

# Capacity shortage

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Market based solutions for Reserve Capacity

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# Technical report

## “Capacity pricing in a free market”

### TR A6037, January 2005

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:*

$$\text{Revenue} = \text{Capacity} \cdot (\text{spot price} - \text{marginal cost})$$

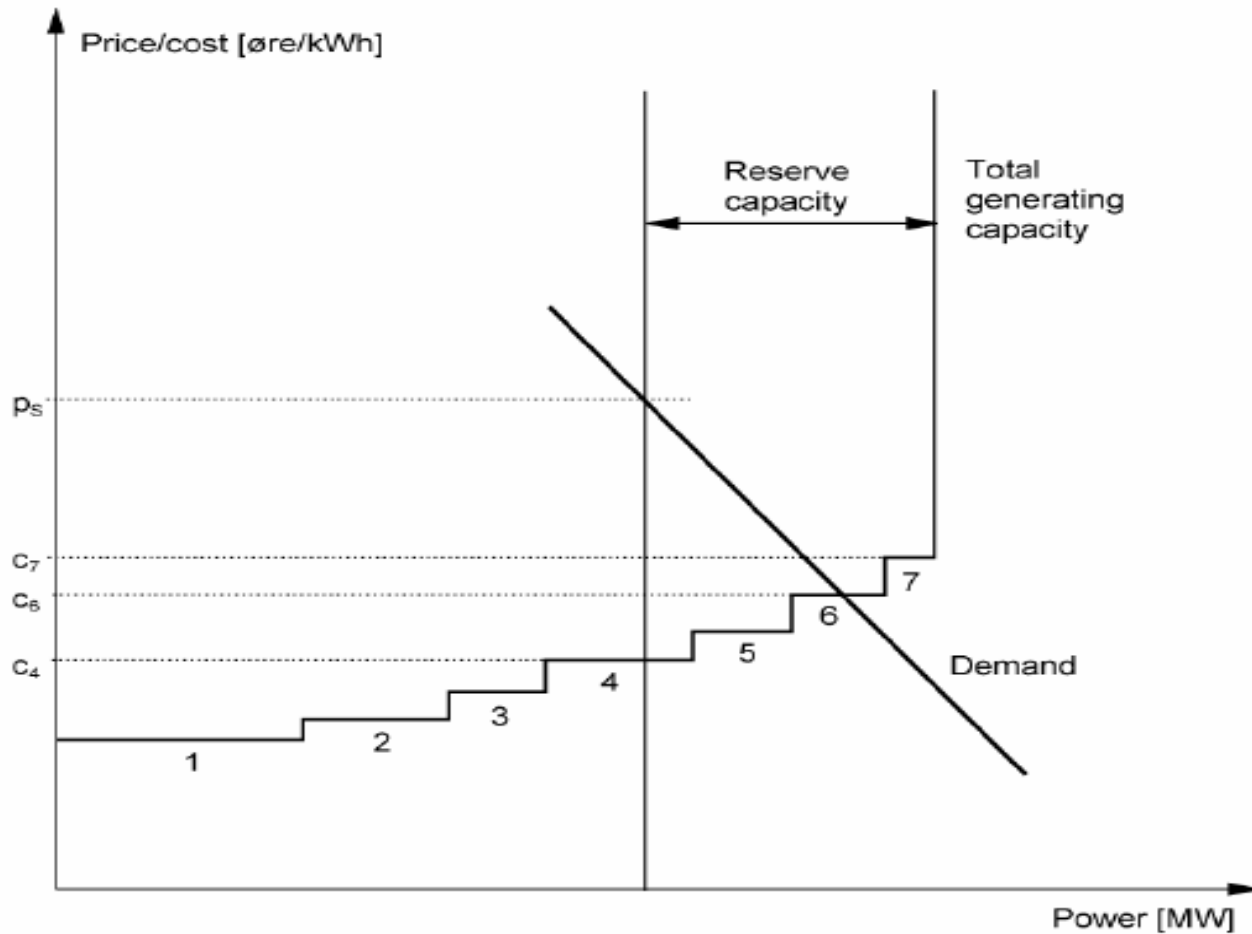
*Reserve Option Market:*

