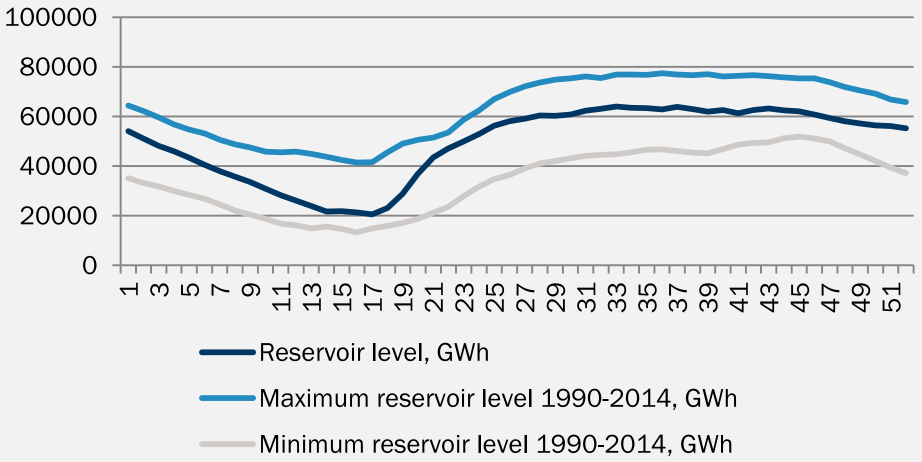
- Reservoir production is modeled in Plexos in two runs
  - Medium Term (MT) Schedule is run first to schedule the optimal reservoir use over the year while satisfying the reservoir constraints.
  - Short-term (ST) Schedule is run next with hourly intervals and full set of unit commitment constraints. It uses the hydro inputs from the MT Schedule.

Run-of-the-river production



Source: Stattnett

2012 reservoir hydro constraints

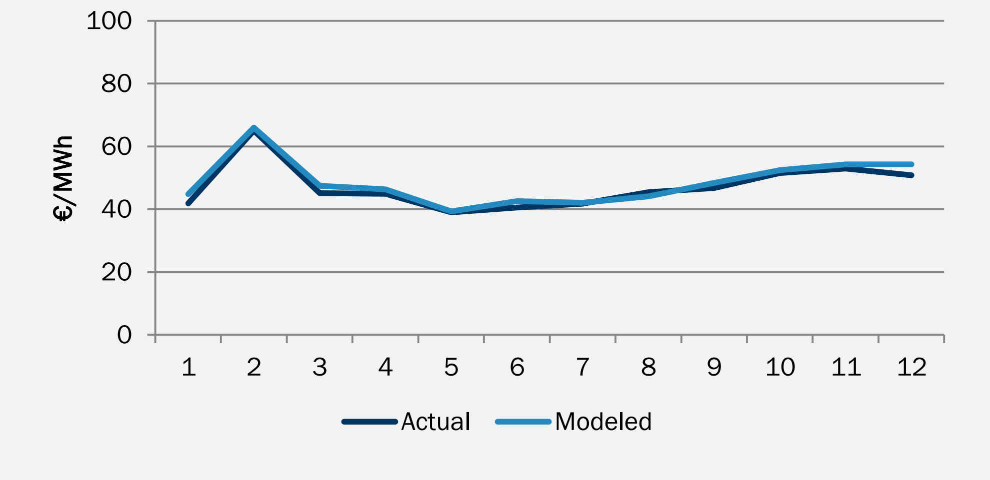


The model accurately back-casts the seasonal price variation in 2012

Model calibration

- The model is calibrated to correctly capture the seasonal evolution of the electricity prices in 2012
- The model correctly picks up the price spike occurred in most European countries in February 2012 due to the cold weather
- The model traces well the drop in prices observed in July 2012 in the Nordic region

Germany



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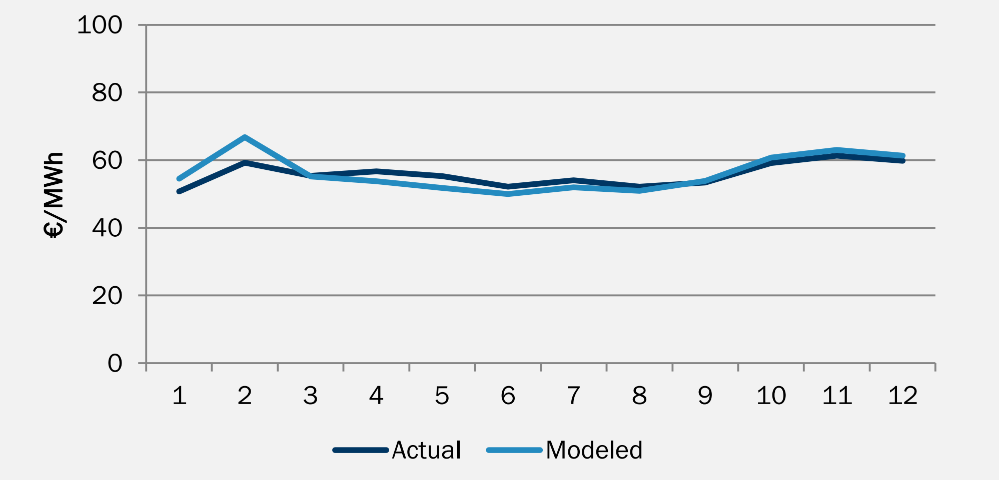
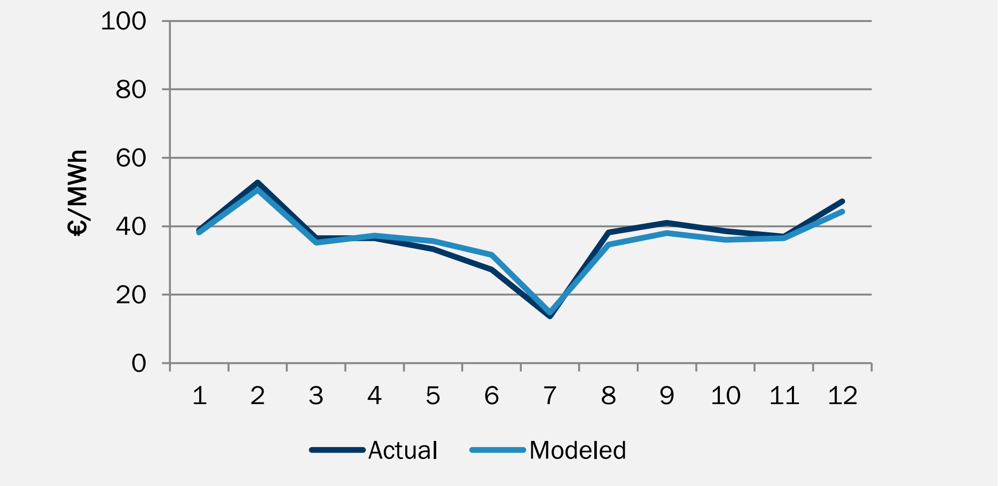


