Capacity shortage
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Market based solutions for Reserve Capacity

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The report deals primarily with pricing of reserve capacity, partly on a theoretical basis and partly based on practical experience from the Norwegian market.

The theoretical part, which will be presented here, describes a simple model for investigation of equilibrium prices on capacity reserves, spot power and balancing power. This model is based on strong simplifying assumptions.

In a later presentation (Ove Wolfgang) a computer model is introduced, which enables more complexity and makes it possible to analyse more realistic scenarios. But still there is considerable distance between model and reality.

What is meant by market solution?

- The electricity market open to competition (free market)
- The market for reserves (or more general: ancillary services) must be as close as possible to a free competitive market.

Electricity (as other commodities) has a quality as well as a quantity dimension. The special feature of electricity is that the quality dimension is *collective*. Individual consumers can buy individual quantities of electricity but not individual qualities.

Collective or public goods are goods that are nonexclusive. They provide benefit to a group of consumers. Classical examples of collective goods are police and military defence. It is generally acknowledged that a free market alone cannot provide such goods. They must be provided on a collective basis.

Responsible for the quality: System Operator

- Define or specify the quality requirement:
  - Frequency
  - Voltage
  - Security of supply
- On the basis of quality requirement, find the need for ancillary services:
  - Primary reserve
  - Secondary reserve
  - Etc.

Two alternatives for the System Operator to secure adequate supply of ancillary services:

1.

- The SO can put obligations on the market participants
- The participants can then chose self-provision or they can buy in the market
- Thereby a market for ancillary services is established.

2.

- The SO can operate as a single buyer.
- Different tendering procedures can be used.

Both solutions are being used. Solution 1 especially in the US, solution 2 in Europe

Basic assumptions

- Available efficient electricity markets:
  - Spot Market
  - Balancing Market
  - Reserve Options Market
- Participants in the market can switch between different sub-markets
- An equilibrium in and between markets will occur

Decisive factors for the price of reserves:
(in an ideal market)

- What is the value to the system
- What is the opportunity cost (in use for other purposes)
- What is the direct cost (disregarded opportunity cost)
- Expected payoff when called up to generate

Given capacity, given reserve requirement.

The market will create balance between expected revenue in the Spot Market and the Reserve Option Market (ROM):

Spot Market:

Revenue = Capacity · (spot price – marginal cost)