$$\text{Revenue} = \text{Capacity} \cdot \text{ROM price}$$

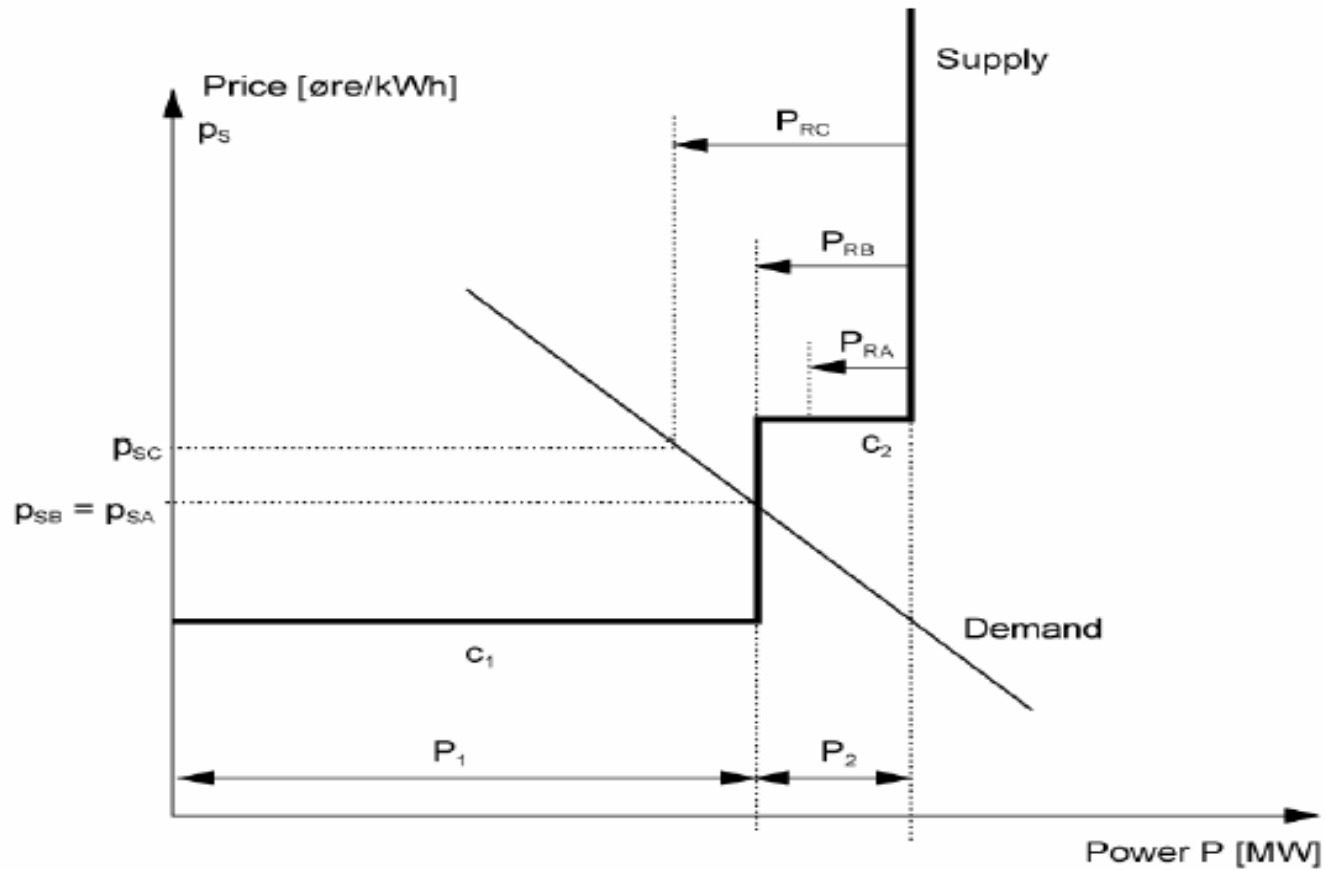
– Cost for holding reserves ready

+ Expected net revenue from possible activation

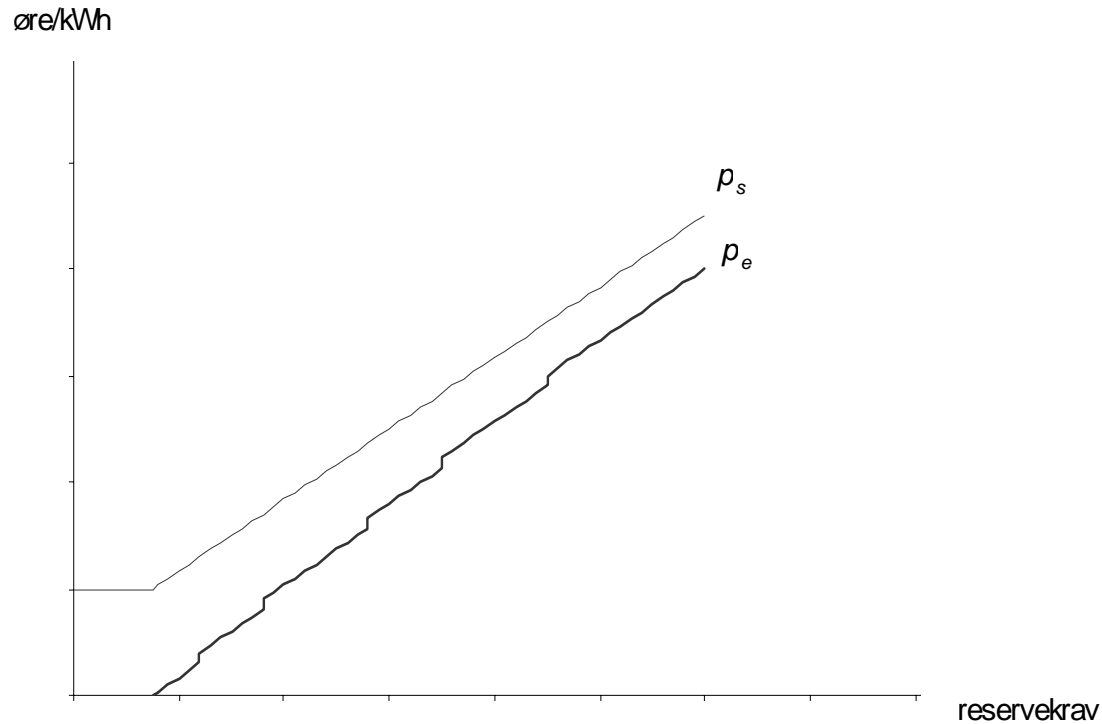
# Market balance for a given reserve capacity



