ELECTRICITY PRICING

Lectures 3–4
in
EG2050 System Planning

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COURSE OBJECTIVES

To pass the course, the students should show that they are able to

- perform rough estimations of electricity prices.

To receive a higher grade (A, B, C, D) the students should also show that they are able to

- identify factors that have a large importance for the electricity pricing, and to indicate how these factors affect for example producers and consumers.

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IDEAL PRICING

What price would we have in an ideal market?

- Assume a set, $\mathcal{G}$, of producers, where each producer has to decide their production, G_g.
- Assume a set, $\mathcal{C}$, of consumers, where each consumer has to decide their consumption, D_c.
- Ignore transaction costs.

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PRICE-TAKING PRODUCER

A price-taking producer has such a small market share that the market price, λ, is not affected by the choice of production level, G_g.

The profit is equal to

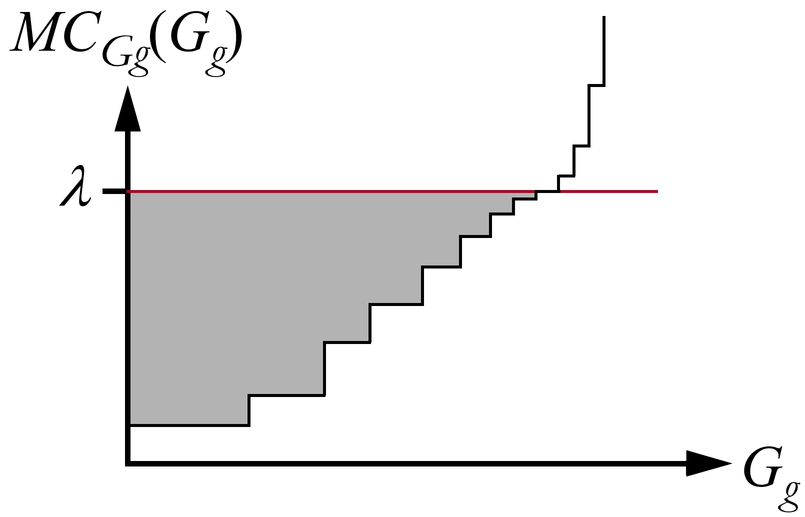
$$PS_g = \lambda \cdot G_g - C_{Gg}(G_g),$$

where

$$PS = \text{producer's surplus},$$

$$C_{Gg}(G_g) = \text{cost to produce } G_g.$$

PRICE-TAKING PRODUCER



Which production level maximises profits?

Study the marginal cost curve, i.e., the variable costs

$$MC_{Gg}(G_g) = \frac{dC_{Gg}(G_g)}{dG_g}.$$

$\Rightarrow$ Choose G_g so that $MC_{Gg}(G_g) = \lambda$.

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PRICE-TAKING CONSUMER

A price-taking consumer has such a small market share that the market price, λ, is not affected by the choice of consumption level, D_c.

The profit is equal to

$$CS_c = B_{Dc}(D_c) - \lambda \cdot D_c,$$

where

CS = consumer's surplus,

$B_{Dc}(D_c)$ = benefit of consuming D_c.

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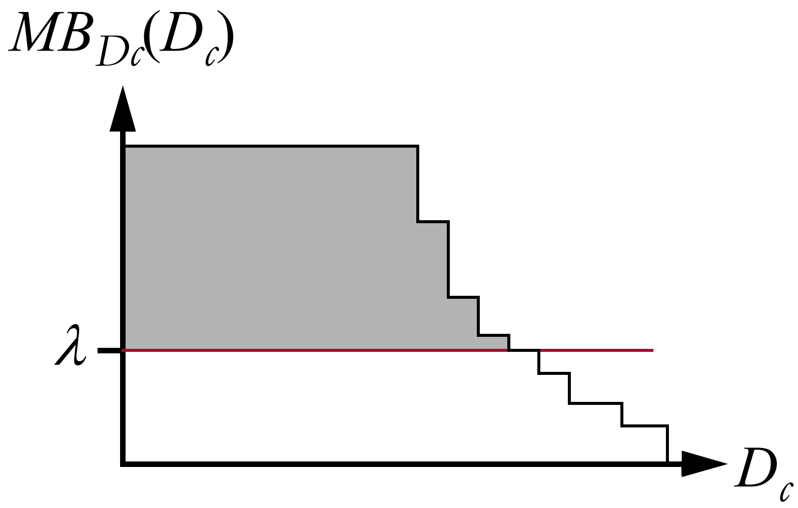
PRICE-TAKING CONSUMER

Which consumption level maximises profits?

