Design of the Wilmar Planning tool

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Overview of presentation

1. The main idea of the Planning tool
2. Design of the Planning tool
    1. Overview
    2. Joint Market model
    3. Generation of scenario trees for wind power production
    4. Calculation secondary reserve need
    5. Data handling

Main idea behind the Planning tool

- Improve decision making by using information contained in wind power production forecasts
- Information: Expected wind power production, but also precision of forecast, i.e. the distribution of the wind power production forecast errors
- Decisions before wind power is known: Trade on day-ahead market
- Decision after wind power is known (recourse actions): Activation of regulating power

Main idea behind the Planning tool

- How:
  - Build system-wide stochastic optimisation model with the wind power production as a stochastic input parameter
  - Covering both day-ahead and intraday (regulating power) market
- Consequence: Model makes optimal unit dispatch on these markets that are robust towards wind power production forecast errors

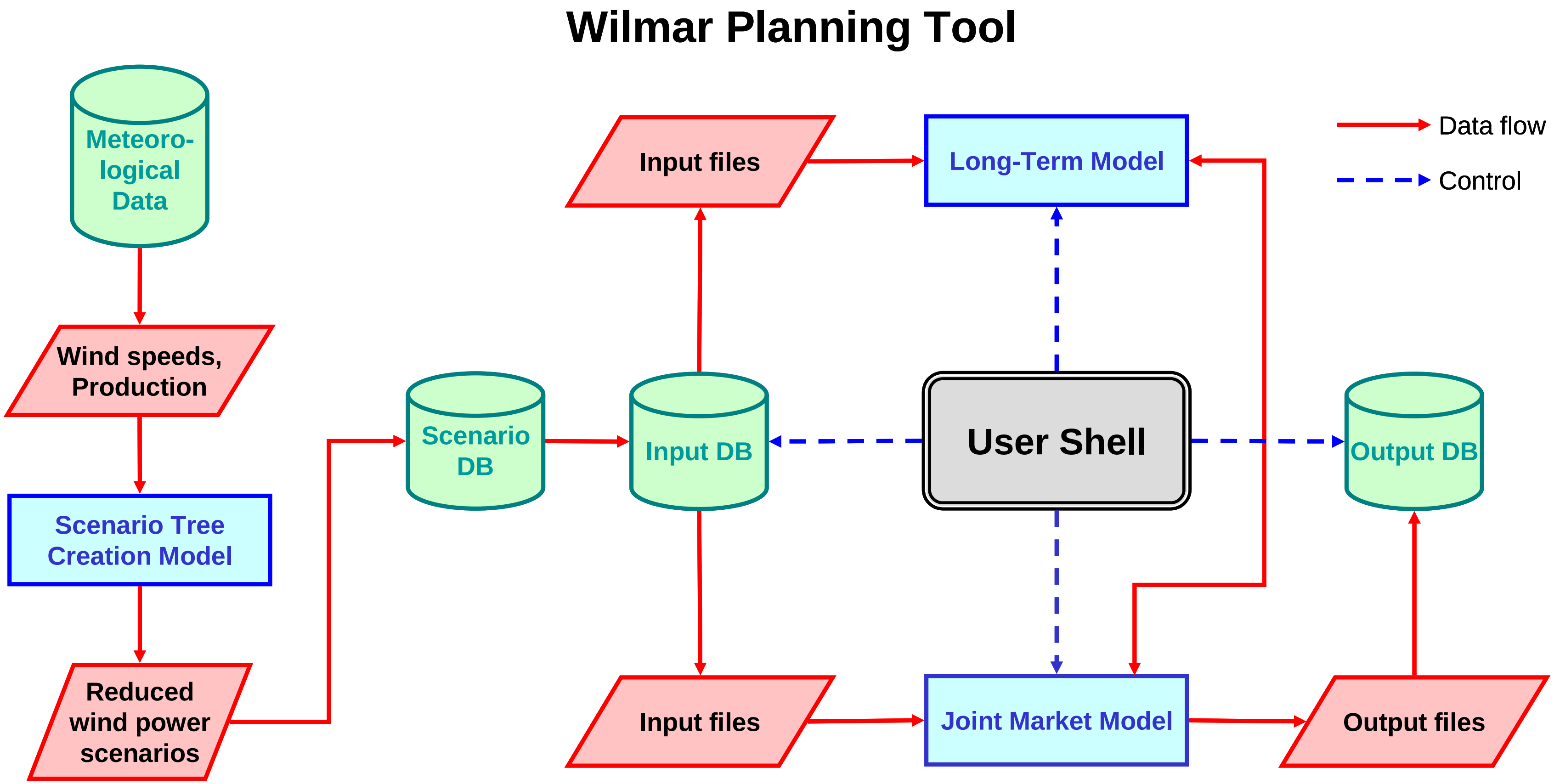
Why is it relevant?

