Determining future electricity prices for Hydro Balance project

Discussion of methodology
(work in progress)

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Trondheim

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Content

- European electricity market model COMPETES
- Set of COMPETES runs for hydro balancing project
  - Scenario assumptions
  - Year of analysis: 2030

The COMPETES model

COMPETES unit commitment (UC) model

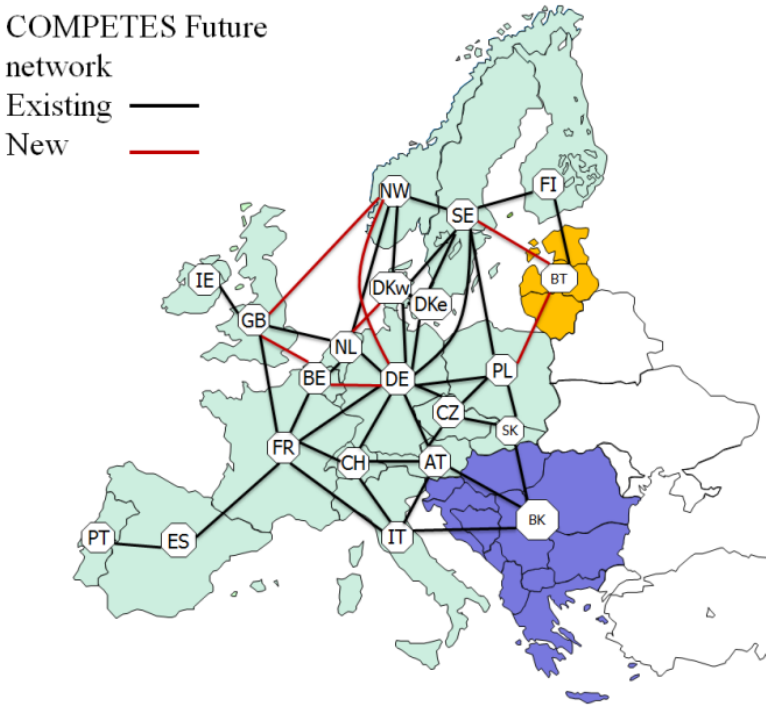
- Hourly network constrained model
- UC model well able to model **system flexibility**

- Ramping rates
- Start up/shut down times
- Minimum load levels
- (non) spinning reserves

- Other constraints account for:
  - Electricity balance constraints
  - Generation capacity constraints
  - Cross-border transmission constraints

- Model objective is to minimize total var. costs + min. load costs + start up costs + load shedding costs

Geographical coverage in COMPETES and representation of cross-border infrastructure



Day-ahead and intraday market modeling in COMPETES

ECN

- Both markets are assumed to be perfectly competitive
- Two-stage modelling of two markets

1. Day-ahead market
   - Wind forecasts
   - Minimum reserve size is determined based on hourly wind generation
   - Full EU coordination
2. Intraday market (1h-5 min prior to delivery)
   - Forecast errors of wind one of main drivers for trade in intraday market
   - (Non) spinning reserves available to intraday market
   - Level of coordination is optional in COMPETES

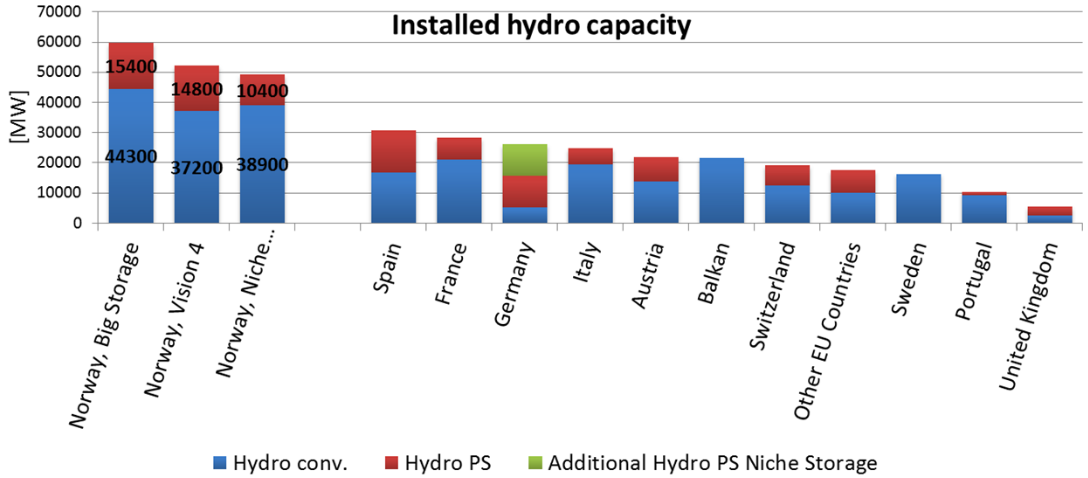
- Real time balancing (e.g. contingency events) done by TSOs
- We will not assume any contingency events, hence → single price for intraday/balancing