Study the marginal benefit curve, i.e., the willingness to pay



$$MB_{Dc}(D_c) = \frac{dB_{Dc}(D_c)}{dD_c}.$$

$\Rightarrow$ Choose D_c so that $MB_{Dc}(D_c) = \lambda$.

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BENEFIT TO THE SOCIETY

- Producers will increase their production until the marginal production cost is equal to the market price.
- Consumers will increase their consumption until the marginal benefit is equal to the market price.

Is this behaviour beneficial to the society?

⇒ Study the total surplus.

TOTAL SURPLUS

Definition 1: The total surplus, TS, is given by

$$TS = \sum_{\mathcal{C}} CS_c + \sum_{\mathcal{G}} PS_g = \ldots =$$

$$= \sum_{\mathcal{C}} B_{Dc}(D_c) - \sum_{\mathcal{G}} C_{Gg}(G_g).$$

Notice! The total surplus is not a perfect measure of the benefit to the society, as it presumes that all benefits and costs can be assigned a monetary value!

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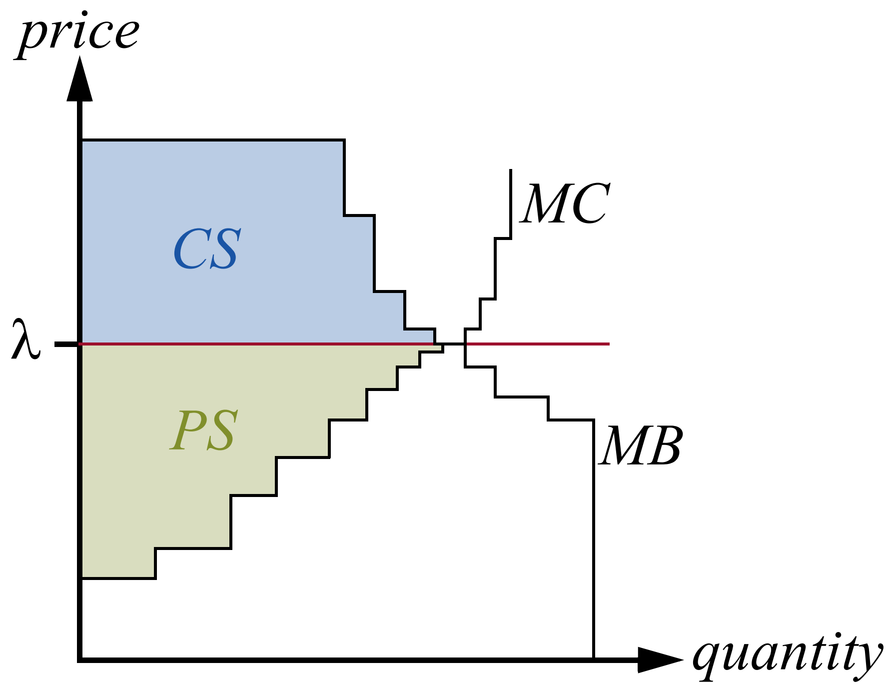
TOTAL SURPLUS



- Combine all marginal benefit functions into a demand curve, MB.
- Combine all marginal cost functions into a supply curve, MC.

The total surplus is maximised if

$$MB = MC = \lambda.$$

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MARKET PRICE

- In an ideal market (perfect competition, perfect information, etc.) there will be a market price which maximises both the total surplus and the surplus of all producers and consumers.
- The market price is set by the intersection of the supply curve and the demand curve, i.e., marginal production costs and willingness to pay.

SIMPLE PRICE MODEL

Assume

- Perfect competition
- Perfect information
- No capacity limitations
- No transmission limitations
- No reservoir limitations
- Price insensitive load

$\Rightarrow$ Mean electricity price can be estimated by studying the supply curve on an annual basis.