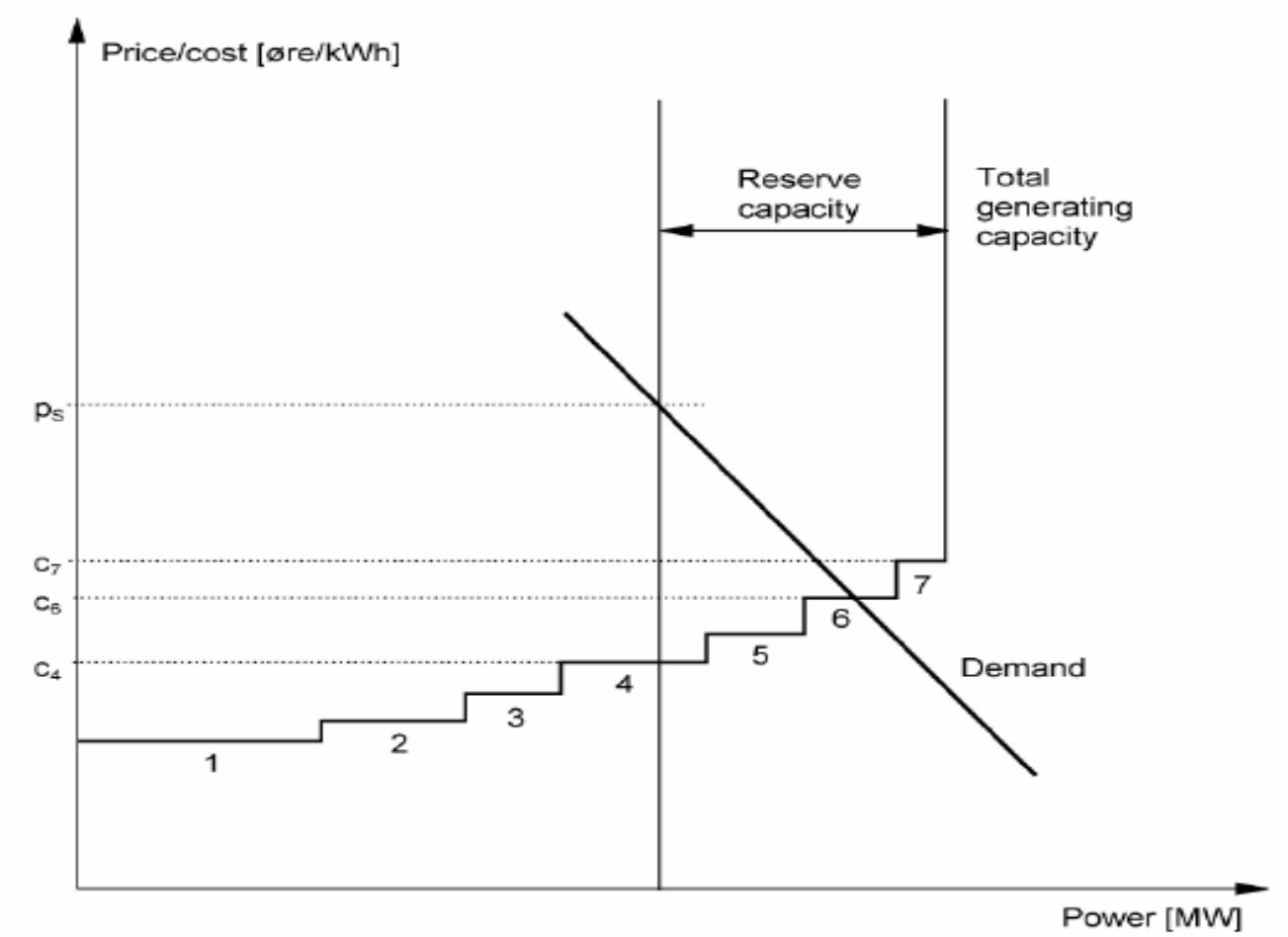
Reserve Option Market:

Revenue = Capacity ·ROM price

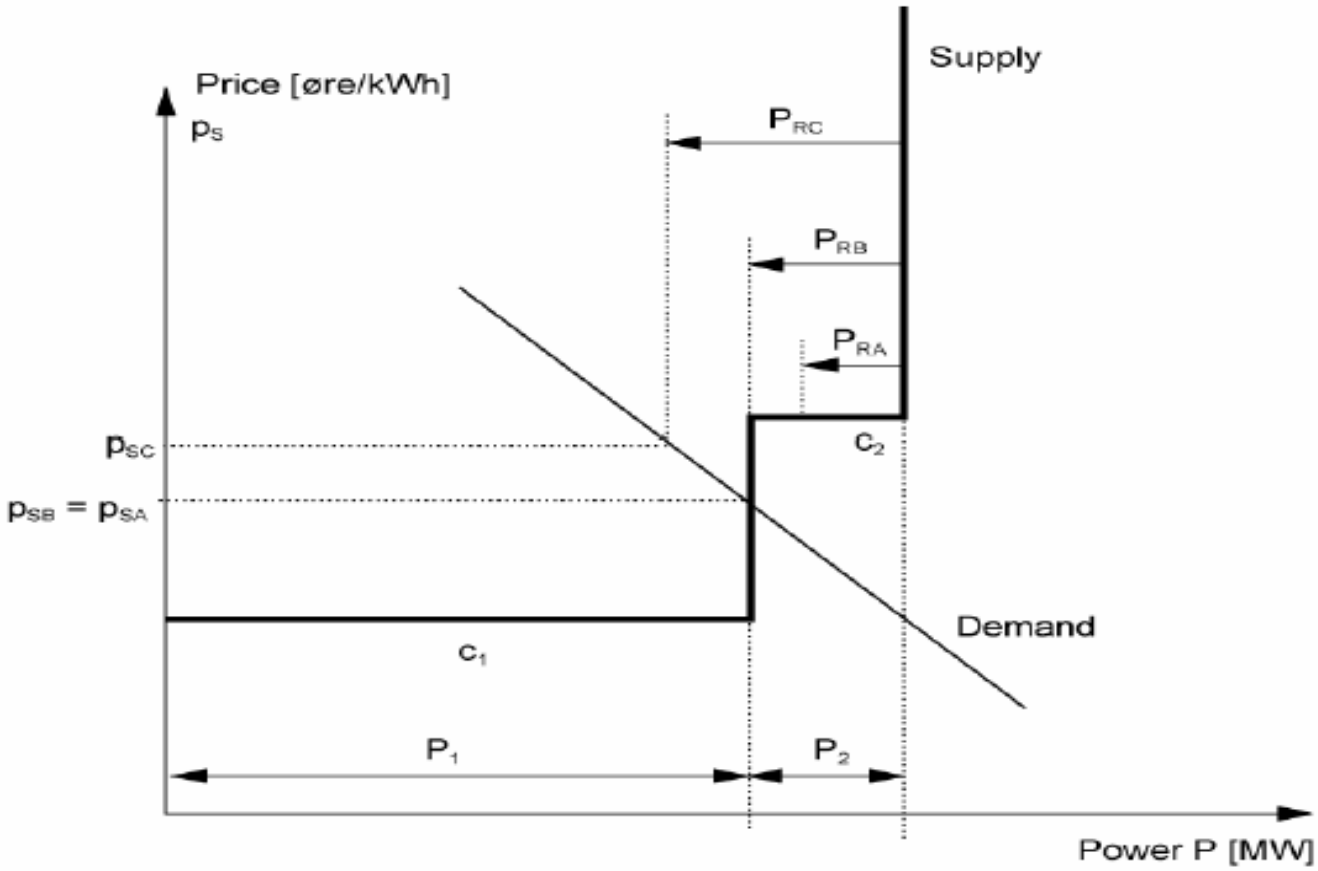
– Cost for holding reserves ready

+ Expected net revenue from possible activation

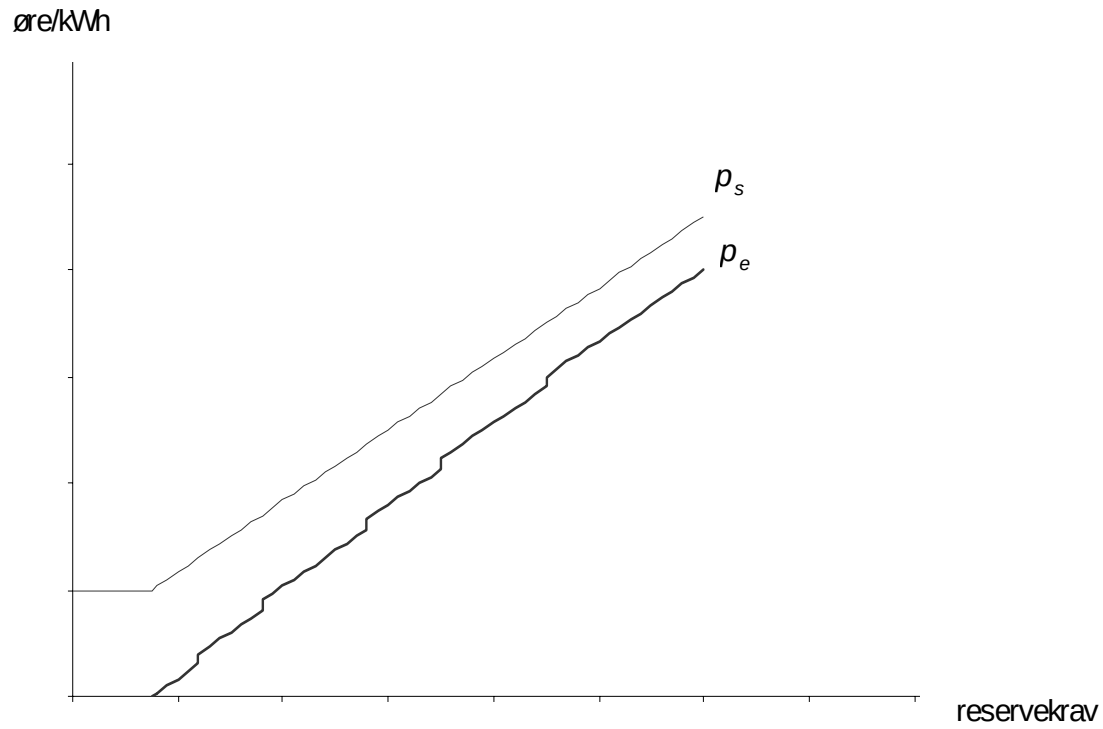
Market balance for a given reserve capacity