Finland

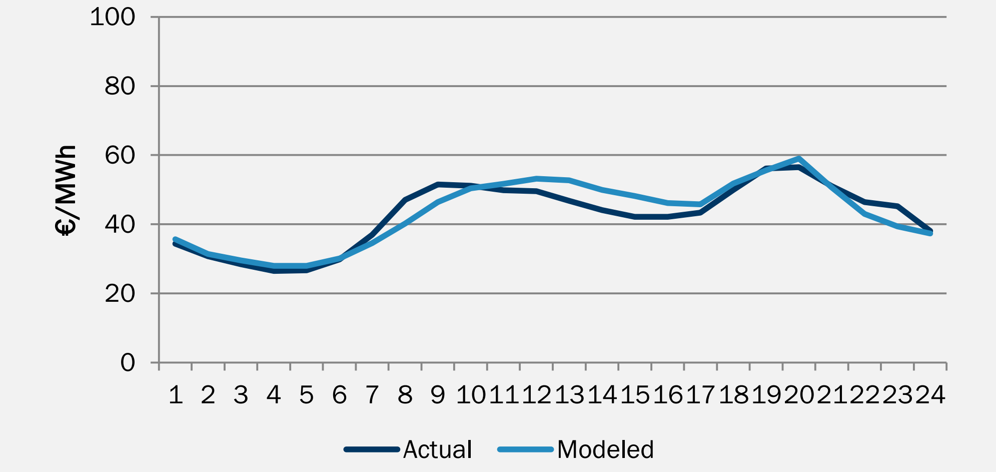


The model accurately back-casts the daily price variation in 2012

Model calibration

- The model captures well the daily price variation
- In particular, explicit modelling of the unit commitment constraints of the CCGT plants allows capturing the afternoon peak in thermal-dominated countries, such as Germany and GB

Germany



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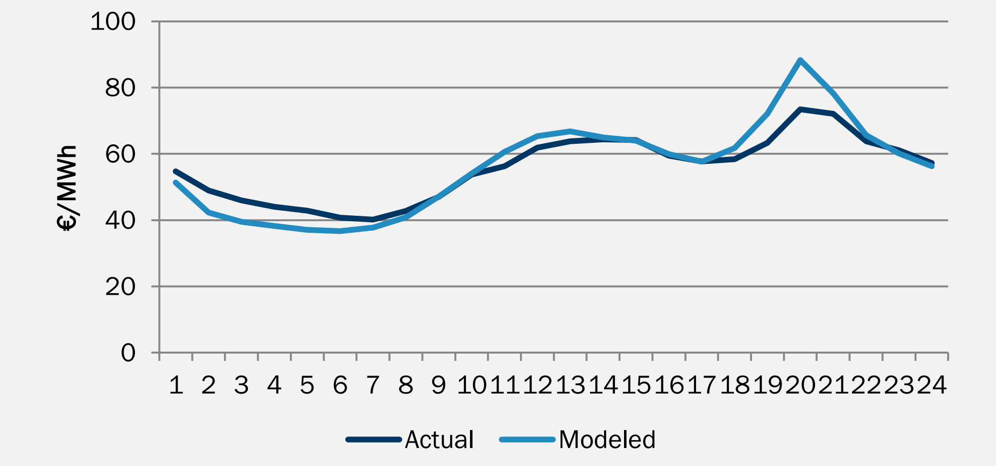
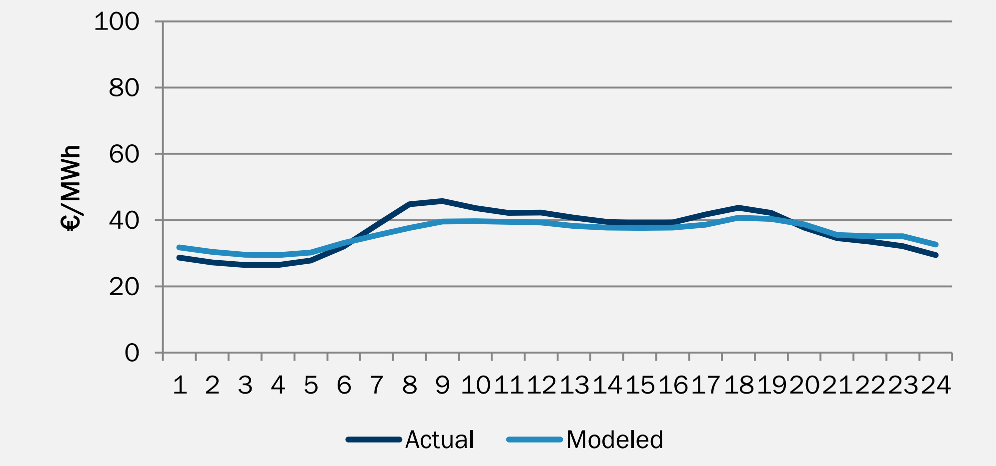