Scenarios and assumptions for hydro balancing project

Link with hydro balance storylines/scenarios

Storylines of **B**ig Storage and **N**iche Storage form base of runs:

- High RES share in **B/N** represented by Vision 4 (Green Revolution) of ENTSO-E
- Hydro in Norway is in line with capacities suggested by SINTEF
- To take into account higher competition in **N**, difference in NO hydro capacity with **B** (±10 GW) added as hydro PS to Germany



Other assumptions..

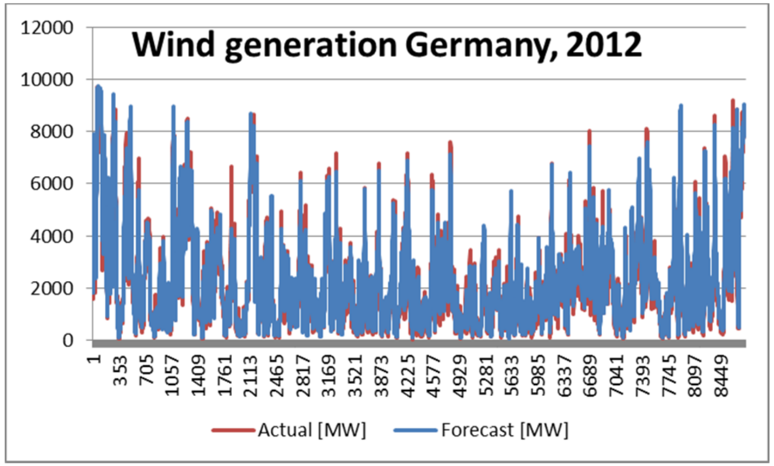
- No other storage types than Hydro PS considered
- Fuel and CO_2 prices: WEO 2014, “450” scenario for 2030
- Transmission network in line with ENTSO-E TYNDP 2014
- In Niche storage and Big storage additional 10-15 GW assumed on Norwegian Cross-borders as proposed by SINTEF
- Divided over cross-borders in proportion to variable RES generation

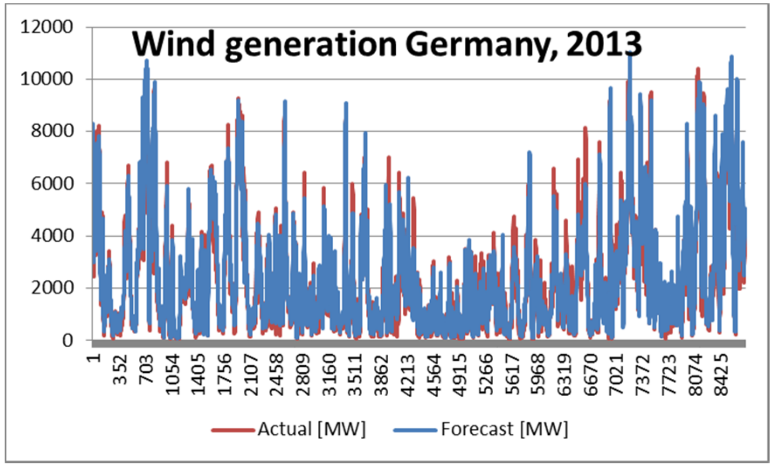
	2014	2030 – ENTSO-E TYNDP	Niche storage (+10 GW)	Big storage (+15 GW)
Sum	6050 MW	10250 MW	20250 MW	25250 MW

- Two climate years analyzed (‘12/’13):
- Hydro conv. generation of climate year under consideration taken
- Hourly forecasted and realized wind data