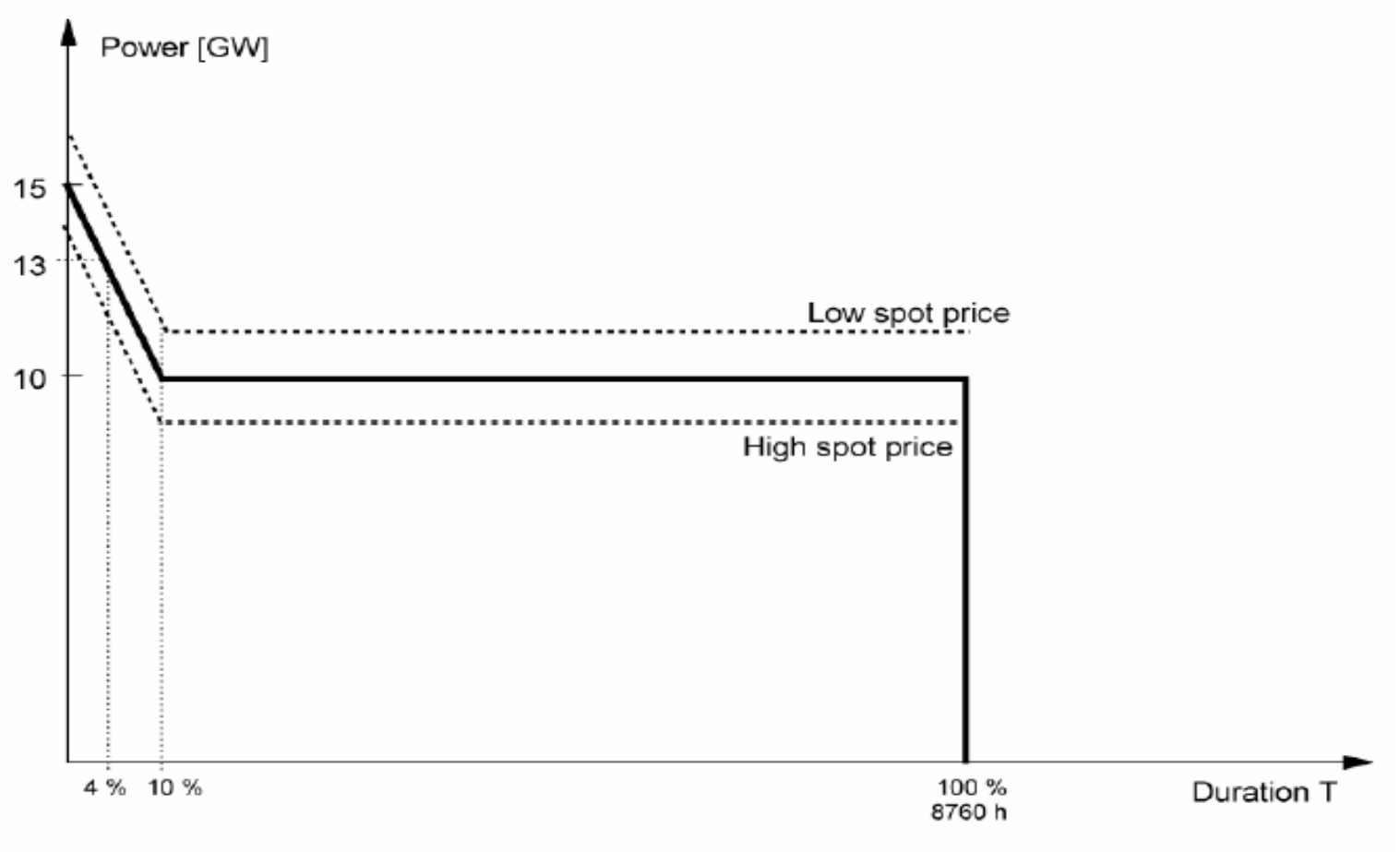
Simplified supply curve



