# Overview: Market, planning hierarchy and models Norway/Nordics

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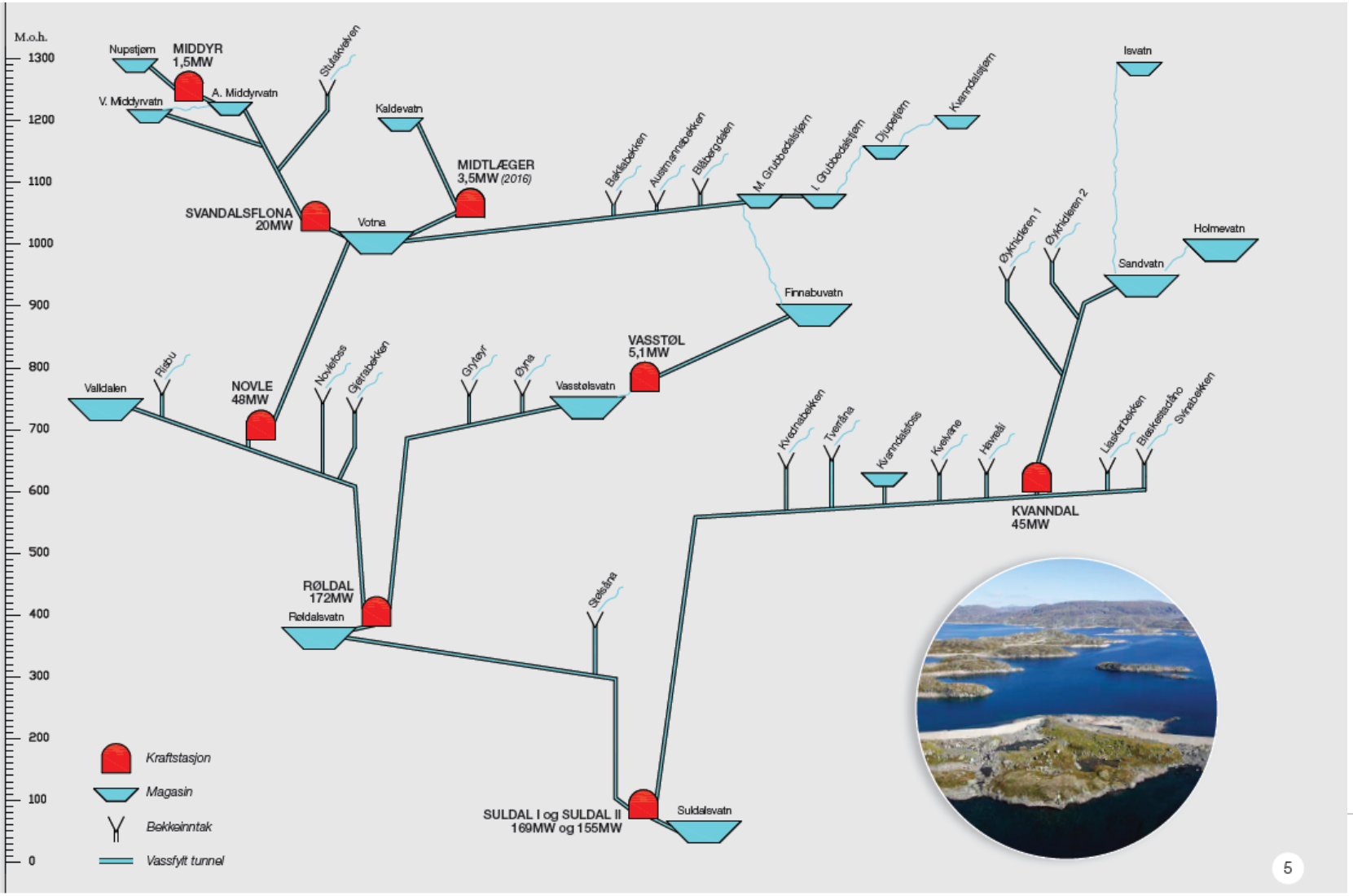
# Agenda