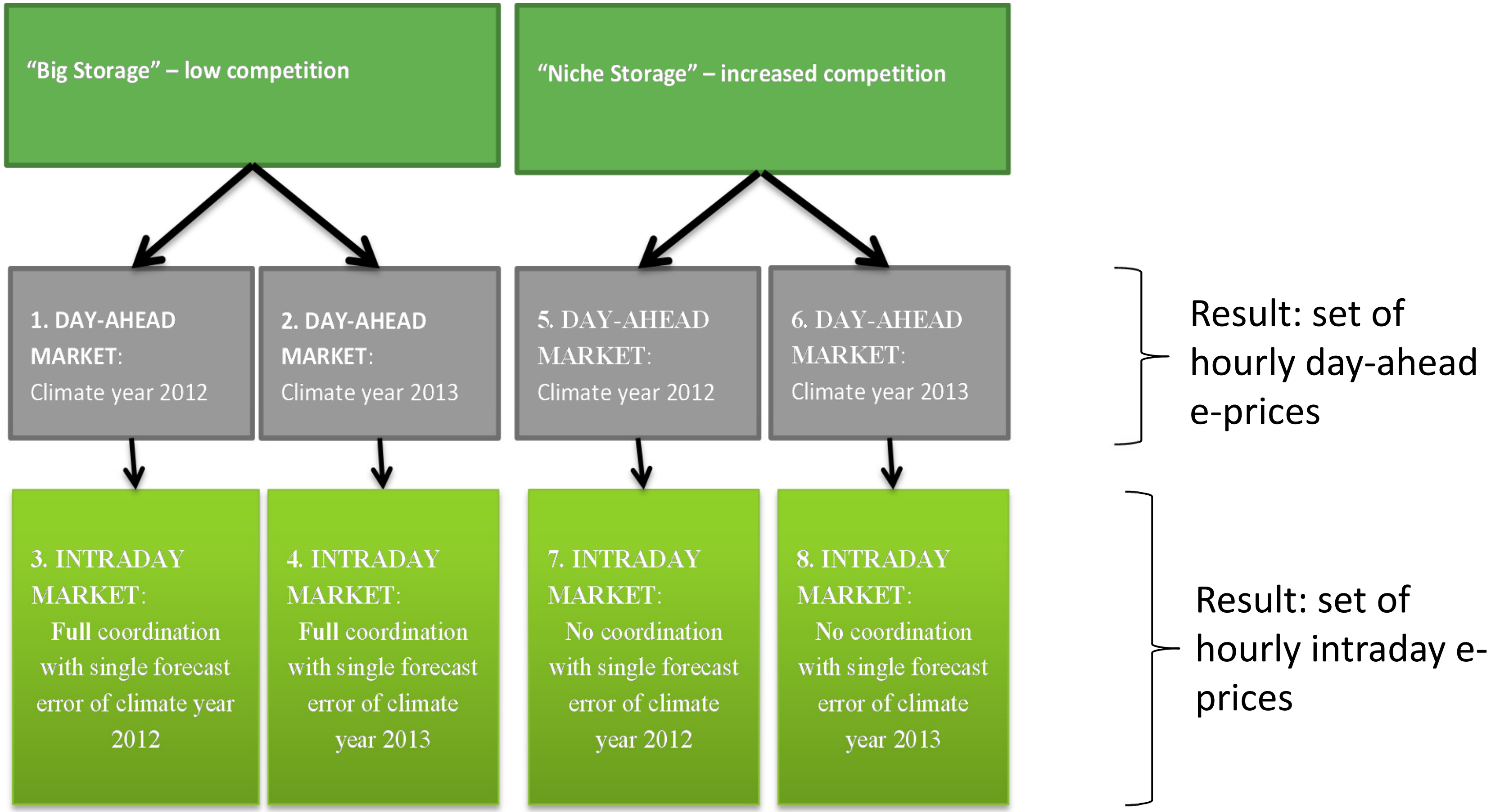
Climate years 2012 vs. 2013 - wind

- Realized hourly wind data of most NW-EU countries available for ‘12/’13
- Forecast errors derived from Wind Forecast Autogression (AR) model based on historical data, e.g.: realized and forecasted wind data of Germany.





In summary: scenario runs (8) with COMPETES model



Thank you for your attention, are there any questions?