Finland

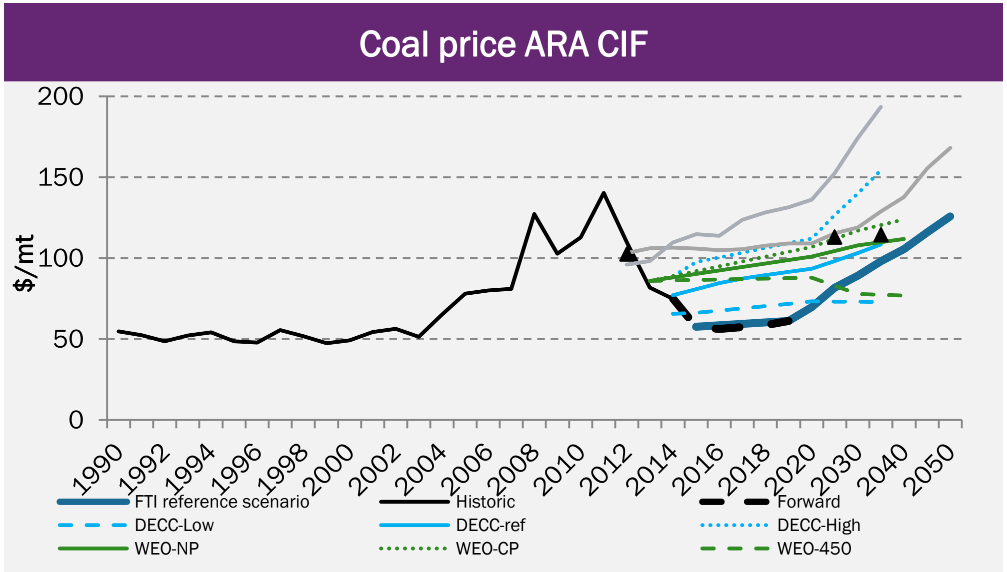


Background assumptions

We expect the fuel prices to remain low until 2020 and rebound afterwards

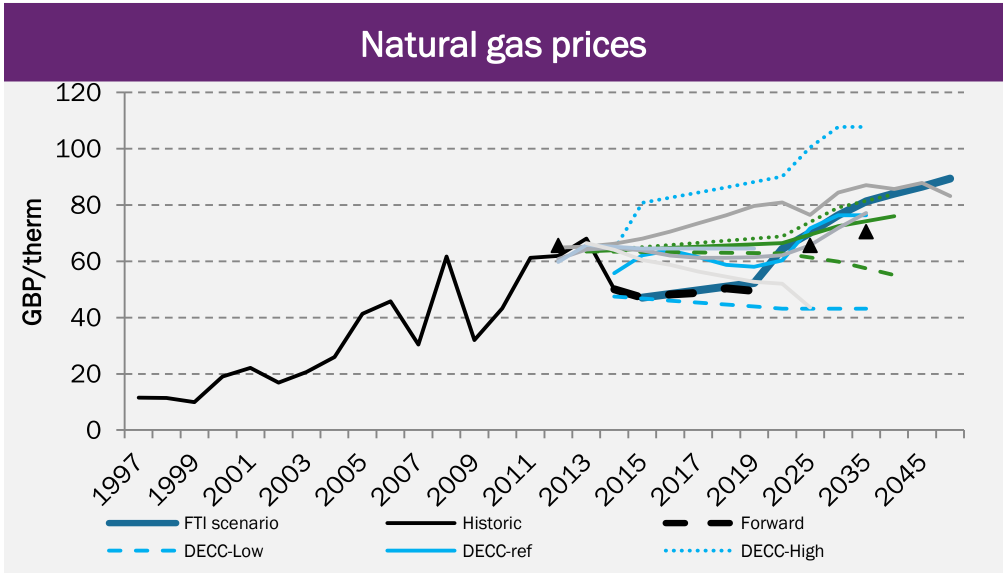
Coal price

- Remain low in the medium term
  - Shell gas in the US forces American coal on the market
  - Reduced net demand in China
  - Reduced transportation costs
- Gradual increase
  - Supply rebalancing, closure of marginal coal plants
- Our fuel price assumptions are benchmarked against external scenarios built before the oil price fall in the end 2014



Natural gas price

- Gradual decoupling from oil indexation and more convergence with the global gas market
- Remain low in the medium term
  - LNG surplus remains due to oversupply in Asia
- Long term
  - Rebound expected as LNG market becomes tighter with further growth in Asia



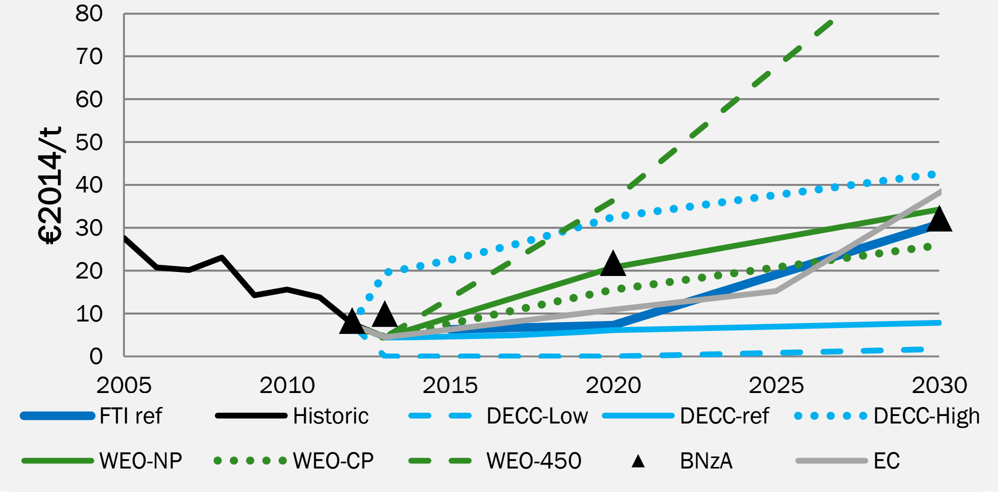
Assumptions on the CO2 prices are based on the EU ETS reform and the UK Carbon Price Floor

