



A Simulation Model for Reserve Markets

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Modelling the Reserves Option Market

- ROM, spot, BM are integrated markets (Slide)
- A generation unit
 - Participation in spot or ROM+BM?
 - Payoff must be equal for balancing unit (Graph)
- Thus: A model for ROM should include spot and BM too
- First model of this kind?

Model description

■ Markets

- ROM, spot, BM (stochastic)
- ONE clearing for each market in three stages
- One region

■ Agent-based model

- Power producers
- Large industrial consumers
- Ordinary consumers (households etc)
- System operator

Power producers

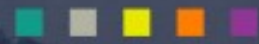
- Supply
 - Capacity reserves
 - Spot electricity
 - Adjustments in BM

- Maximize expected profit in rest of game at each stage

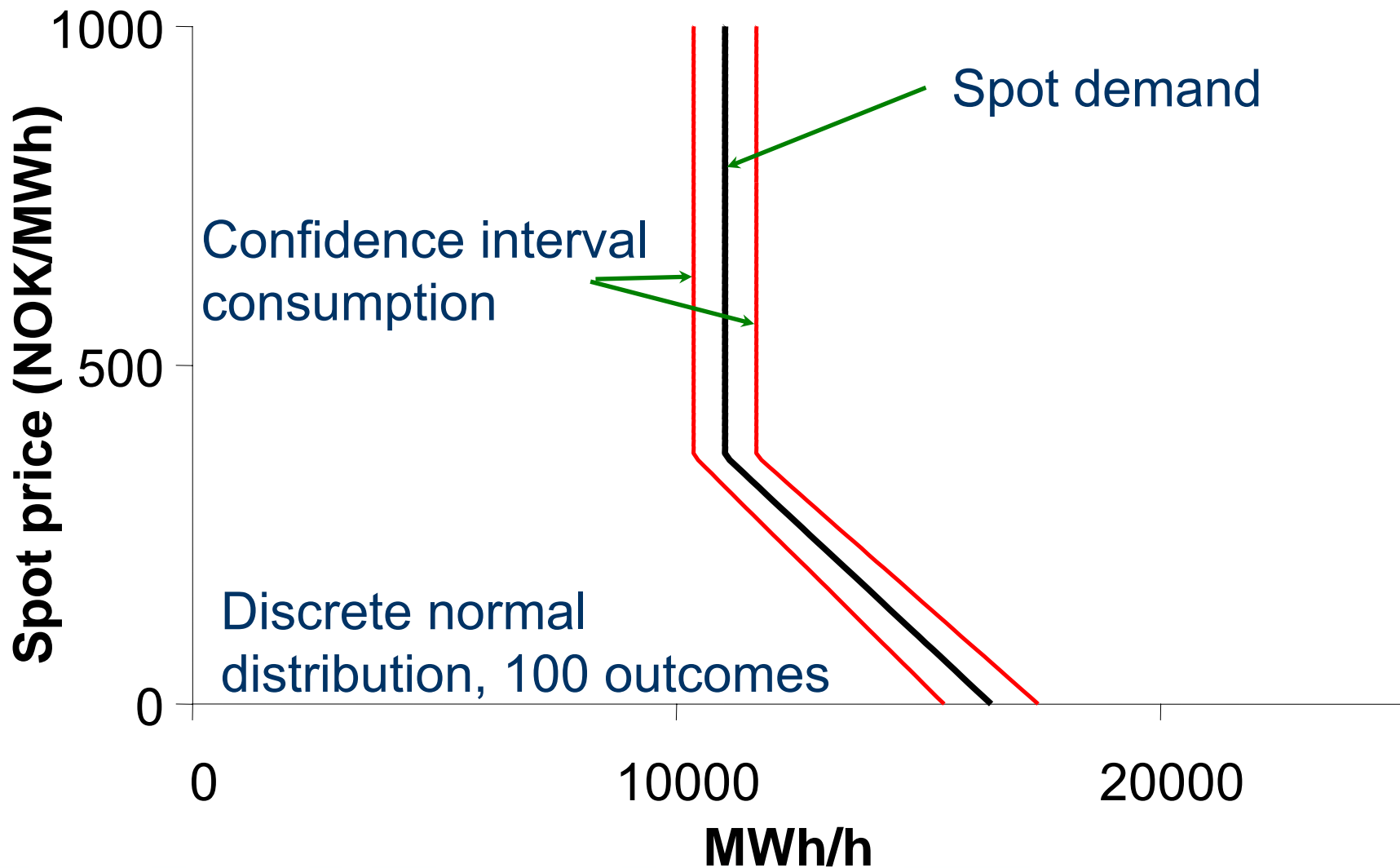
- Method: stochastic dynamic programming