- Planning tool enables analysis of:
  - Power prices (Day-Ahead and intraday)
  - Operation patterns
  - Reserve power need
  - Feasibility of integration measures
  - Value of wind power production (avoided costs)
- As a function of:
  - Installed wind power
  - Precision of wind power forecasting tools
  - Market design
  - Power system configuration

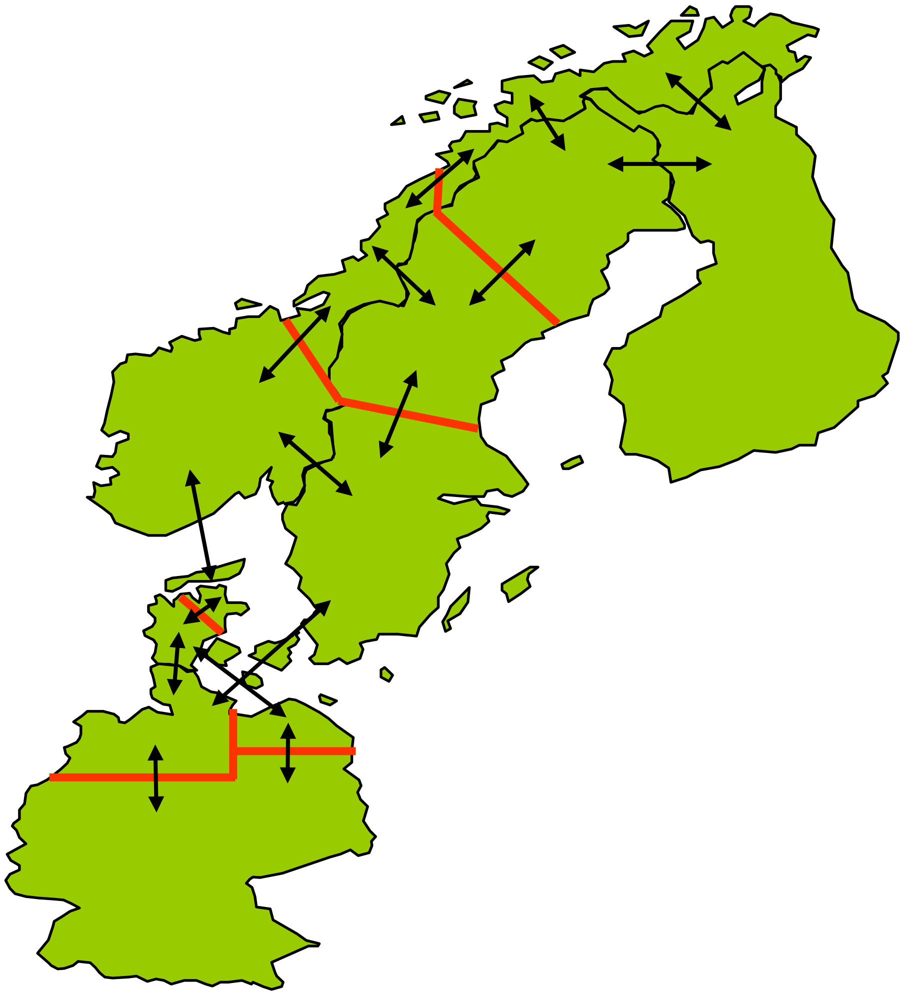
Framework of Planning Tool

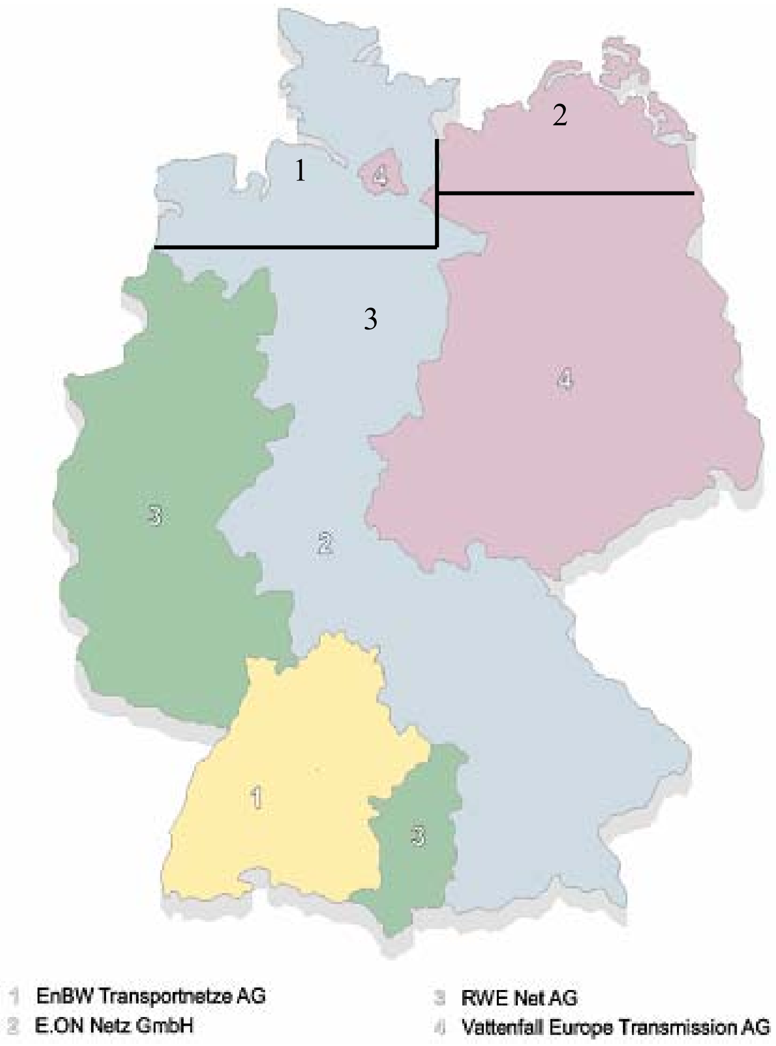
- Large-scale integration of wind power in a large liberalised electricity system
- Marginal costs determine unit dispatch, i.e. market power not analysed
- Market structure:
  - Day-ahead market (Elspot at Nord Pool)
  - Intraday market (Elbas at Nord Pool + Regulating power market run by Nordic TSOs)
  - Market for primary (spinning) reserves
  - Market for secondary (minute) reserves
  - Heat markets