- The Nordic electricity system
- Hydro optimization at SINTEF
- Research challenges

# The Nordic electricity system

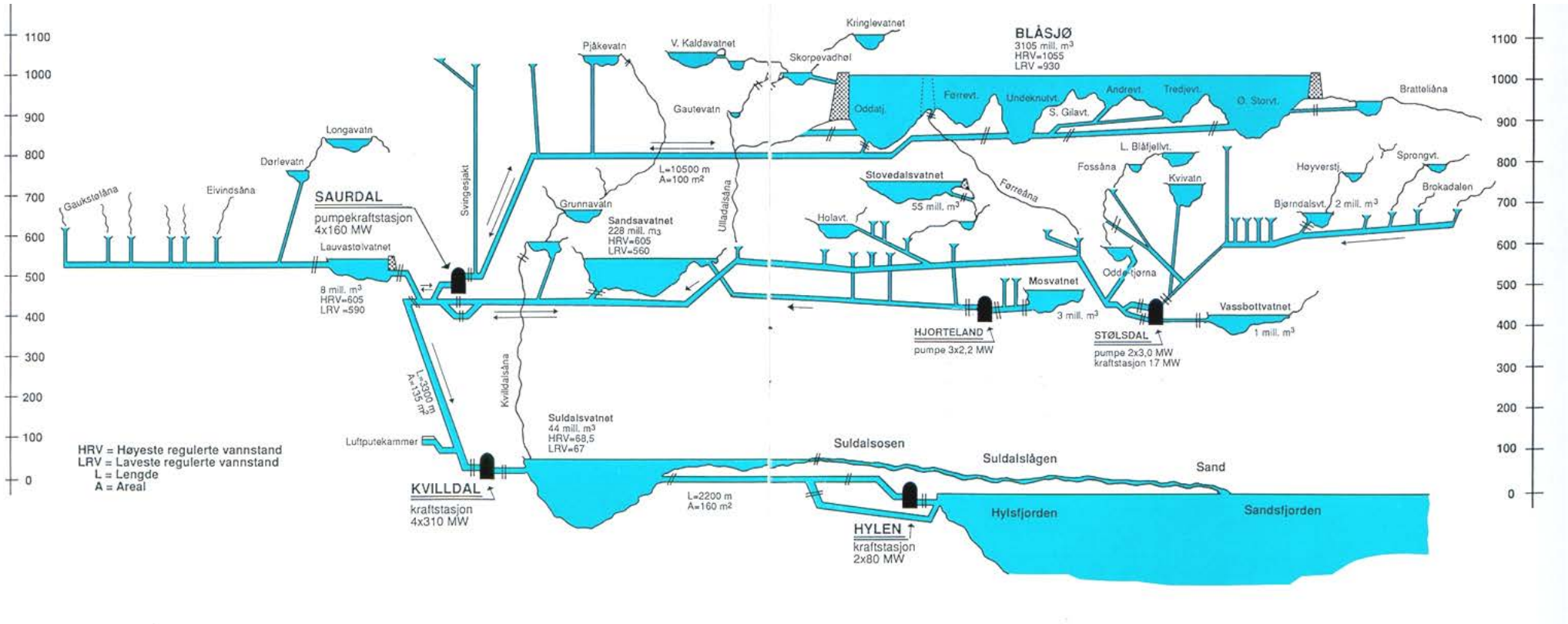
- About 50 % hydro,  thermal and wind  power
- More  than 1000 storages and several hundred hydro plants
- Market based system
- Exchange: NordPool (day ahead and intra day markets)
- Well functioning market
- Most producers owned by states, counties or municipalities
- Main transmission constraints handled by price areas