CO2 prices

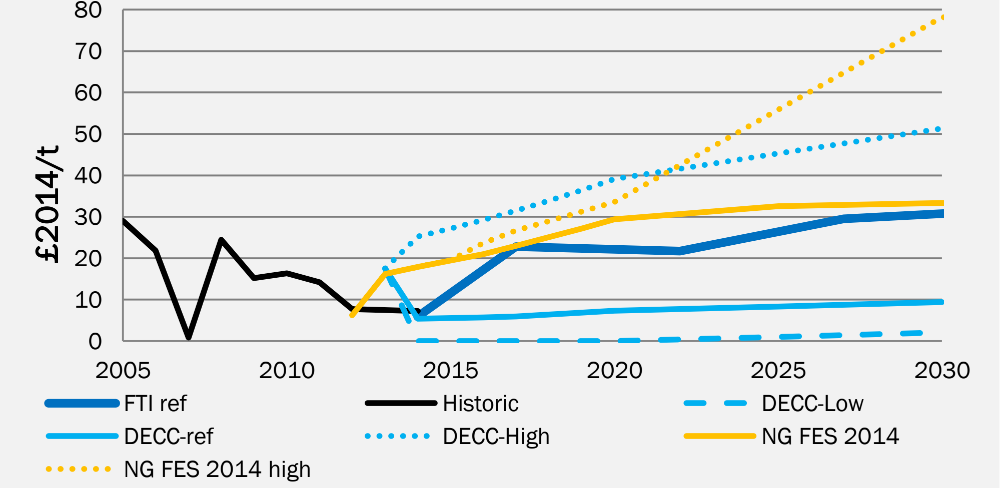
- We assume that the European Commission takes action to address the surplus of emission allowances that has built up in the EU ETS, largely as a result of the economic crisis.
- At the start of phase 3 the surplus stood at almost two billion allowances, double its level in early 2012, and by the end of 2013 it had grown further to over 2.1 billion.
- While the rapid build-up is expected to end from 2014, it is not anticipated that the overall surplus will decline significantly during phase 3.
- We assume that the implementation of a market stability reserve (MSR) will not start before 2020
- This will gradually bring price support to the ETS, starting from 2020.

- With regard to the UK Carbon Price Floor (CPF), the recent freeze in the 2015 budget of the level of support suggests that the anticipated CPF trajectory is too ambitious.
- We therefore assume that the level of support will be frozen at a more modest level than the anticipated trajectory.

EU ETS



GB CO2

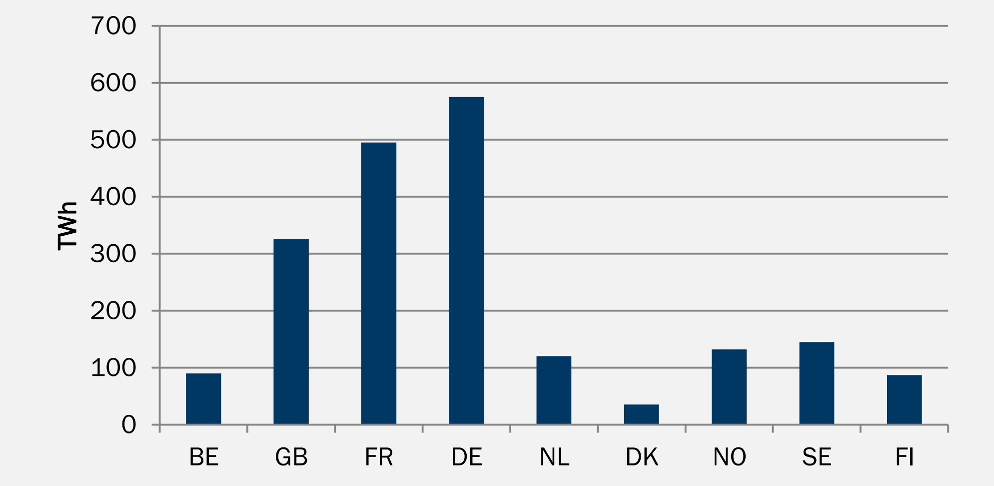


Annual demand growth is determined by the macroeconomic assumptions, energy efficiency and new uses of electricity

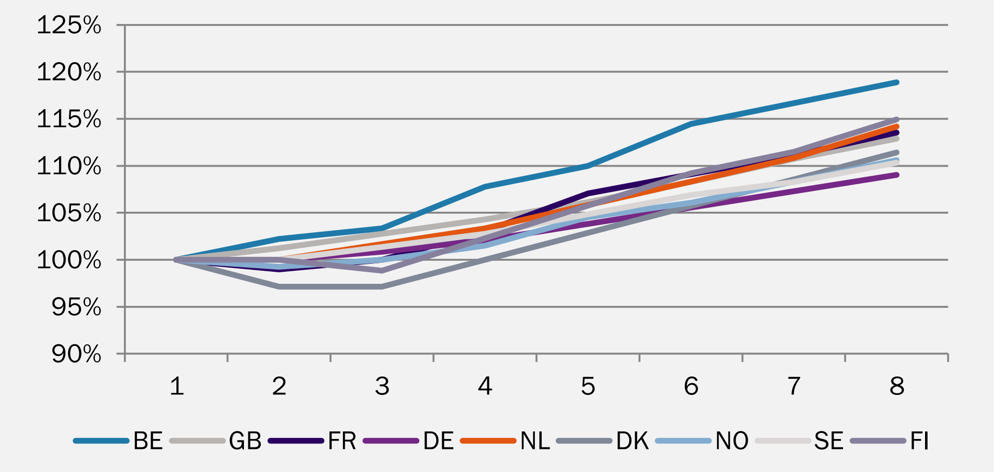
Annual demand

- Our demand projections are defined at the end customer level
- We construct the demand projection based on the statistical relationship between the weather-corrected demand and macroeconomic parameters, such as GDP growth and population
- Other factors paying the role in the demand projections are the offsetting assumptions on the energy efficiency directive implementation and the increased role of new electricity uses (e.g. electric vehicles post 2030)
- We benchmark our electricity demand assumptions against a range of other scenarios