EXAMPLE 3.1 - Problem

- Load 75 TWh/yr.
- Coal condensing 30 TWh/yr., 160-180 SEK/MWh
- Hydro power 60 TWh/yr., 30-60 SEK/MWh

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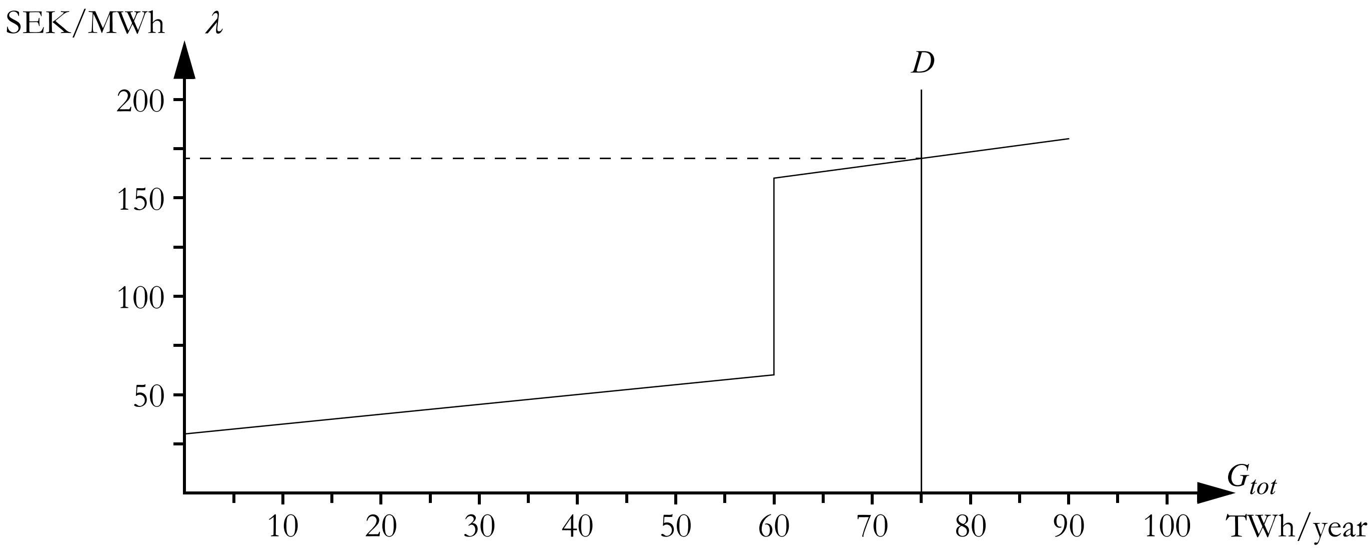
EXAMPLE 3.1 - Solution



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$\Rightarrow \lambda = 170$ SEK/MWh

EXERCISE 3.6 - Problem

3.6 Table 3.2 shows the available generation resources, marginal generation costs and annual consumption in the Nordic countries during year 2000. The operation costs are assumed to be linear within the stated intervals, i.e., if the generation is equal to zero then the price is equal to the lower value, and for maximal generation the price is equal to the higher value. Assume perfect competition, perfect information and that there are neither any capacity, transmission nor reservoir limitations. Finland imports 4 TWh from Russia, Denmark exports 5 TWh to Germany, Sweden exports 0.5 TWh to Germany as well as 0.5 TWh to Poland.

Table 3.2 Available generation resources and annual consumption.

Power source	Production capability [TWh/year]				Cost [SEK/MWh]
	Sweden	Norway	Finland	Denmark	
Hydro power	78	142	14	-	40
Wind power	0.5	0	0	4	20
Nuclear power	55	-	21.5	-	50–75
Industrial backpressure	5	-	13	2	40–100
Comb. heat and power	5	-	13	24	60–140
Coal condensing	-	-	13	24	120–140
Consumption	146	124	79	35	

a) Estimate the electricity price.

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EXERCISE 3.6 - Solution

- Total consumption in the Nordic countries:

  $146 + 124 + 79 + 35 + 2$ (net export) $= 386$.
- Assume that all hydro wind nuclear and industrial back-pressure is utilised $\Rightarrow$ Total production 335 TWh, which is not enough.
- Assume a price between 100 and 120 SEK/MWh:

$$\underbrace{\frac{\lambda - 60}{140 - 60}}_{\text{Utilised}} \cdot \underbrace{42}_{\text{Total CHP}} = \underbrace{51}_{\text{Necessary}}$$

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EXERCISE 3.6 - Solution

- Assume a price between 120 and 140 SEK/MWh:

$$\underbrace{\frac{\lambda - 60}{140 - 60} \cdot 42}_{\text{CHP}} + \underbrace{\frac{\lambda - 120}{140 - 120} \cdot 37}_{\text{Coal condensing}} = 51$$

$\Rightarrow \lambda \approx 128.21$ SEK/MWh.

Hint: Check that the resulting electricity price is within the assumed range!