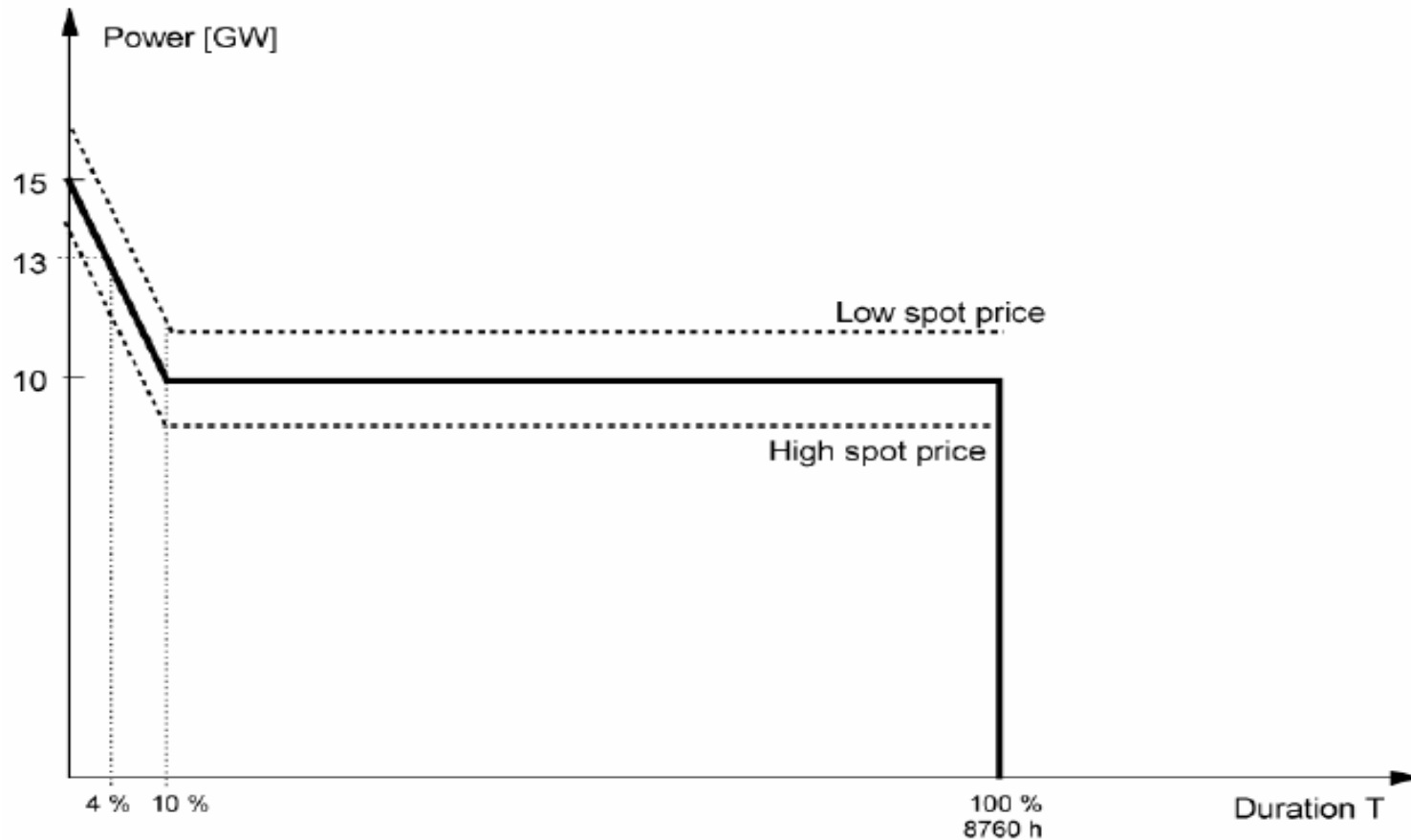
# Simplified supply curve