Annual demand in 2015, TWh



Annual demand growth, %

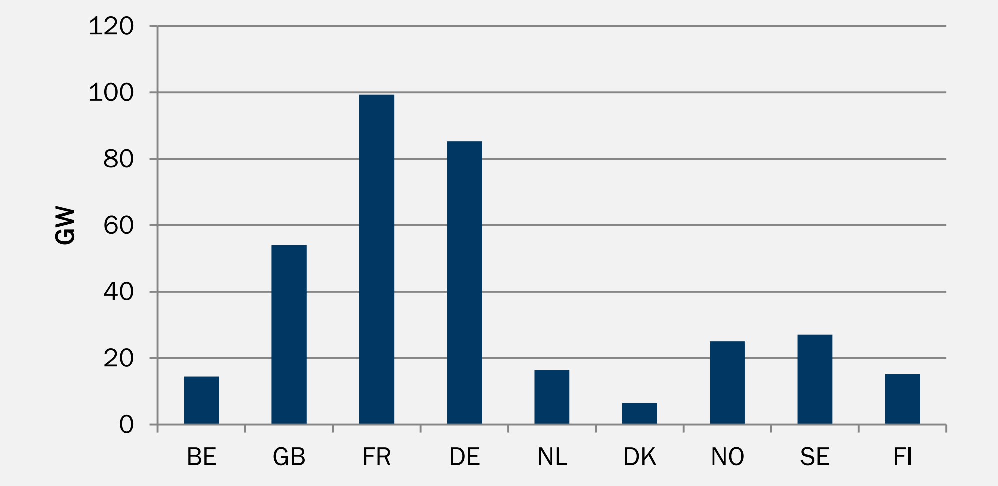


Peak load is set to increase with the total demand, but at a slower rate due to the demand response

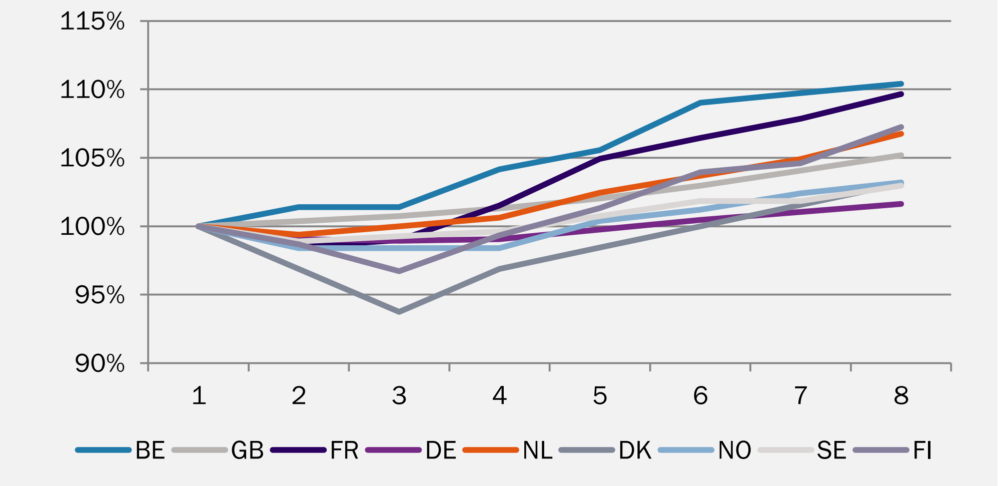
Peak load

- Our peak demand projections are constructed based on the country-specific historical ratio of the peak and total demand
- We account for a gradual flattening of demand profile because of the increasing role of the distributed generation and demand response
- We benchmark our electricity peak demand assumptions against a range of other scenarios

Annual demand in 2015



Annual peak demand growth



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A number of new transmission projects will increase the integration of the NEW region by 2050