Overview Planning tool



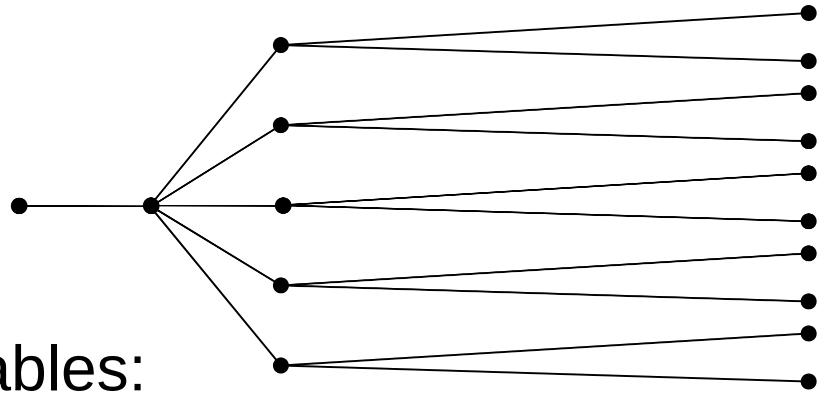
Overview of the Planning Tool





Going from deterministic to stochastic approach

- Clarify decision structure:
  - Time structure for new information arrival & decisions $\Rightarrow$ Number of stages and hours in each stage
- Introduce scenario tree:
  - Equations node and time dependant



- Partitioning of decision variables:

$$P_{i,s,t} = P_{i,t}^{DAYAHEAD} + P_{i,s,t}^{+INTRADAY} - P_{i,s,t}^{-INTRADAY}$$

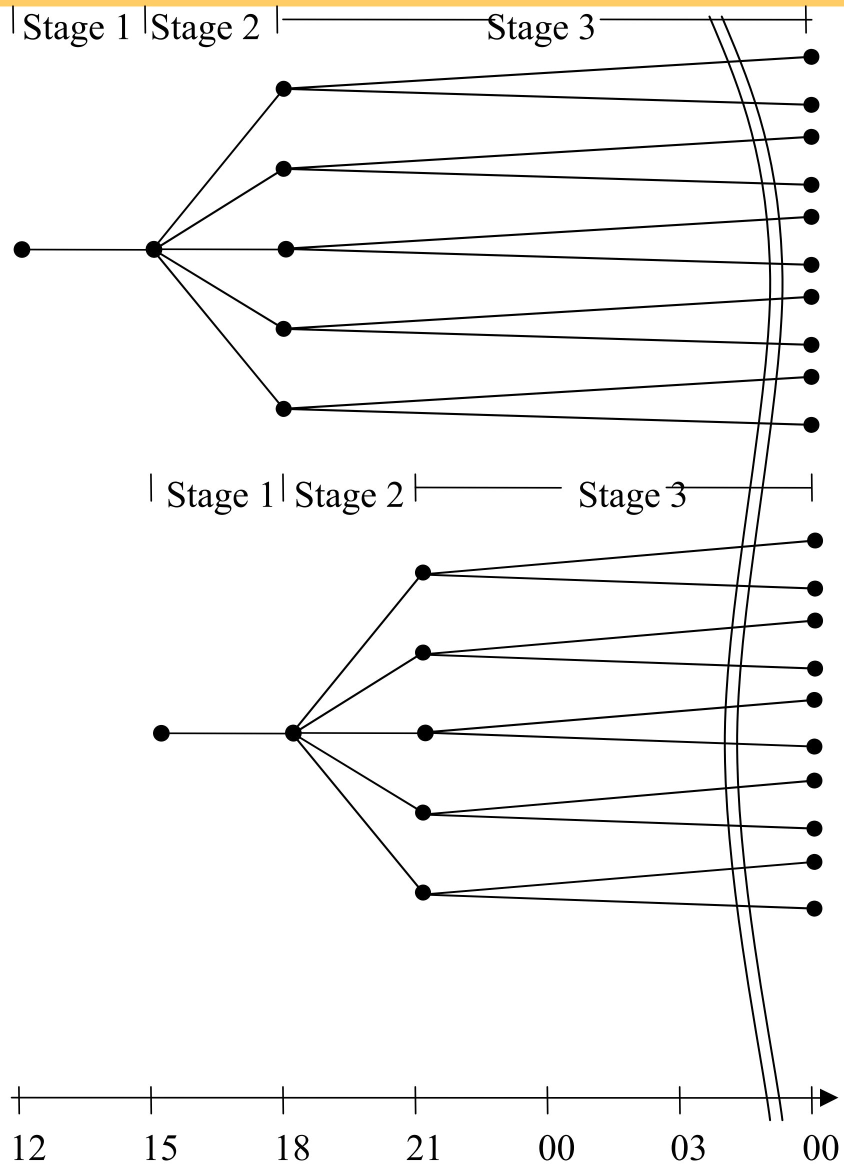
- Introduce rolling planning

Design of Joint Market model

Rolling Planning Period 1:

Day- ahead market cleared

Rolling Planning Period 2



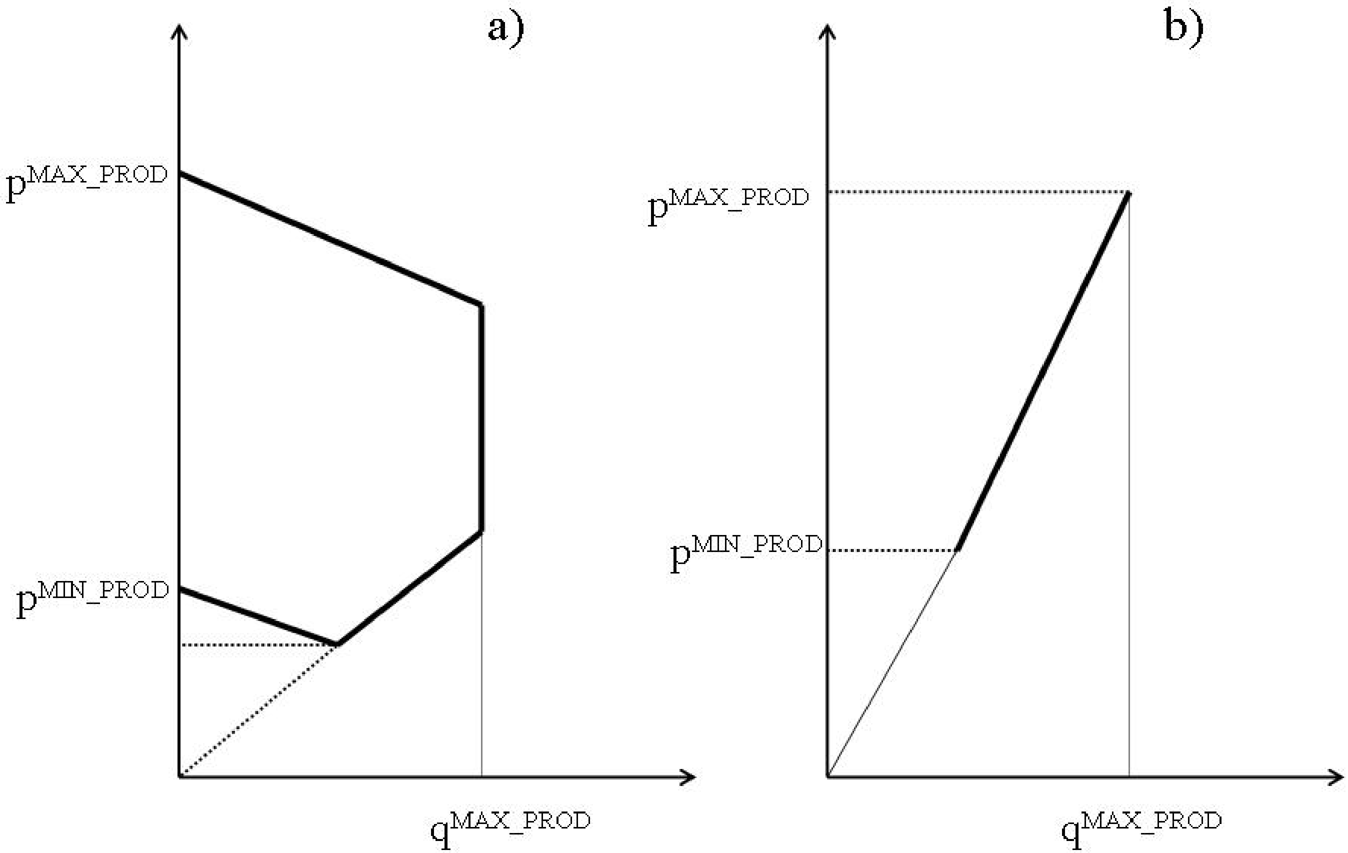
Design Joint Market model

- Objective function F
  = Fuel costs
  + Variable O&M costs
  + Start-up costs
  – Value at the end of optimisation period of heat and elec storage & hydro reservoir
  + Decrease in consumer surplus
  – Increase in consumer surplus
  + CO_2 & SO_2 Taxes
  + Taxes on fuels used for heat production
  – Support for renewable elec prod
  + Infeasibility penalties

Restrictions

- Elec balance on day-ahead market
- Elec balance on intraday market
- Heat balance on each heat market
- Balance on primary reserve market
- Balance on secondary reserve market
- Production below capacity online
- Transmission restrictions
- Balance: heat and elect storage and hydropower reservoirs
- Storage restrictions (max load, max unload,..)