# A typical  Norwegian hydro system



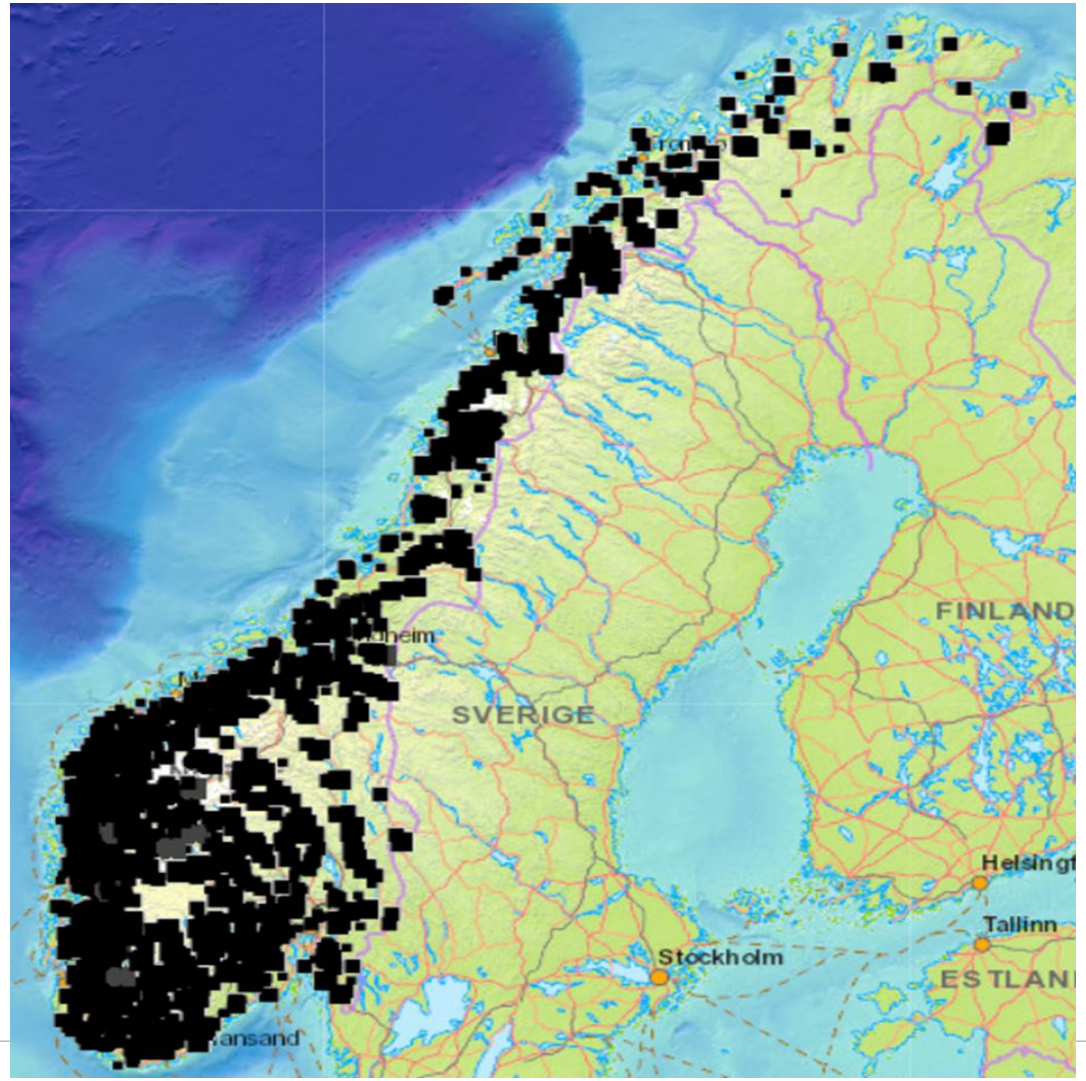

Source: http://www.hydro.com/globalassets/1-english/pressroom/news/energi_rsk_folder_oct2015_lo-res.pdf