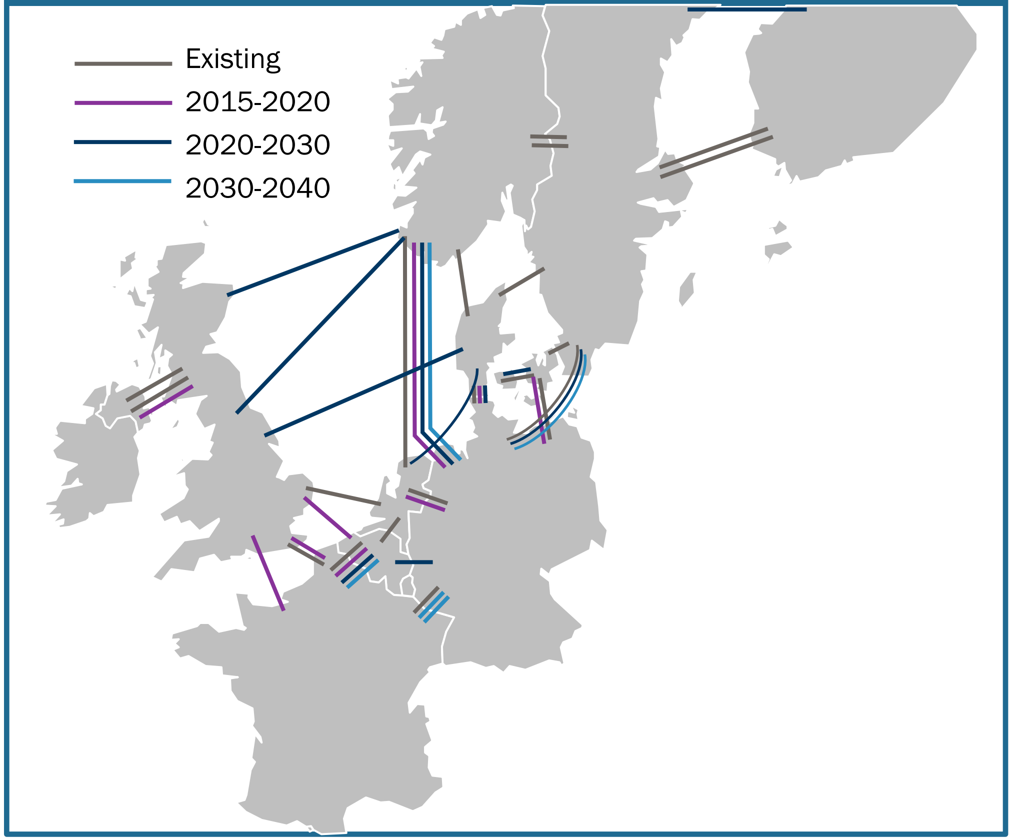
Upgrades 2015-2020

Border	New (MW)	Total (MW)
BE - FR	380	2580
DE - DK1 (Kassoe-Audorf)	720	2220
DE - DK2 (Krieger Flak)	400	1000
DE – NL	1500	5350
DE – NO (Nord Link)	1400	1400
GB – BE (NEMO)	1000	1000
IE - GB	500	500

Upgrades 2020-2030

2020 - 2030	New (MW)	Total (MW)
BE - DE	1000	1000
BE - FR	2200	4780
DE - DK1	500	2720
DE – NO	1400	2800
DE – SE (Hansa Power Bridge)	600	1200
DK1 - DK2 (Great Belt II)	600	1190
FI – SE (North FI-North SE)	500	3075
FR – GB (Eleclink/IFA 2)	2000	3940
GB - DK1 (Viking Link)	1000	1000
GB – NO (NSN/ North Connect)	1400x2	2800
NL - DK1 (Cobra)	700	700

Existing and new interconnectors



2030-2040

2030 - 2040	New (MW)	Total (MW)
BE - FR	1000	5780
DE - FR	400/1500	4900
DE - NO	1400	4200
DE - SE	1000	2200

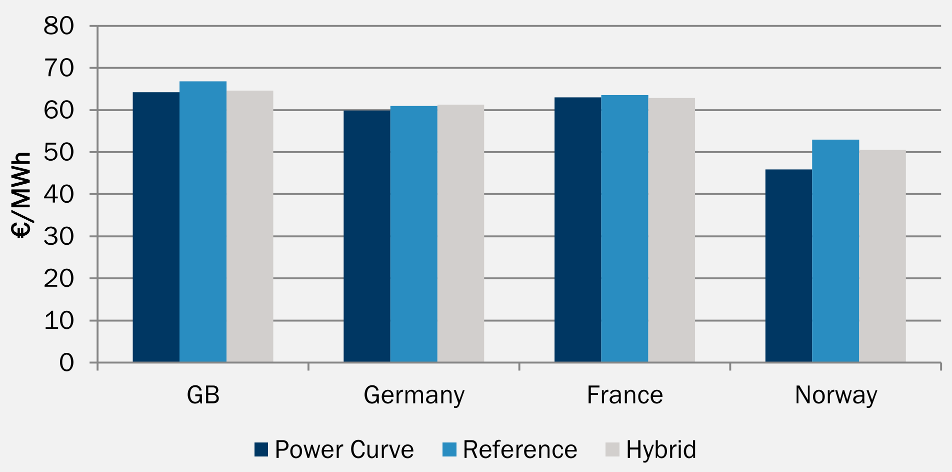
Results

Wind speeds approach generally provides the lowest average price

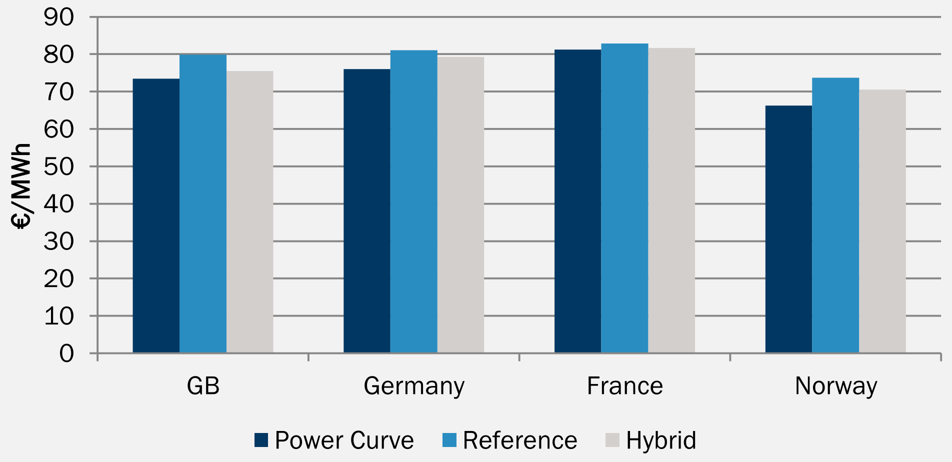
Average prices

- Compared to the historic power production method (reference), power curve and hybrid method slightly lowers average power price:
  - In GB the offshore wind is expected to increase significantly
  - In Norway prices are set by marginal plants in Finland and Sweden where wind capacity is expected to increase.
- Difference between methodologies increase overtime as wind capacity increases.