Restrictions



Restrictions

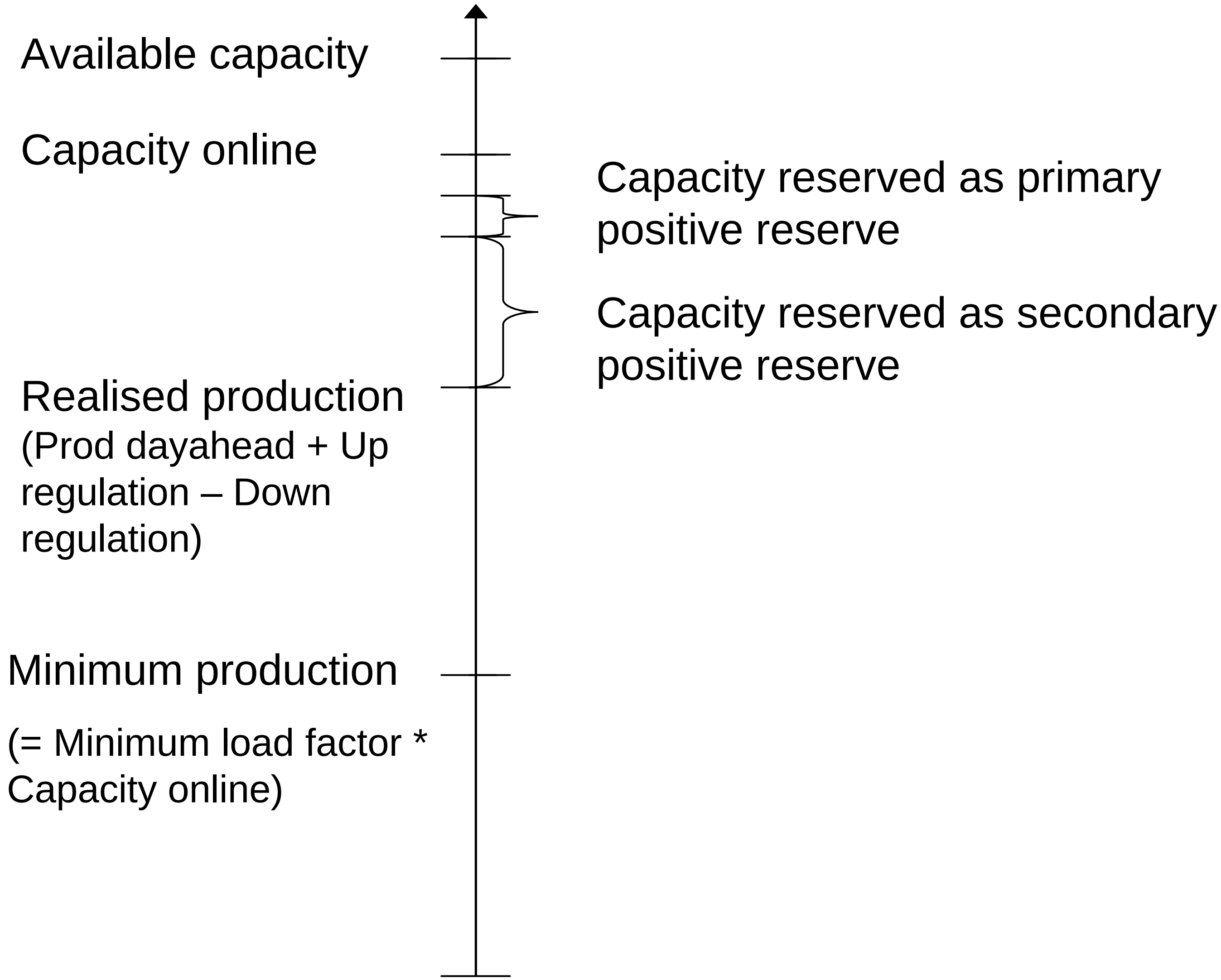
- Linear approximation of startup costs, partload efficiency, startup times and minimum load (C. Weber):
  - Introduce additional real variable ”Capacity online”
  - Startup costs proportional to capacity put online in time step t
  - Efficiency = Max_Eff*Elec_Prod + PartLoad_Eff_Factor*Cap_Online

Restrictions

Start-up times:

1. Decision about bringing capacity online has to be done before observing wind power production scenario $\Rightarrow$ Capacity online constant over the first LEADTIME hours of the wind power production scenarios
2. Capacity online in planning loop n in the first LEADTIME hours equal to capacity online found in planning loop n-1 in the corresponding hours