# Previous river system also include this

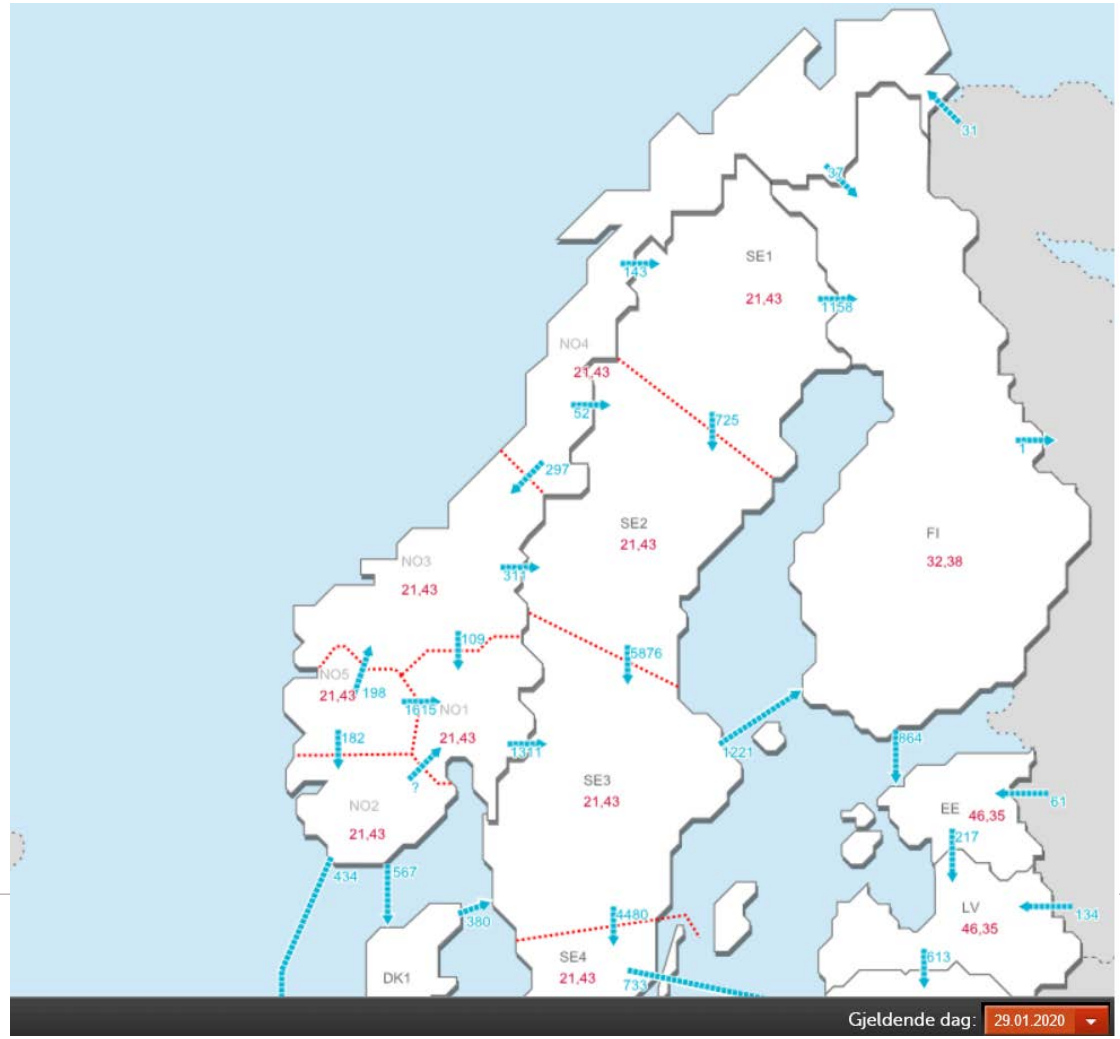



*Courtesy from Jan Alne, Statkraft*

# Hydropower plants in Norway



# NordPool market




370 Power producers
More than 300 market players
Day ahead market:  500 TWh traded
Source: https://www.nordpoolgroup.com/the-power-market

Yearly production: 400 TWh
Norway, Sweden, Denmark and Finland

Source:www.statnett.no

# HydroPower optimization at SINTEF

- About 25 persons
- R&D
- Develop and maintain commercial tools to the industry
- Financing
  - R&D projects: Research Council of Norway combined with industry contribution
  - Development: Fully financed by one or more industry partners
  - Long  tradition for common R&D in the Nordic electricity market
- Together with the university (NTNU) one of the largest hydropower optimization R&D groups in Europe