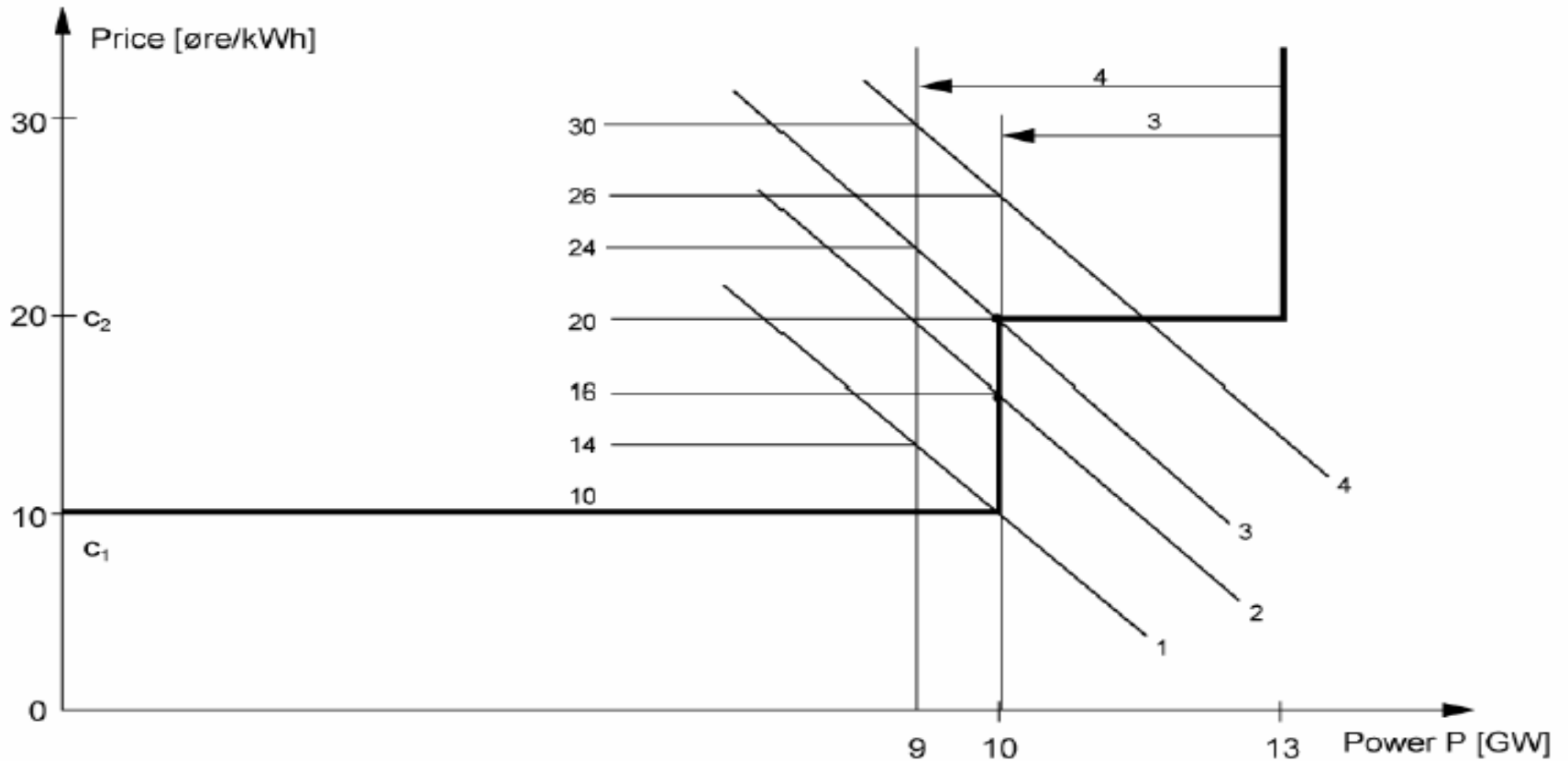
# Price development with increasing reserve requirement.