Dispatch of unit group



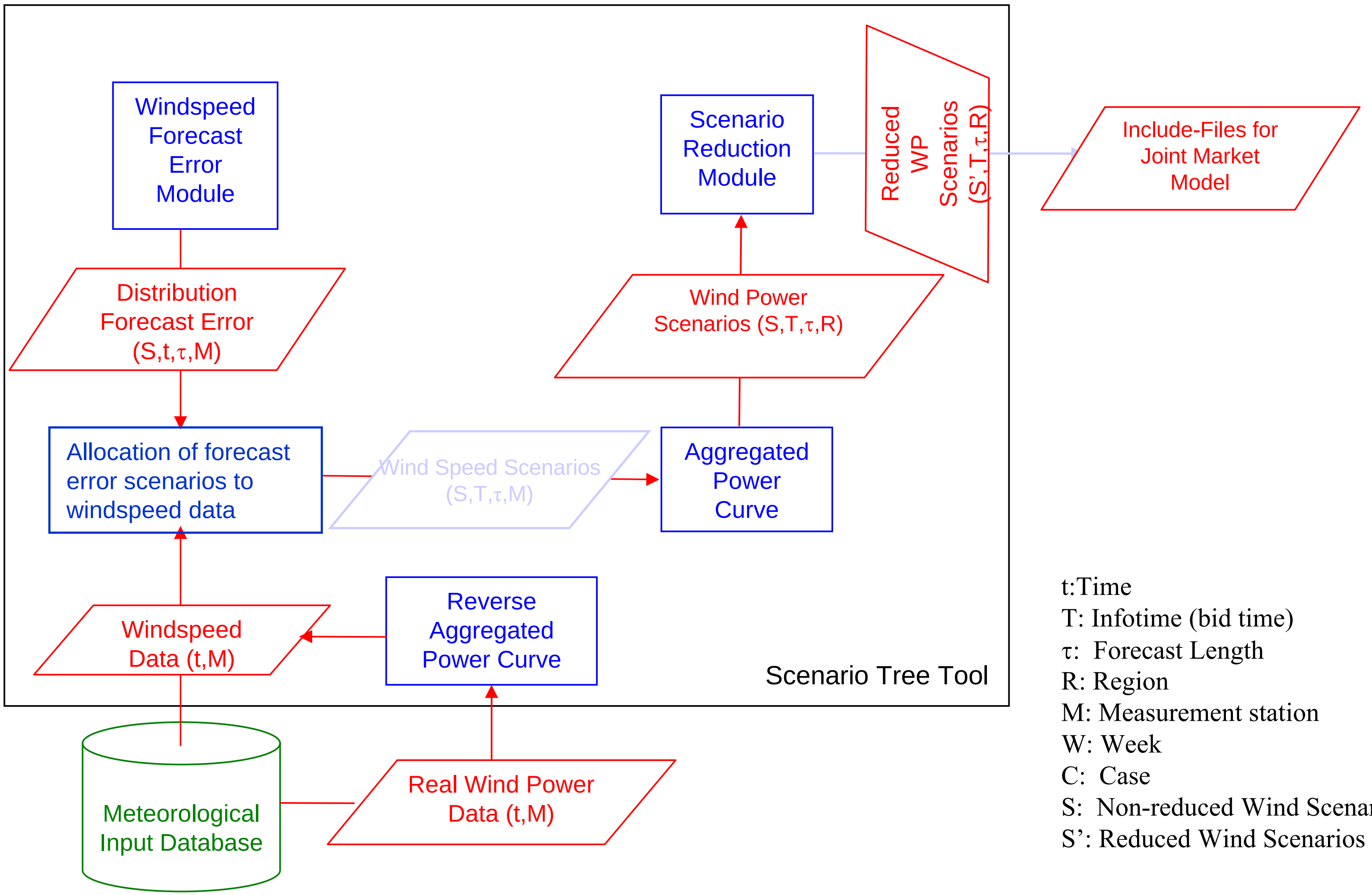
Deterministic JMM

- Easy choice between stochastic and deterministic version
- Only 3 nodes (one for each stage) in deterministic version
- Deterministic version runs faster, can be used for whole year simulations (problems with the water)

Scenario Tree tool

- Task of the Scenario Tree Tool: Generation of n (currently n = 10) wind power forecast scenarios based on measured wind speed and wind power data for the Planning Tool and further for the Stepwise Powerflow Model.
- Scenario Tree Tool consists of the following models:
  - Wind speed forecast error model
  - Aggregated power curve model
  - Scenario reduction model
- All models are implemented and combined in MatLab.
- Needed data are stored in the “Scenario Tree Tool Input Database” (MS Access).