# Industry application of advanced optimization models.

- Energy balance dependent on weather (inflow, snow, temperature and wind)
- Relatively detailed system information available
  - NVE (regulator): hydro plant and reservoir data, historical inflows
  - Other weather data
- Long tradition for model application – long before deregulation and liberalization in 1991.
- Users: Hydro producers, consultants, TSOs, regulator

# Application areas

- Fundamental based price forecasting
  - Producers, Consultants
- Security of supply, transmission investment, system analyses

- Local hydro planning tasks
  - Hydro scheduling with different planning horizons
  - Forecasting:  production, reservoir, profit, risk management

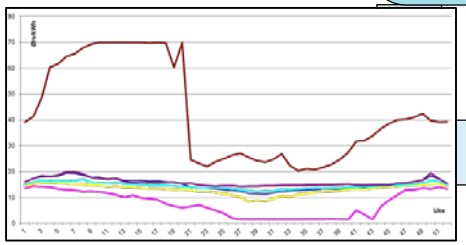
  - Investment and upgrading

# Fundamental price forecasting

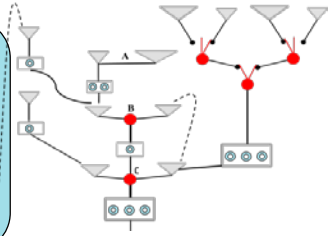
- Very complicated stochastic dynamic optimization problem :
  - Linearized formulation
  - Cost minimization formulation – well functioning market
- Complicating factors
  - Time resolution (a few hours to hourly)
  - Long planning horizon because of large storages (e.g. 5 years)
  - Many states (reservoirs)
  - Many  uncertainties (inflows, temperatures, wind, solar, CO2, gas and oil prices)
  - Computation time requirements for operational use