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References

- ENTSO-E (2014a), Scenario Outlook & Adequacy Forecast 2014-2013. https://www.entsoe.eu/fileadmin/user_upload/_library/SDC/SOAF/140602_SOAF%202014-2030.pdf
- ENTSO-E (2014b), 10-Year Network Development Plan 2014. https://www.entsoe.eu/major-projects/ten-year-network-development-plan/tyndp-2014/Pages/default.aspx
- WEO (2014), World Energy Outlook 2014.

Appendices

Main I/O COMPETES

Main inputs	
Generation	Installed capacity per technology per country
	Availability and efficiency per technology per country
	CO_2 emission factors per fuel and technology
	Hourly time series of intermittent RES (wind, solar)
	Flexibility characteristics of generation unit (e.g. ramping rates and start-up costs)
Demand	Hourly e-demand based on historical profile of final available year (2014) (ENTSO-E)
Network	Interconnection capacity between nodes represented by NTC values (ENTSO-E TYNDP, 2014)

Main Outputs
The allocation of generation and transmission capacity
The associated hourly perfectly competitive prices per country (DA/intraday market)
Hourly congestion pattern and congestion prices per interconnection
Yearly generation mix in each country
CO_2 emissions

WEO “450” scenario

Fuel	Fuel- and CO2 prices
Coal (€2013/MBtu)	58.7
Gas (€2013/MBtu)	7.5
Oil (€2013/barrel)	76.8
CO_2 (€2013/tonne)	75.3

Technologies in COMPETES

FUEL	TECHNOLOGY	DESCRIPTION
CONVENTIONAL TECHNOLOGIES		
Gas	GT	Gas Turbine
Gas	CCGT	Combined cycle
Gas	CHP	Cogeneration
Gas	CCS	
Derived Gas	IC	
Derived Gas	CHP	
Coal	PC	
Coal	IGCC	
Coal	CCS	
Lignite	PC	
Oil	-	
Nuclear	-	
RENEWABLES		
Biomass	Cofiring	
Biomass	Standalone	
Waste	Standalone	
Geo	-	
Sun	PV	Photovoltaic
Sun	CSP	
Wind	Onshore	
Wind	Offshore	
Hydro	CONV	Conventional
Hydro	PS	Pump Storage
RES	Other	

Other

Reserve sizing:

- We adopt a dynamic statistical approach where reserve size is not fixed, but expressed as a function of wind power production and/or load pattern
- Since demand forecast errors are not considered, the focus is on wind
- Total required hourly reserve capacity = 5% * total hourly wind production in a certain country

Real time balancing:

- After closing of intra-day market, real time balancing is done by TSOs that will resolve the remaining imbalances due to contingency events (e.g. outage of transmission line).
- In this study we will not consider internal congestion/contingency events. Hence, we will consider a single price for intraday and balancing that will give the impact of wind forecast errors on prices

Our experience on power markets in Europe (National projects)

ECN

TenneT – Taking power further

Quantifying flexibility markets (2014)

With COMPETES UC model volumes and prices of flexibility on the future day-ahead and intraday market are determined given increasing levels of intermittent generation in the generation mix. In addition, a number of business cases have been evaluated for different sources of flexibility such as gas fired power plants and electricity storage.

ECN 2014

energy valley

The market value of large scale storage options (2014)

With COMPETES UC model three types of storage options operating in the Dutch electricity system are analyzed and compared w.r.t. their utilization and (marginal) revenues, namely; Compressed Air Energy Storage (CAES), Power2Gas (P2G) and an Energy Island with hydro pumping.

ECN 2014

Ministerie van Economische Zaken, Landbouw en Innovatie

National Energy Outlook

Within the National Energy Outlook Modelling System (NEOMS), COMPETES covers the developments in the Dutch electricity system. Hence, projections on for example the generation mix, e-prices and trade flows are based on calculations with the COMPETES model.

ECN 2014

Agentschap NL
Ministerie van Economische Zaken

North Sea Transnational Grid

In dit project is COMPETES gebruikt voor het doorrekenen van verschillende offshore grid The impact of wind offshore generation on the benefits of the major players in the electricity sector are analyzed from a social welfare perspective within a set of North Sea Transnational Grid scenarios. ECN uses COMPETES model for the economic analysis.

ECN 2012-2013

Ministerie van Economische Zaken, Landbouw en Innovatie

Financing investments in new generation capacity

Study on the incentives for investments in new generation capacity with an increasing share of renewable energy in the generation mix and the effects of introducing a national capacity market in Germany on the electricity markets in neighboring countries including the Netherlands. This has been examined with the European electricity model COMPETES.