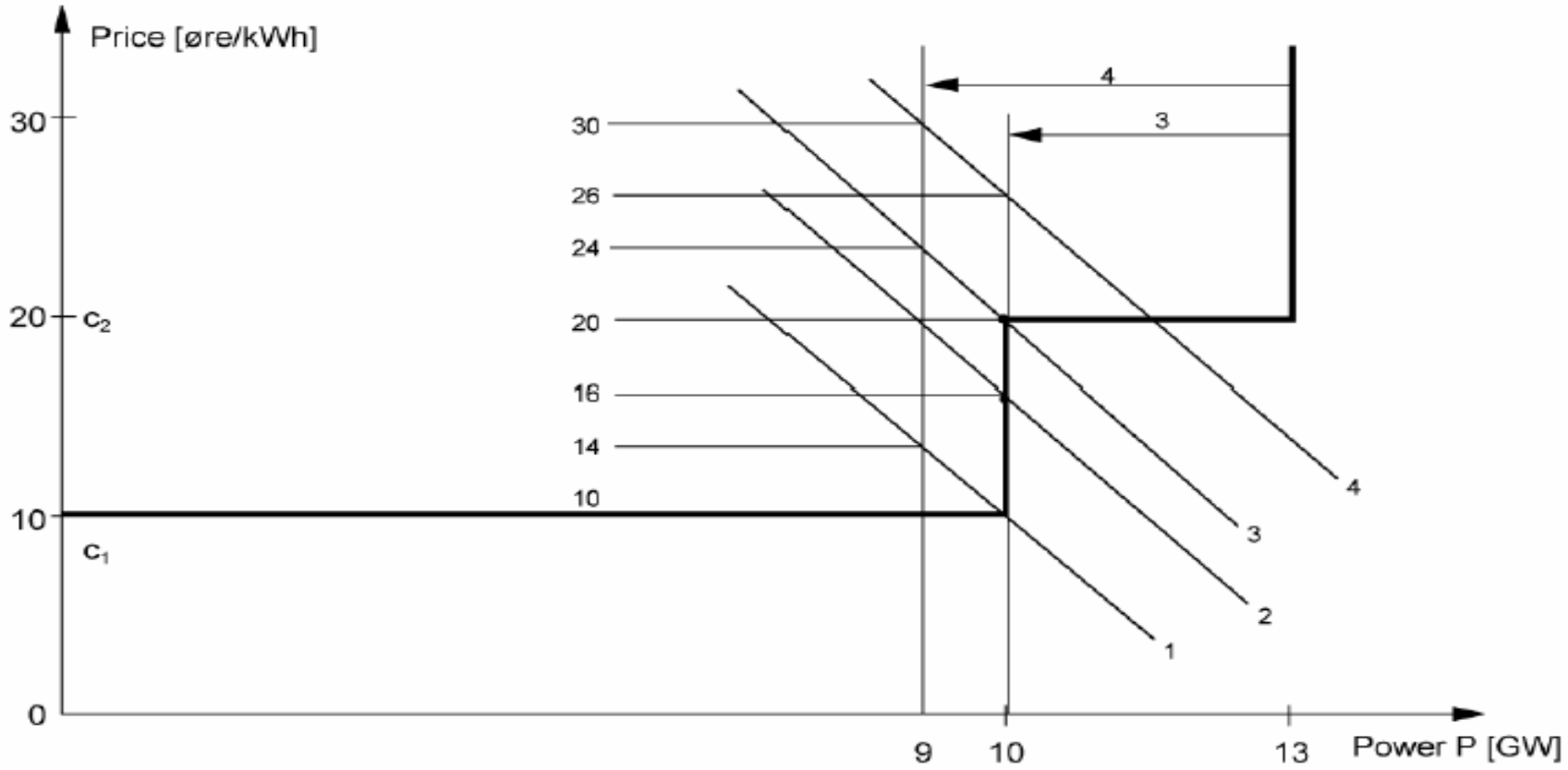
Price development with increasing reserve requirement.