# Load duration curve



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



# Two alternative levels for max price for balancing power:

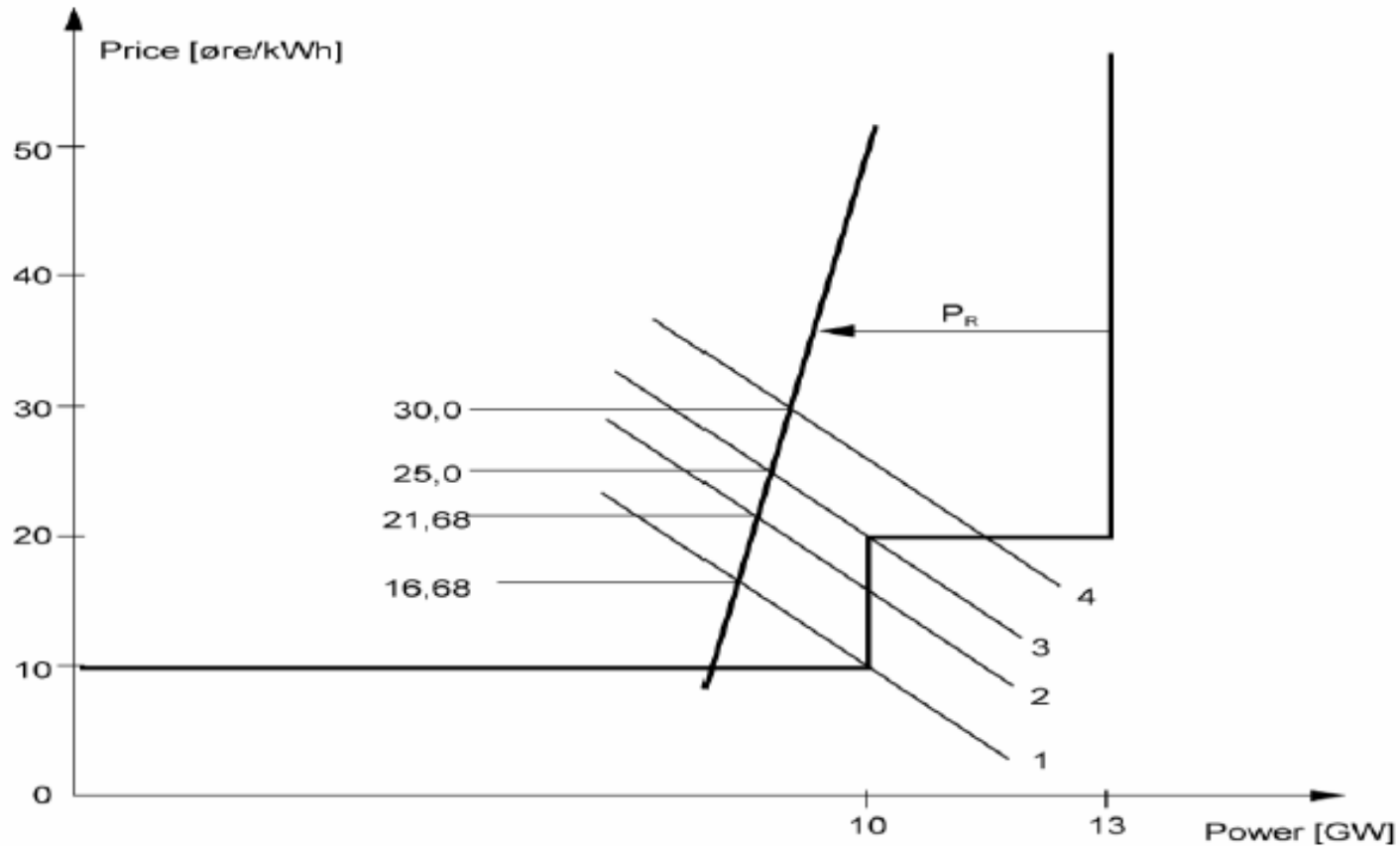
- Low level: 2 NOK/kWh
- High level: 10 NOK/kWh (= Value of Lost Load, VLL)

# ROM prices for given reserve requirements

	3 GW reserve requirement		4 GW reserve requirement	
	$p_{\text{RegMax}} = 2$	$p_{\text{RegMax}} = 10$	$p_{\text{RegMax}} = 2$	$p_{\text{RegMax}} = 10$
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:*

$$\text{Revenue} = \text{Capacity} \cdot (\text{spot price} - \text{marginal cost})$$

*Reserve Option Market:*

$$\begin{aligned} \text{Revenue} &= \text{Capacity} \cdot \text{ROM price} \\ &- \text{Cost for holding reserves ready} \\ &+ \text{Expected net revenue from possible activation} \end{aligned}$$

*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**