Data flow within the Scenario Tree Tool



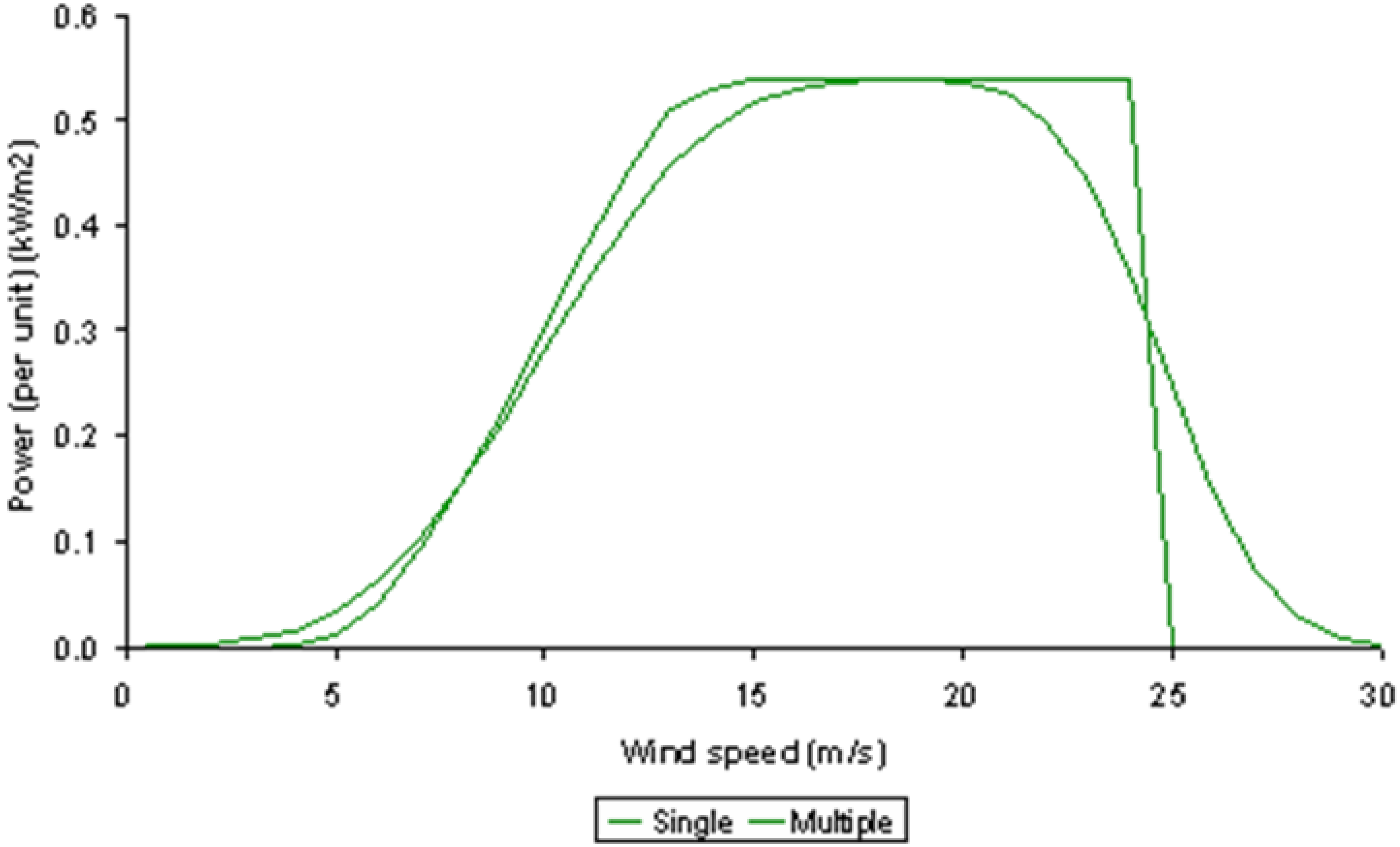
t:Time
T: Infotime (bid time)
τ: Forecast Length
R: Region
M: Measurement station
W: Week
C: Case
S: Non-reduced Wind Scenarios (1000)
S': Reduced Wind Scenarios

Wind speed forecast error model

Based on work of Lennart Söder (KTH) and Rüdiger Barth (IER) :

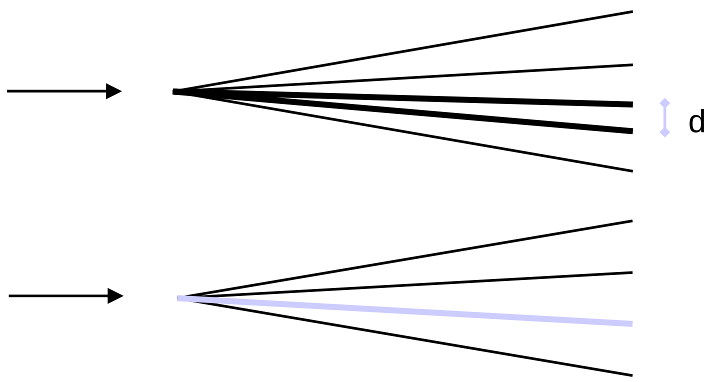
- Based on wind speed data and historical forecast errors
- Simulation of wind speed forecast error using a multidimensional ARMA time series
- Including the autocorrelation of the wind speed forecast errors over the forecast length
- Including the correlations of the wind speed forecast errors between individual wind speed measurement stations for the individual forecast hours
- One sampling for determination of the average wind speed forecast error.
- One thousand samplings to describe the distribution of the wind speed forecast error.

Aggregated power curve model



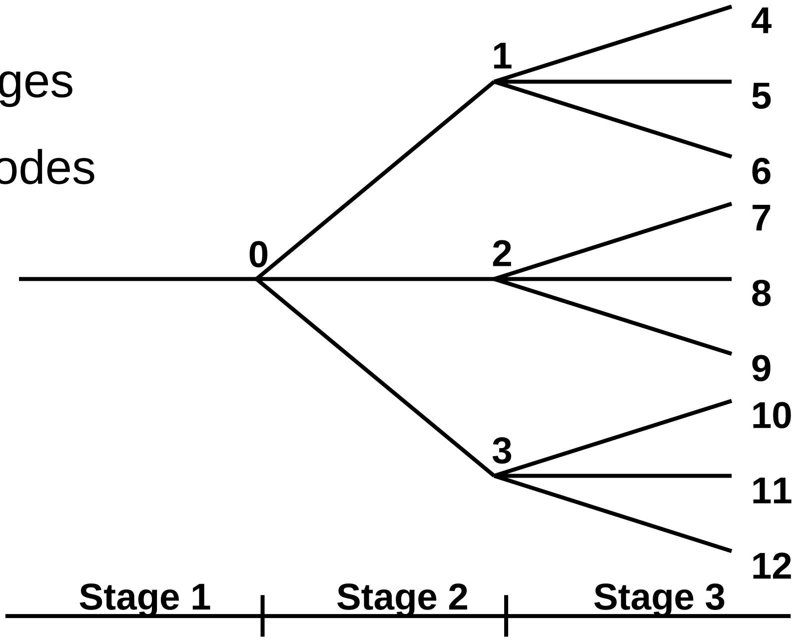
Scenario reduction model

- Wind speed forecast error model creates 1000 scenarios of wind speed forecast errors.
- Reduction of resulting 1000 wind power forecast scenarios to 10 scenarios:
    1. Scenario reduction model calculates the distances of the individual scenarios using as distance function the sum of squares.
    2. 2 similar scenarios are represented by one scenario.
    3. While bundling the scenarios the probabilities of the individual remaining scenarios are calculated.
    4. Reduced scenarios have to show the same variance as the original 1000 scenarios.
    5. Creation of the scenario tree.