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EXAMPLE 3.3 - Problem

- Load:
  - 1 January - 30 June: 35 TWh
  - 1 July - 31 December: 40 TWh
- Coal condensing 30 TWh/yr. (evenly distributed over the year), 160-180 SEK/MWh

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EXAMPLE 3.3 - Problem

- Reservoir capacity 18 TWh
- Reservoir contents:
  - 1 January: 0 TWh
  - 1 July: 18 TWh
  - 31 December: 0 TWh
- Inflow:
  - 1 January - 30 June: 50 TWh
  - 1 July - 31 December: 10 TWh

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EXAMPLE 3.3 - Solution

- First six months:
  - Hydro potential: 32 TWh. Fully utilised $\Rightarrow \lambda > 60$ SEK/MWh.
  - Coal condensing potential: 15 TWh. 20% utilised $\Rightarrow$ $\lambda = 164$ SEK/MWh.
- Last six months:
  - Hydro potential: 28 TWh. Fully utilised $\Rightarrow \lambda > 60$ SEK/MWh.
  - Coal condensing potential: 15 TWh. 80% utilised $\Rightarrow$ $\lambda = 176$ SEK/MWh.

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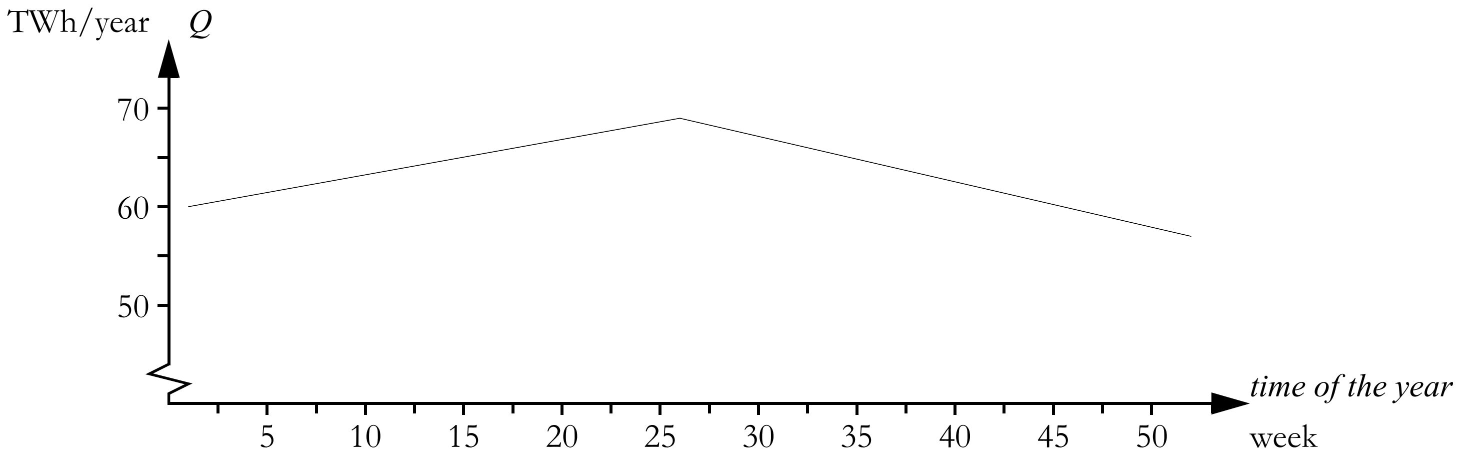
EXAMPLE 3.4 - Problem

Same system as in example 3.1, but the inflow forecast for the next 12 months varies as follows:



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EXAMPLE 3.4 - Solution

- Week 1: Same as in example 3.1
  $\Rightarrow \lambda = 170$ SEK/MWh
- Week 26:
  - Hydro potential: 69 TWh. Fully utilised $\Rightarrow \lambda > 60$ SEK/MWh.
  - Coal condensing potential: 30 TWh. 20% utilised $\Rightarrow \lambda = 164$ SEK/MWh.
- Week 52:
  - Hydro potential: 57 TWh. Fully utilised $\Rightarrow \lambda > 60$ SEK/MWh.
  - Coal condensing potential: 30 TWh. 60% utilised $\Rightarrow \lambda = 172$ SEK/MWh.