Load duration curve



Different demand levels, Reserve level given (3 or 4 GW)



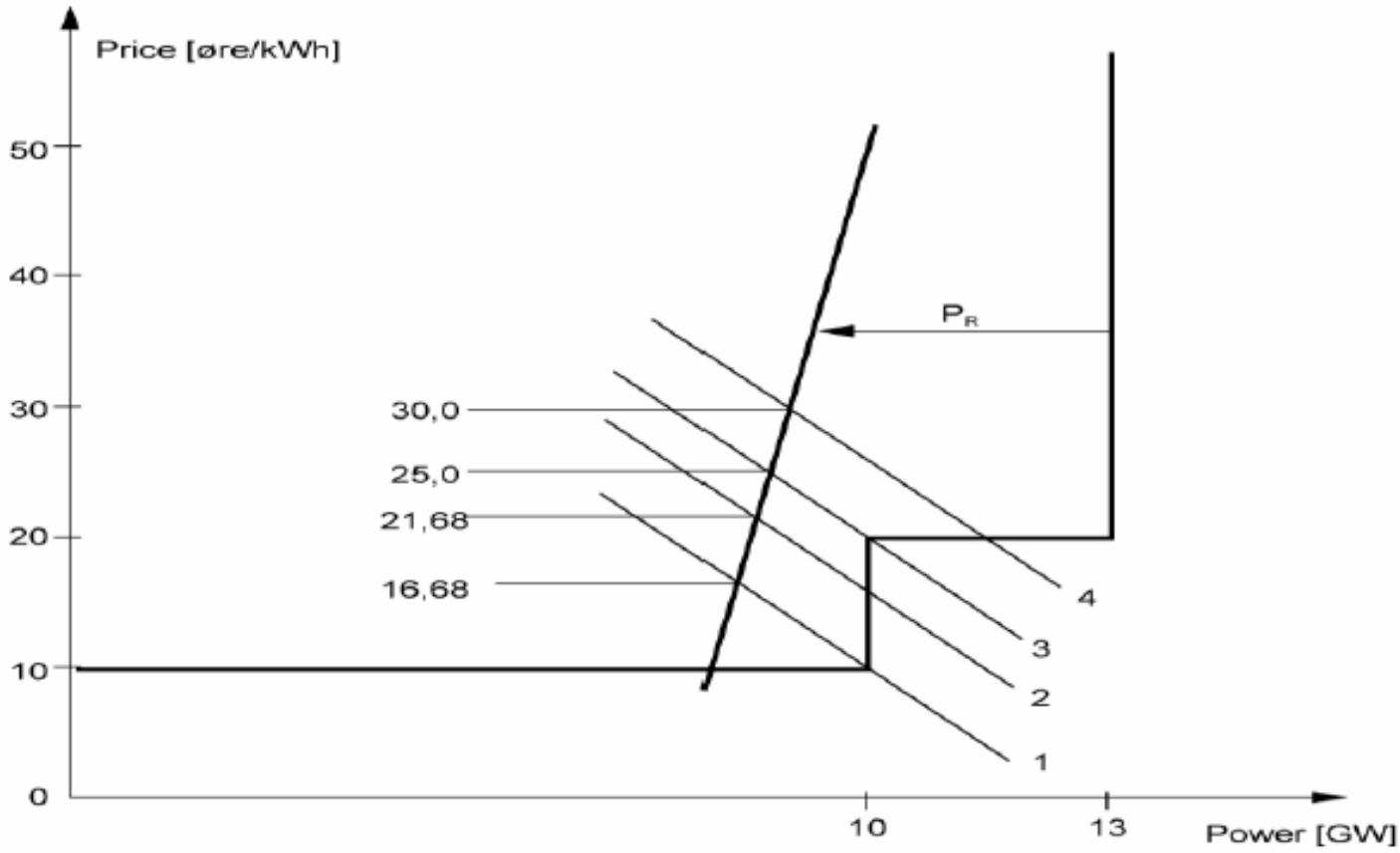
Two alternative levels for max price for balancing power:

- Low level: 2 NOK/kWh
- High level: 10 NOK/kWh (= Value of Lost Load, VLL)

ROM prices for given reserve requirements

	3 GW reserve requirement		4 GW reserve requirement	
	$p_{RegMax} = 2$	$p_{RegMax} = 10$	$p_{RegMax} = 2$	$p_{RegMax} = 10$
Demand level 1	0	0	0	0
Demand level 2	0	0	482	0
Demand level 3	0	0	805	0
Demand level 4	0	0	1297	0

Flexible reserve requirement



Given capacity, flexible (optimal) reserve requirement. Balance between expected revenue in the Spot Market or the Reserve Option Market (ROM) and marginal benefit of more reserves:

Spot Market:

Revenue = Capacity · (spot price – marginal cost)

Reserve Option Market:

Revenue = Capacity ·ROM price

– Cost for holding reserves ready

+ Expected net revenue from possible activation

Marginal benefit (improved security of supply) of more reserves

Flexible (optimal) reserve requirement

	p_S (øre/kWh)	P_L (GW)	LOLP (%)	p_R (NOK/kW år)	
				p_{RegMax} = 2	p_{RegMax} =10
Demand level 1	16.67	8.33	0.667	117	0
Demand level 2	21.67	8.58	1.167	467	0
Demand level 3	25.00	8.75	1.40	1051	0
Demand level 4	30.00	9.00	2.00	1403	0

Possible investments in new capacity and flexible (optimal) reserve requirement

Balance between expected revenue in the Spot Market or the Reserve Option Market (ROM) and marginal benefit of more reserves and marginal cost of investments:

Spot Market:

Revenue = Capacity · (spot price – marginal cost)

Reserve Option Market:

Revenue = Capacity ·ROM price

– Cost for holding reserves ready

+ Expected net revenue from possible activation

Marginal benefit (improved security of supply) of more reserves

Marginal cost of investments

Flexible (optimal) reserve requirement
Investment in new (optimal) capacity with increasing load

Case	LOLP (%)	Spot price (øre/kWh)	Reserve (GW)	Active generation (GW)	Revenue (kr/kW year)	
					Base load units	Peak load units
1	0,233	15,7	4,88	8,6	500	200
2	0,233	15,7	4,88	10,1	500	200
3	0,233	15,7	4,88	11,1	500	200
4	0,233	15,7	4,88	12,6	500	200

Notice:

- The conclusions are based on a theoretical and strongly simplified model
- We assume perfectly risk neutral attitude
- We assume the system is capacity constrained the whole time
- We are excluding costs for keeping reserves ready for operation

Despite these reservations, the model gives some insight into mechanisms that are - and to an increasing extent will be - important for the prices in electricity markets.

Thank you for your attention