Average prices, 2030



Average prices, 2040

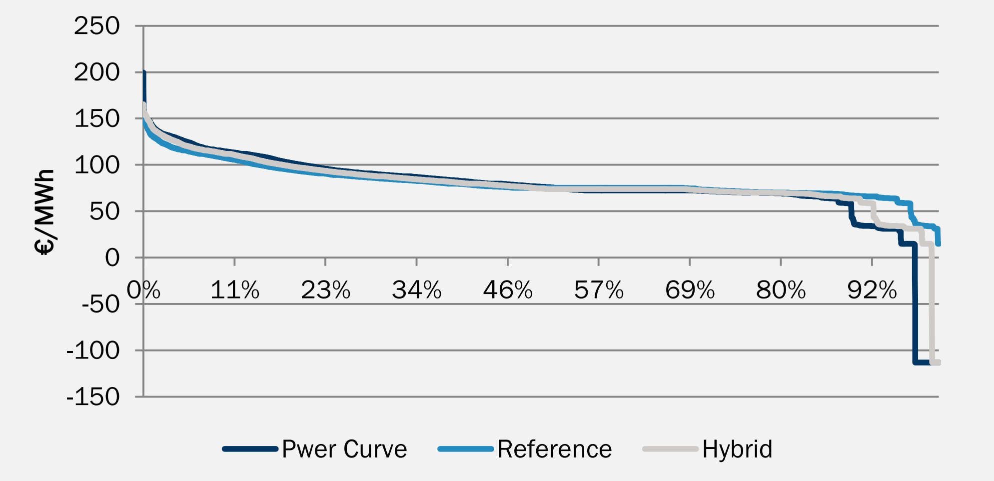


The wind production modelling approach impacts mostly the lower end of the price duration curve

Price duration curves

- Wind speed methods provide lower off peak prices than reference method as they modelled more frequent maximum wind power output.
- Wind modelling methodologies could impact up to 15% of the hourly power price in a given year.
- Wind modelling approach has little impact on the peak prices

Germany



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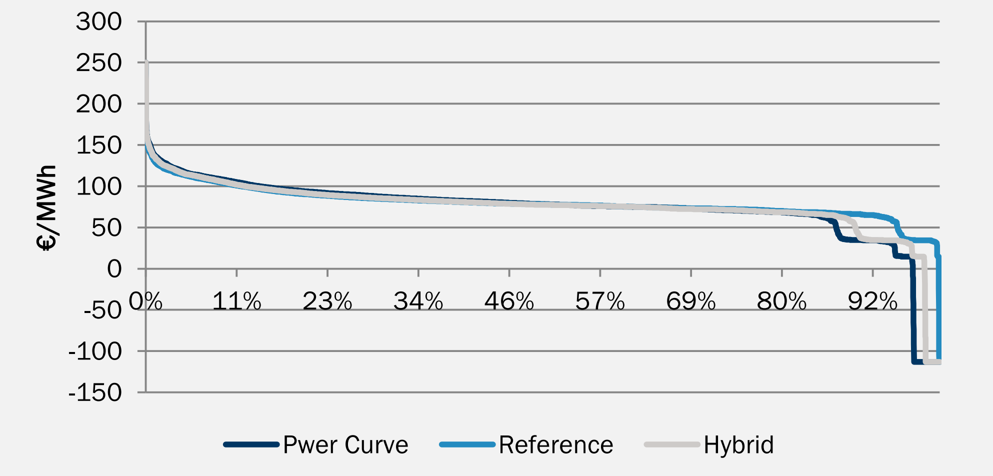
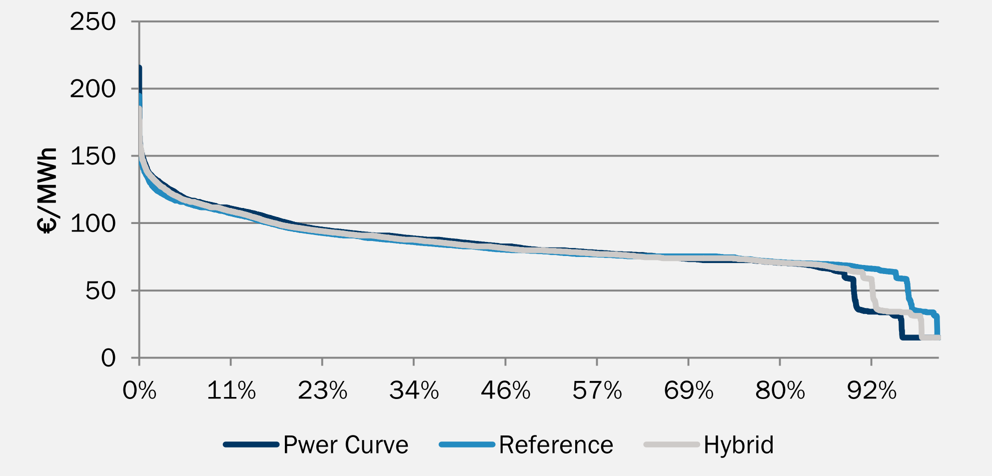