Output: Scenario tree for the Joint Market Model

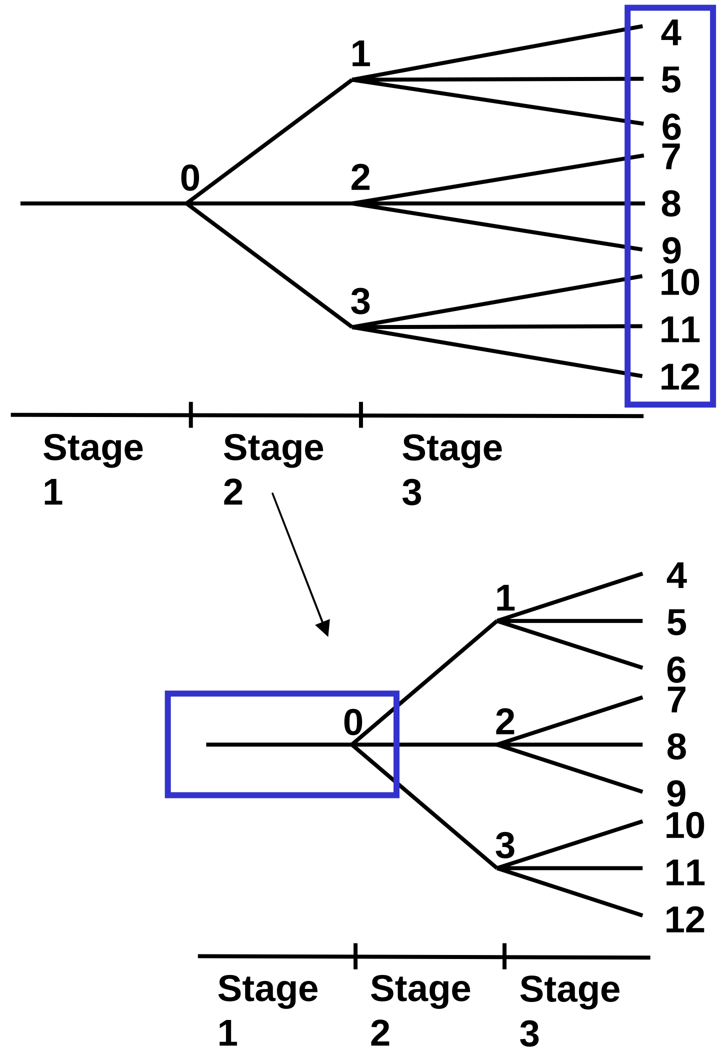
- Scenario tree structure is predefined for usage within the Joint Market Model
  - Number of branches and stages
  - Predecessors of individual nodes



  - Results of the Scenario Tree Tool delivered to the Joint Market Model:
  - Wind power forecast scenarios with predefined node structure and consistent with wind forecasts
  - Probabilities for reaching each node

Interpretation of information in tree

1. Expected amount of wind power sold on the day-ahead market is based on the average (considering the individual probabilities) of the wind power values of the nodes 4 – 12 (stage 3 of the scenario tree).
2. Realised wind power value of the successive time steps is described by the node 0 (stage 1) of the successive scenario trees.
3. Amount of needed up or down regulation is determined by the difference between 1. and 2..



Calculation secondary reserve demand (1)

- Nordel criteria for minimum secondary reserve in each country based on N-1 criteria (outage of largest unit or transmission line)
- Wind power production forecast errors also consume secondary reserve
- New calculation of minimum secondary reserve taking both N-1 criteria and largest wind power forecast error into account
- Distribution of Outages and distribution of wind power forecast errors seen as two independent stochastic distributions

Calculation secondary reserve demand (2)

- Percentiles in the two distributions can be added using $(A^2+B^2)^{½}$
- N-1 criteria representing some percentile in the outage distribution that the TSOs has agreed upon as expressing a reasonable level of system security
- Largest forecast error in unreduced scenarios (i.e. expected wind power production E(r,t) minus the lowest realised wind power production) used to represent wind power production forecast error distribution

Data handling

- Using Access databases to handle both input and output data
- Combined with VBA code for automatic generation of input data and automatic inclusion of output data

What have we learned

- Hard to treat both stochastic wind, CHP and dispatch of hydropower in one tool
- Complications in going from deterministic to stochastic:
  - Generation of stochastic input parameter
  - Rolling planning
  - Calculation time
  - Interpretation
- Data collection a large challenge
- Use of databases in handling of input and output data works very nice

What have we learned

- Advantages:
  - Endogenous treatment of wind power forecasts
  - Inclusion of regulating power and regulating power market
  - Thorough understanding of decision structure