Industrial consumers

- Use electricity as an input in production
- Participate in all three markets
 - Supply capacity reserves
 - Demand in spot market
 - Can cut consumption in BM
- Mathematical optimisation problem similar to power producers' problem



Ordinary consumers



System Operator (SO)

- Buy capacity reserves (parameter)
- Operates the BM
 - Secure the physical balance
 - Set the price according to predefined rules
- Load shedding
 - If needed balancing $>$ available reserves
 - Controlled disconnection of consumption
 - Large socio-economic costs

Output from model

■ Prices

- ROM
- Spot
- BM for each stochastic outcome

■ Quantity

- Held reserves: industry, power producers
- Spot demand: industry, ordinary consumers
- Regulated “units”: industry, power producers

■ Load shedding

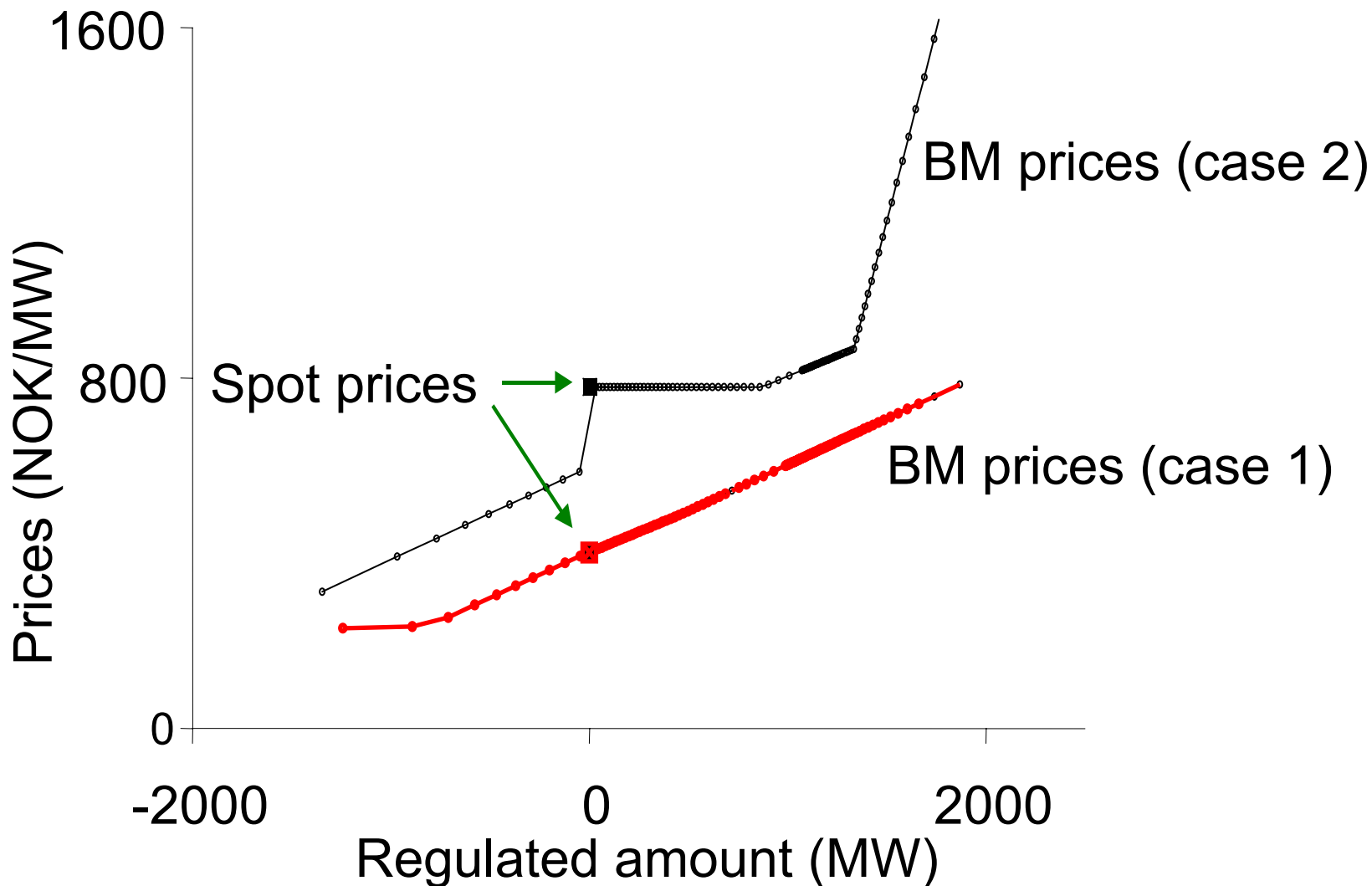
- Probability for event
- Amounts

■ Expected socio-economic surplus

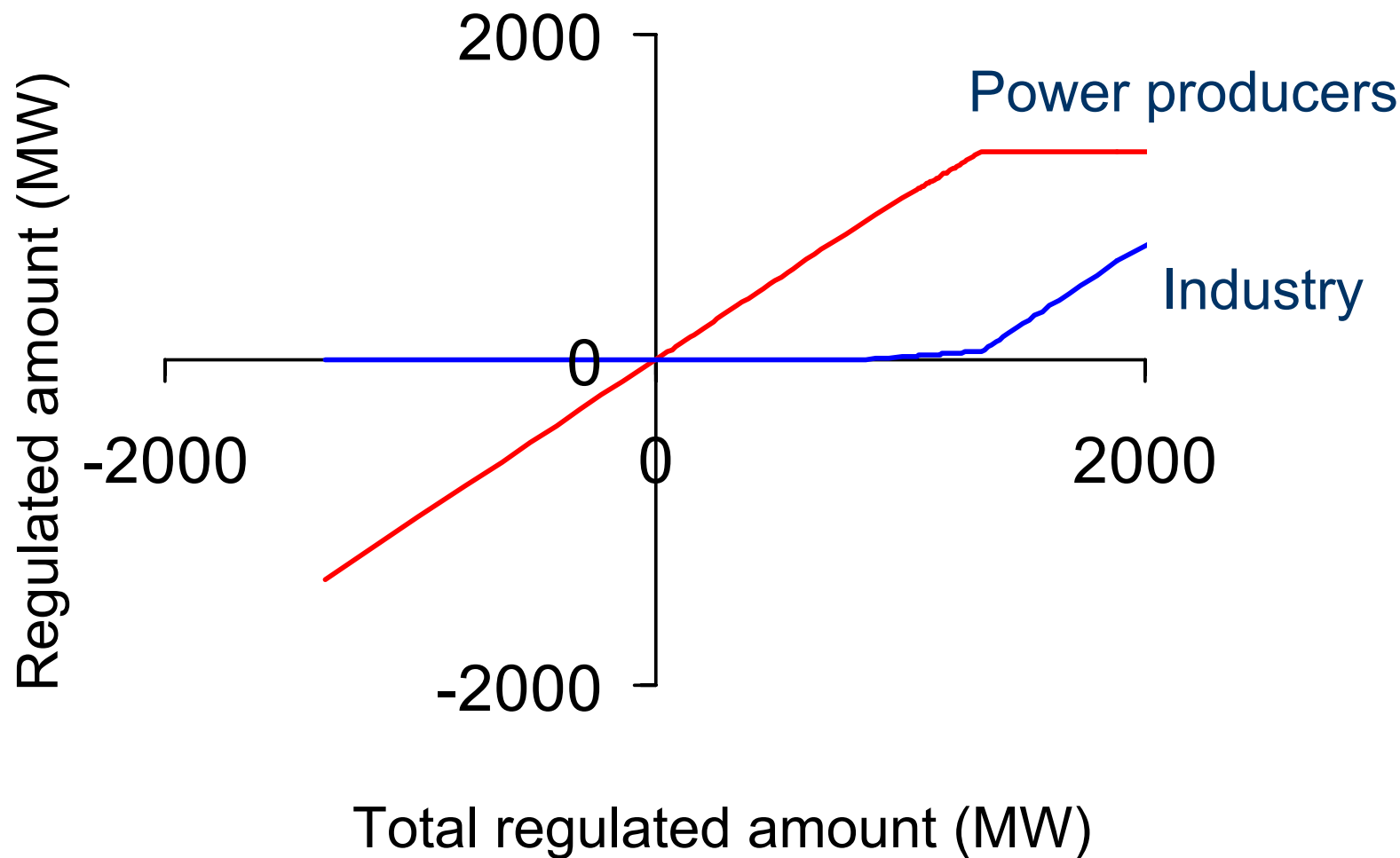
Simulations

- Model is roughly calibrated for Norway
- Two cases for the BM
- Increased spot demand
- Larger reserve requirement

Two cases for the BM: Increased demand



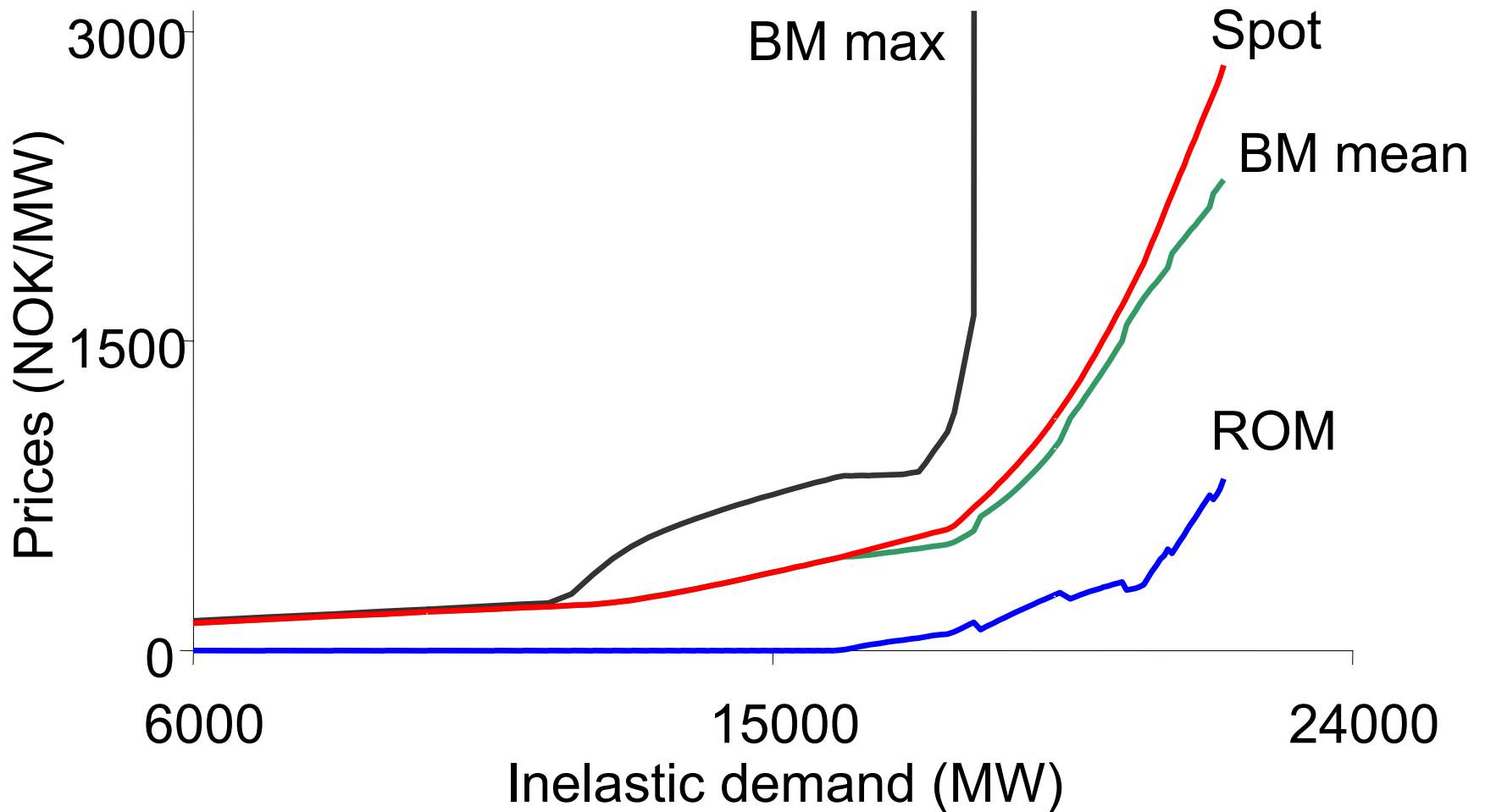
Regulated amounts (case 2)