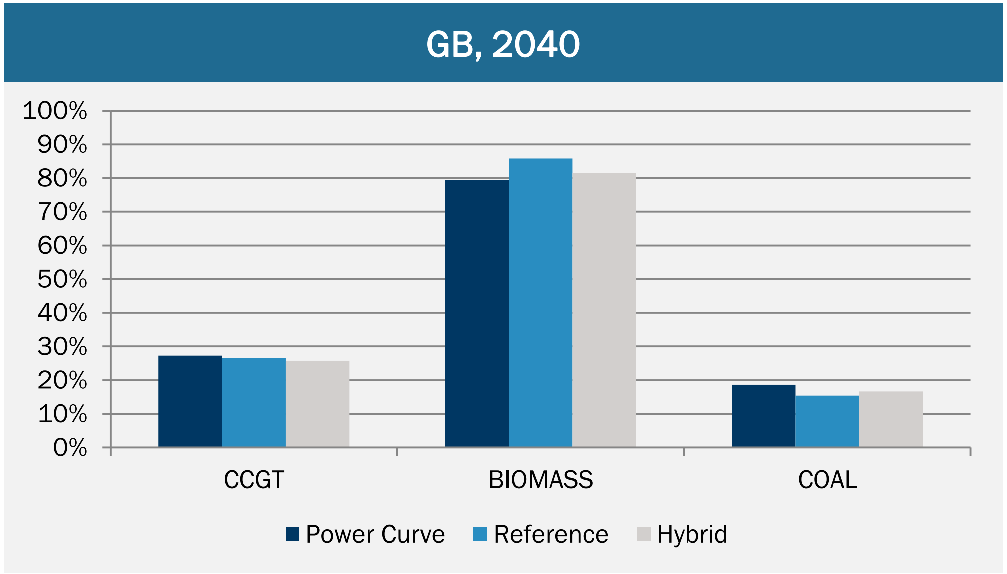
France

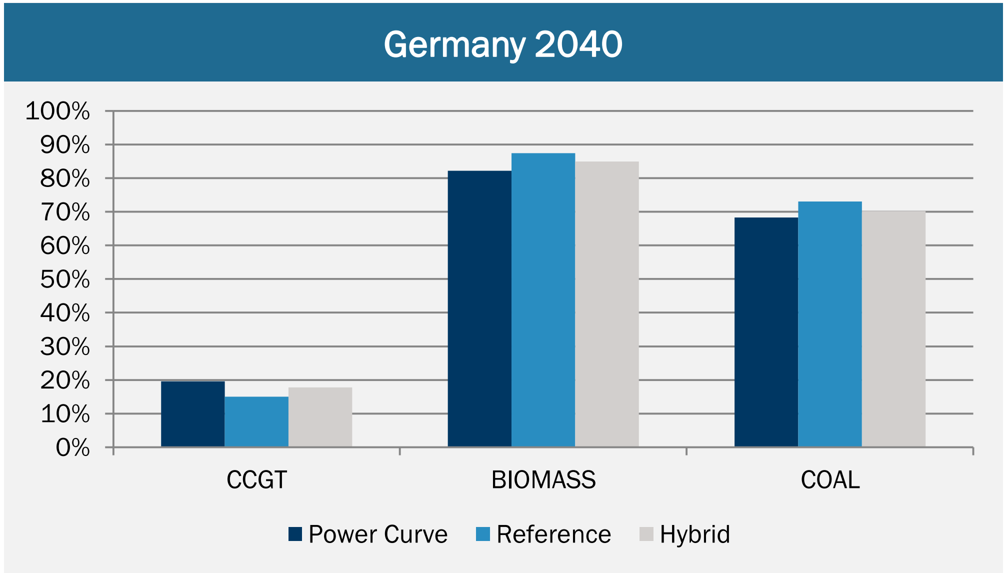


Wind production modelling approach impacts mostly the utilisation of base-load plants

Plant utilisation

- Wind modelling approach has a sensible impact on the utilisaiton of the baseload plants, such as biomass and coal
- CCGTs that are expected to be used during the peak in 2030-2040 are impacted to a lower extent
- This is consistent with the observed asymmetric impact of the wind modelling approach on the price duration curves



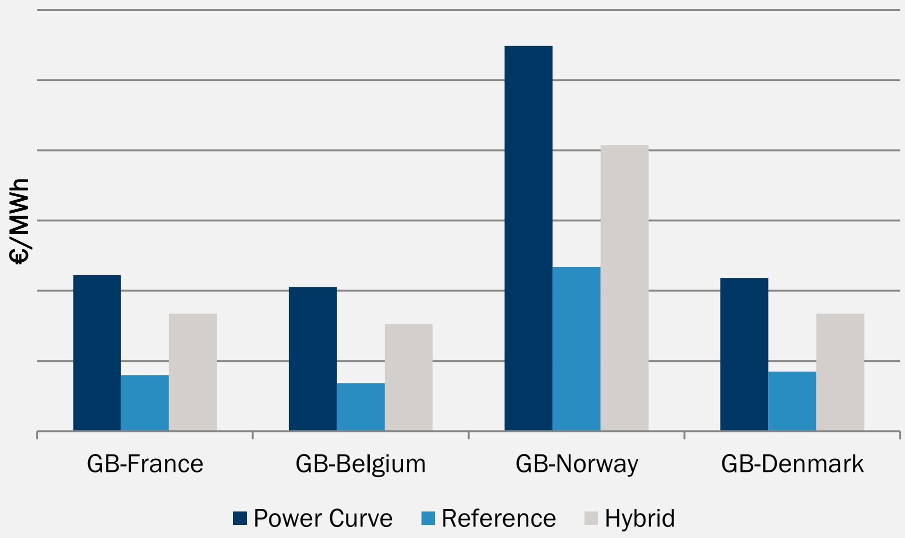


Wind production modelling has a material impact on the value of assets that depend on price volatility and spreads

Congestion rents

- Increased wind output volatility modelled by wind speed methods increases the spreads between prices across locations or across time periods.
- Spreads are further increased because prices are not floored at zero but can be negative at the level of the renewable incentives.
- This means that wind production modelling approach is most important for valuation of assets that depend on such spreads, such as storages or interconnectors

GB congestion rents, 2040



Conclusion

- Detailed profiles of wind production and their correlation between locations are important for accurate modelling of power markets in the future when material wind capacity is expected
- We analyse the impact of three approaches to modelling such profiles on power markets in 2030-2040:
  - Using the wind speeds data converted into the wind production using standard Power Curves results in the most volatile wind production profile
  - Using the historical wind production (Reference) results in the least volatile wind production profile
  - Using a hybrid approach with Power Curves calibrated to historical wind production gives an intermediate volatility of wind production profile
- The wind production modelling approach impacts mostly the lower end of the price distribution. A more volatile standard Power Curves approach reduces the low end of the price distribution the most.
- The wind production modelling approach has a sensible impact on the utilisation of plants, especially the baseload plants
- The wind production modelling approach has a material impact on the value of assets that depend on price volatility and spreads, such as storages or interconnectors. Using a wrong approach may lead to a material under- or overestimation of the asset market value.

Critical Thinking at the Critical Time ™

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