ECN 2012

Ministerie van Economische Zaken, Landbouw en Innovatie

A Social Cost Benefit Analysis (SCBA) was developed to secure optimal contribution of the investments in interconnection to the social welfare of the involved countries. With COMPETES a case study was conducted of a 'fictitious but realistic' investment project in interconnection to illustrate how certain social effects from the developed SCBA framework can be practically and concretely established.

ECN 2012

Ministerie van Economische Zaken/ Ministerie van Milieu

Reference projections and additional policies 2010-2020

A national baseline scenario was developed for energy, greenhouse gases and air pollutants. The aim of the project was also to evaluate the Clean and Efficient programme of the Dutch Government. Three variants op the projections include without policies, with implemented policies and with proposed policies. On top of this, over 40 additional policy options were separately analyzed. In 2012, an update was done up to 2030.

ECN 2009-2012

EDGaR – Energy Delta Gas Research

Dutch consortium aiming to make out a case for the role of the Netherlands w.r.t. sustainable use of energy resources. One of the goals of this project is to explore and understand the inter-market: interaction between the gas and electricity sector, via the technical infrastructure, power and carbon markets resulting from (changing) institutions and regulation. ECN has been developing a combined gas and market model to analyze the interactions between electricity and gas markets.

ECN 2010-2014

Ministerie van Economische Zaken, Landbouw en Innovatie

Net benefits of a new Dutch Congestion Management System

This study analysed the new connection policy that seeks to lift restrictions on grid connection. A scenario-based, quantitative analysis of the net benefits of the new connection policy was presented by using COMPETES model. Furthermore, pros and cons of several alternative designs for a congestion management system were identified and presented.

ECN 2009

Ministerie van Economische Zaken, Landbouw en Innovatie

Future electricity prices

This study analyzed the impact of structural changes (e.g., fuel and CO_2 prices, new investments in generation and transmission capacity) in the Northwest European electricity markets affecting the future wholesale electricity prices and exchanges between these markets. The results of the study supported Ministry's Energy Report in 2008.

ECN 2008

Our experience on power markets in Europe (International projects)

EUROPEAN COMMISSION

E-highways

The project aims to develop a top-down planning methodology providing a modular and robust expansion of the Pan-European Network from 2020 to 2050, in line with the European energy policy pillars. The contribution of ECN to the project involves the scenario development, regulatory assessment, and economic modeling of electricity markets.

ECN 2012-2014

EUROPEAN COMMISSION

IRENE-40

The project aimed to identify strategies for investors and regulators to build a more secure, ecologically sustainable and competitive European electricity system. Main responsibilities of ECN included the roadmap with respect to electricity infrastructure that specifies actions needed to achieve public goals as well as the construction of generation and demand scenarios as a basis for network analyses

ECN 2009-2012

EUROPEAN COMMISSION

SUSPLAN

Development of strategies, recommendations and benchmarks for the integration of RES by 2030-2050 within an Europe-wide context. Our work included reports on trans-national infrastructure developments on the electricity and gas market (ECN being responsible only for gas market modeling), and socio-economic approaches for integration of renewable energy sources into grid infra-structures.

ECN 2008-2011

EUROPEAN COMMISSION

Improgress

Improvement of the Social Optimal Outcome of Market Integration of DG/RES in European Electricity Markets. The project analyzed the interactions of DG/RES operators with markets and networks, developed DG/RES integration scenarios for the EU-27, quantified the market and network impact of DG/RES integration in three case study networks (in Spain, Germany and the Netherlands)

ECN 2007-2010

bremer energie institut

A nodal pricing analysis of the future German electricity market

Scenario-based analysis of the impact of Germany's ambitious renewable agenda, disputed decommissioning of nuclear facilities and unbundling of TSOs as enforced by EU regulation on the future German power market while accounting for internal congestion. The analysis was done by using COMPETES model.

ECN 2008/2009

EUROPEAN COMMISSION

Impact of the EU ETS on electricity prices

The project analyzed the implications of the EU ETS for the power sector, in particular it analyzed the pass through of the (opportunity) costs of CO_2 emissions trading to electricity prices on spot and forward markets in various EU countries.

ECN 2007