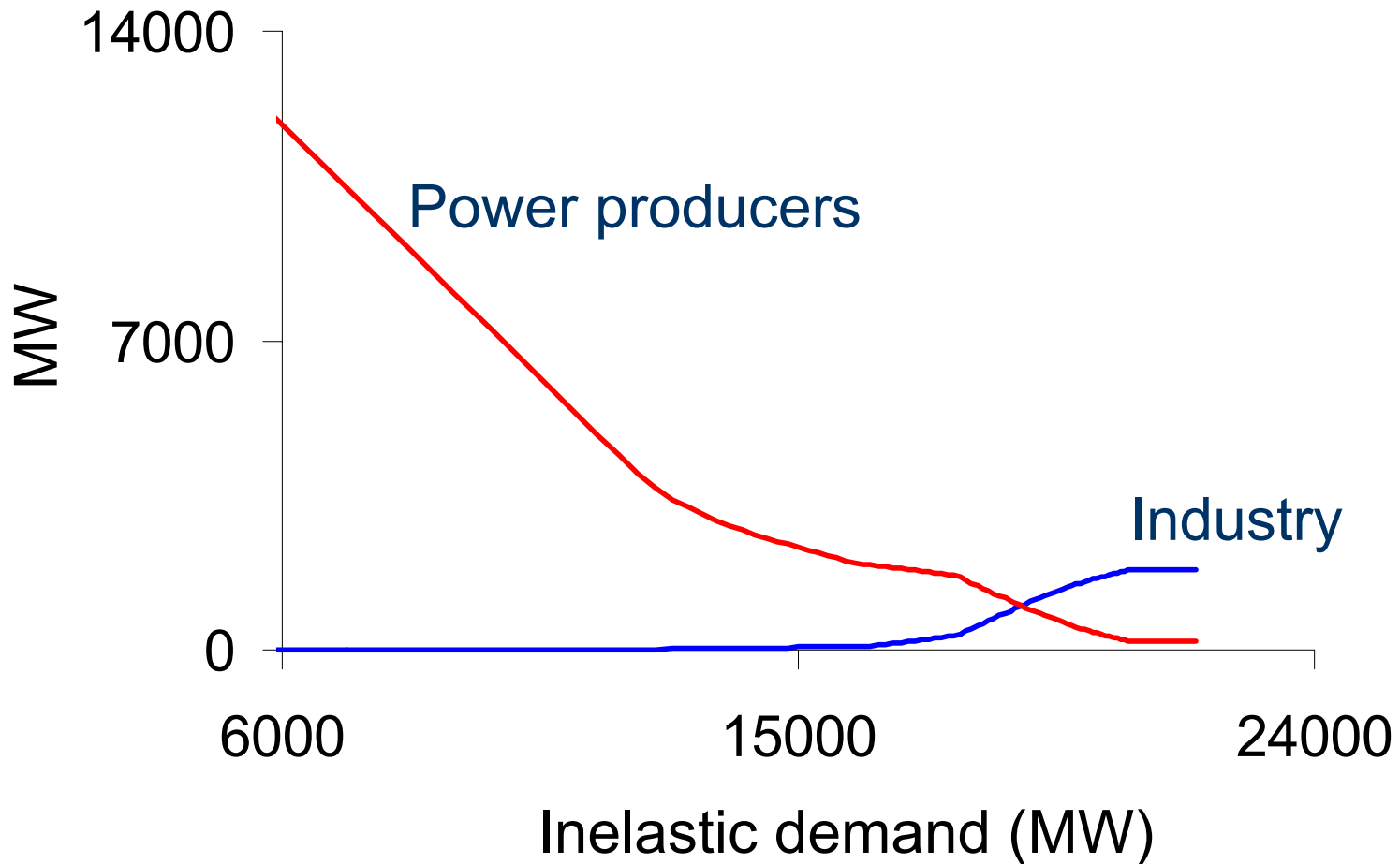
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Spot Demand and Prices