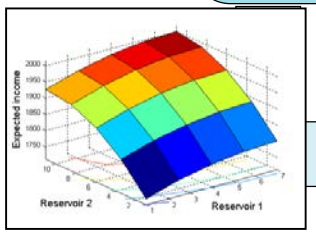
# Market and scheduling tasks

Market analysis Norway, Nordpool, Europe

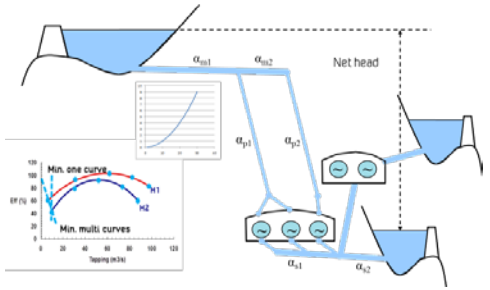


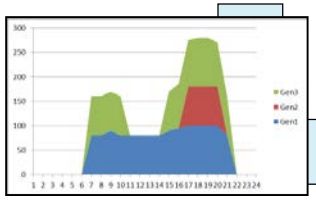
Long- and seasonal scheduling






Short-term scheduling



Simulation and verification

Time

Planning

Implementation

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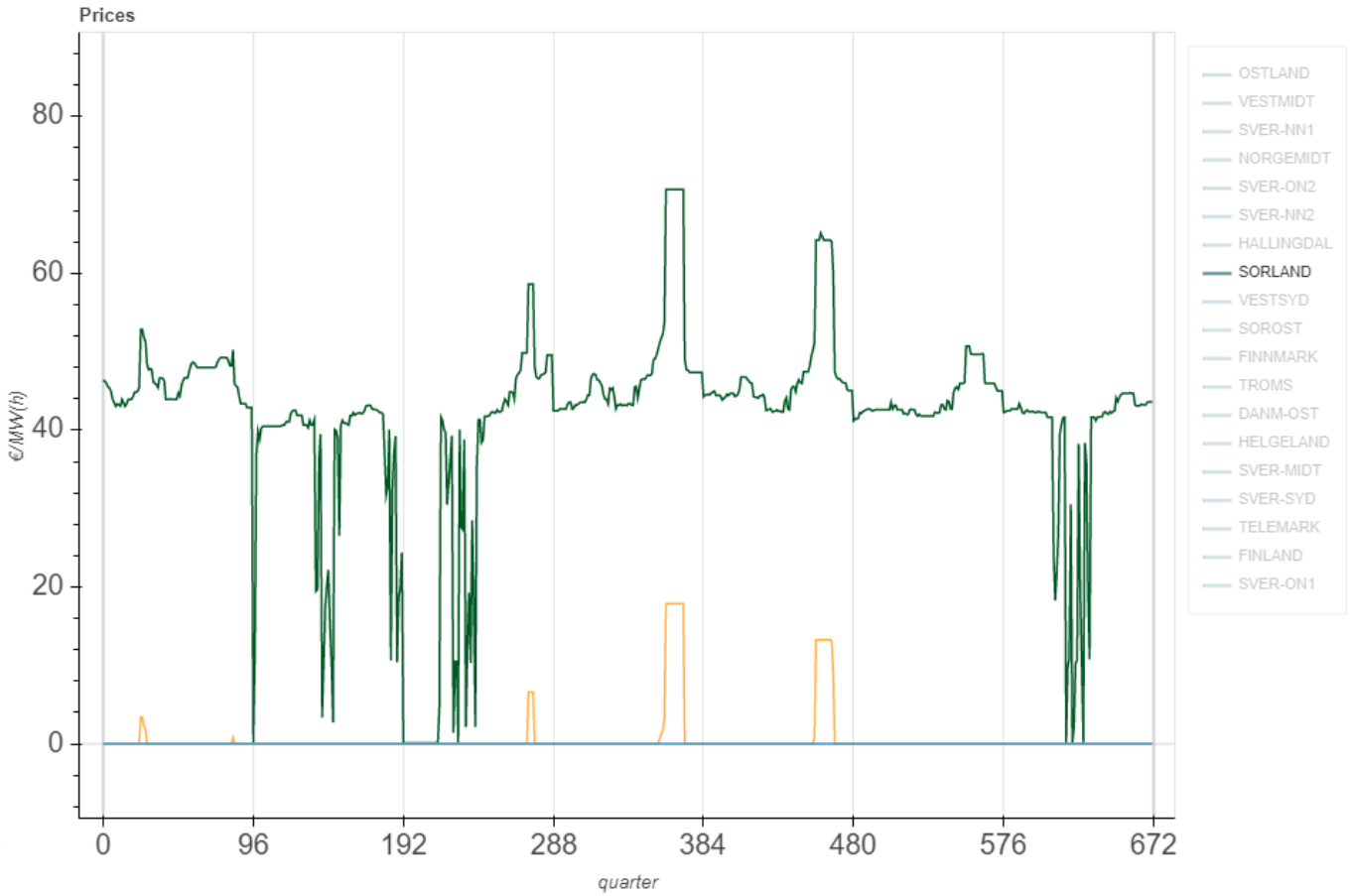
# Main operational models developed by SINTEF

- EMPS: Fundamental market modelling
  - Method: SDP, LP, simulation, heuristics, aggregation, disaggregation
- ProdRisk: Long and medium-term hydro scheduling
  - Method: Stochastic Dual Dynamic Programming
- SHOP: Short-term hydro scheduling
  - Successive Linear Programming, may include mixed integer formulation

# Current important research challenges

- Fundamental market model for the future system
  - Methodology, computation time
  - Basis for all  investment decisions
- Long and medium-term scheduling
  - Including state dependent constraints – environmental or physical in optimization
  - E.g. discharge or pumping capacity dependent on storage level
- Cost of operation – wear and tear that depend on how a plant is operated
  - Finding the cost and include in planning tools
- Multimarket modelling
  - Reserve allocation, activation, intra day ..

# Spot and reserve capacities
# Week 9, 2030, weather year 1958




Green: spot price
Yellow: Price Reserve capacity up
Blue: Price Reserve capacity down

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Thank you