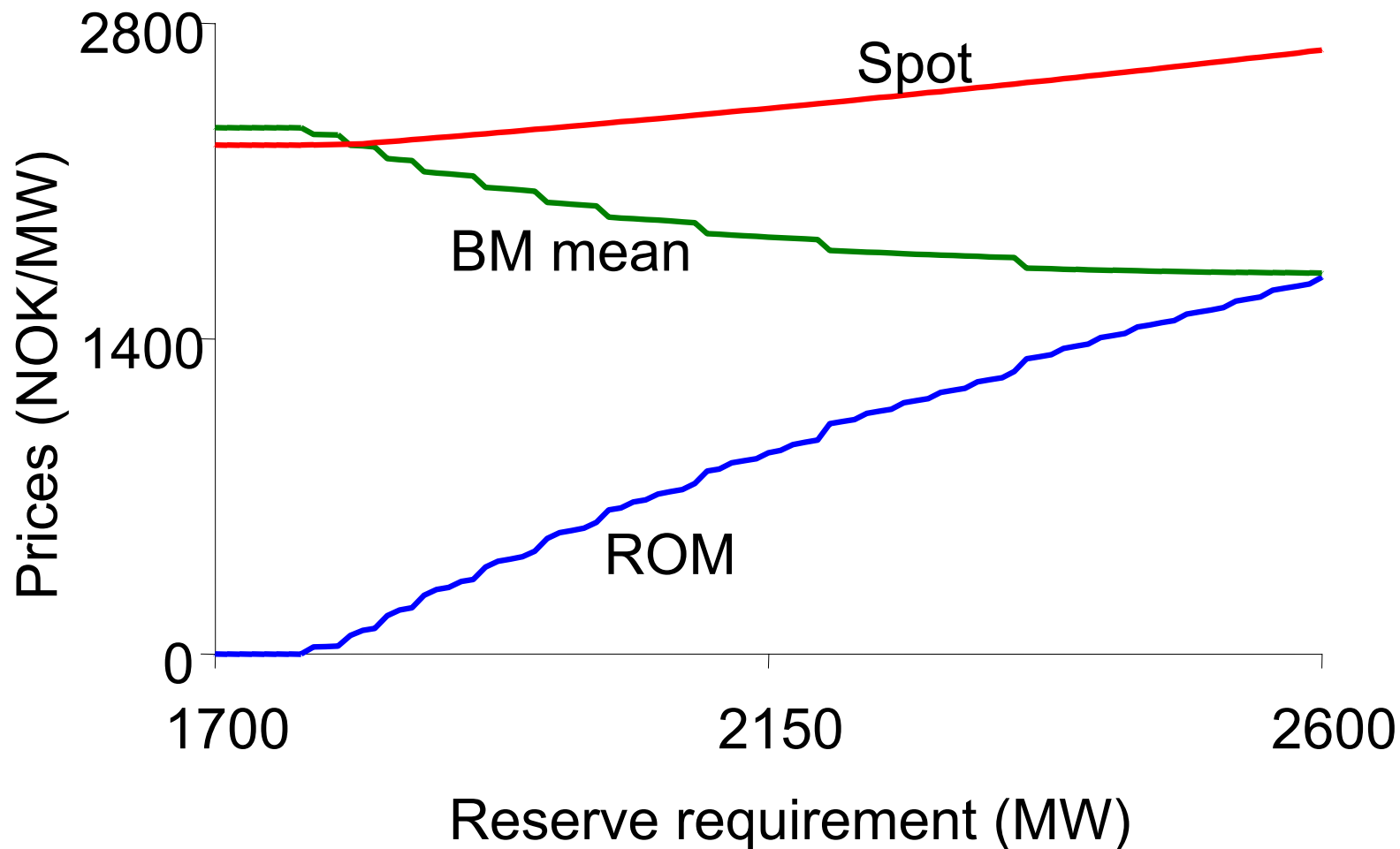
Spot Demand and Held Reserves



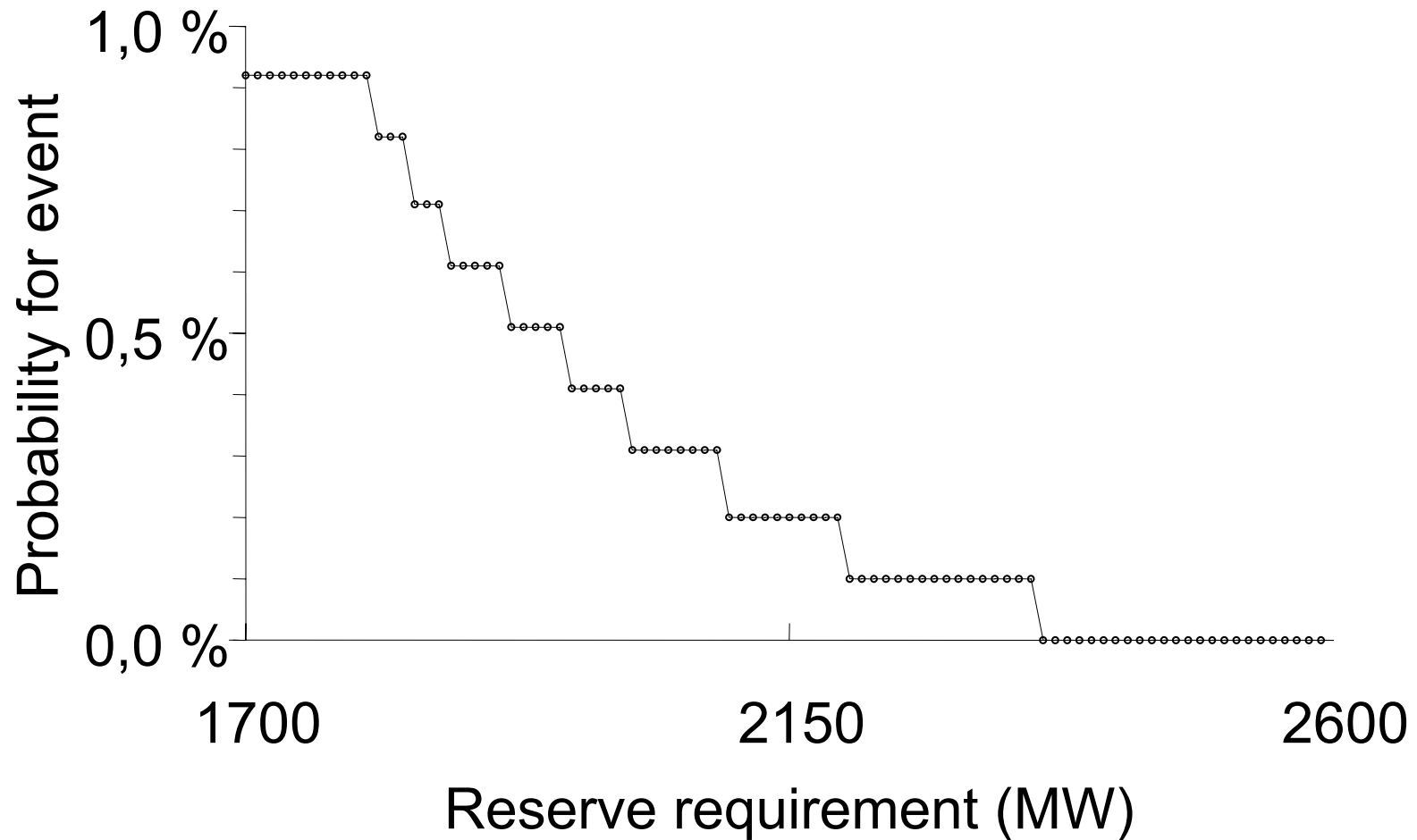
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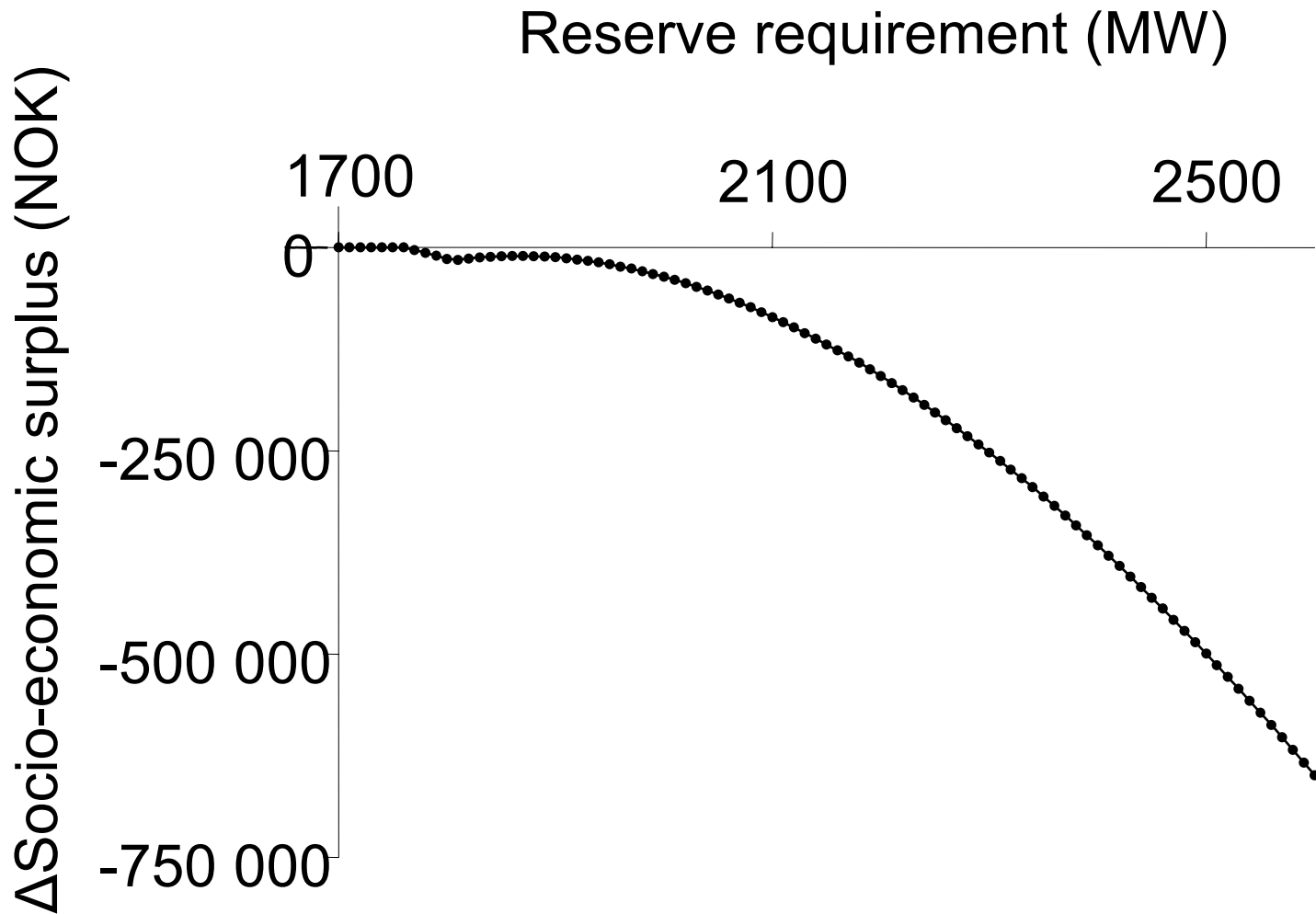
Reserves and Prices



Reserves and Load Shedding



Reserves and Socio-economic Surplus



Possible model improvements

- Multiple regions and trade (Nordic model)
 - Project: Gains of Nordic co-operation (ROM, BM)
- Multiple time steps
- Stochastic spot demand
- Probability for system breakdown

Documentation

- Wangensteen, I., O. Wolfgang and G. L. Doorman (2005),
”*Capacity pricing in a free market*”, TR A6037.
- Wolfgang, O., G. L. Doorman and I. Wangensteen (2004),
”*A Market for Reserve Capacity: Experience and Simulation*”,
IEEE MELECON 2004.

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Last slide

Markets for Electricity in Norway

- Spot market
 - Day ahead energy market for electricity for each hour

- Balancing Market (BM)
 - Ensures physical balance during operational hour
 - Payment only if activated

- Reserves Option Market (ROM)
 - Up-front premium for being available in BM
 - E.g. 1 week duration
 - Open for producers AND large consumers

(Back)

Balance for spot and ROM (not BM)