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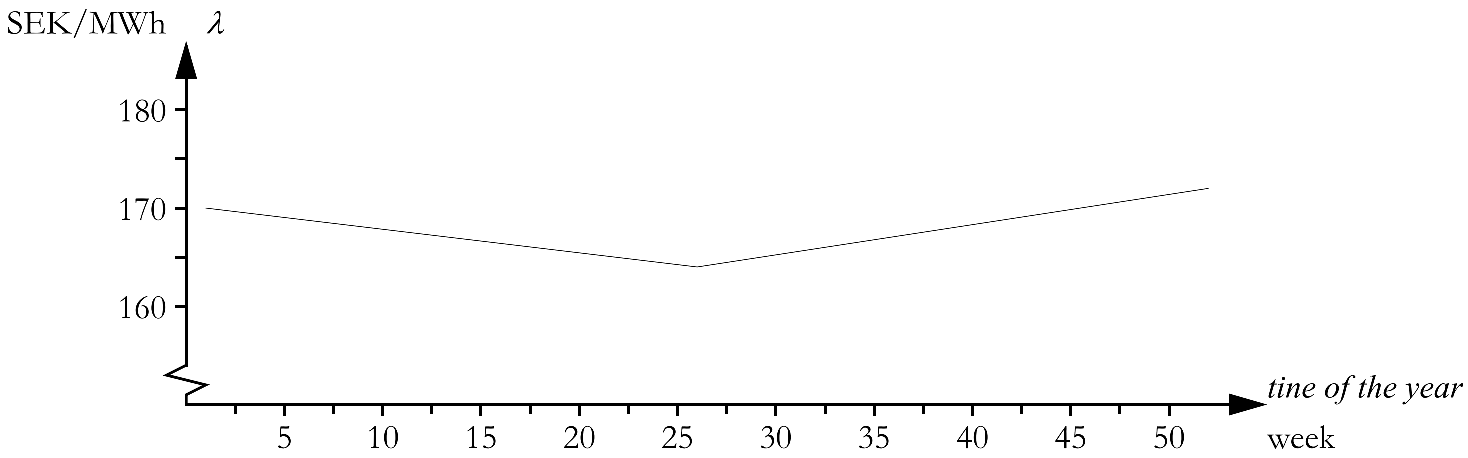
EXAMPLE 3.4 - Solution



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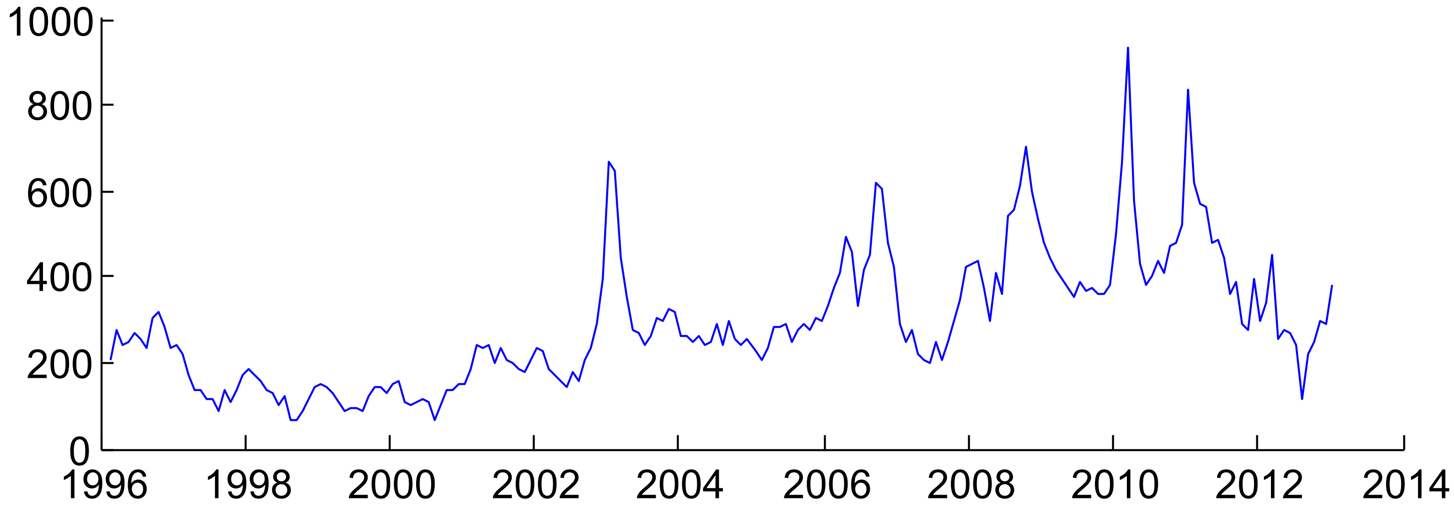
NORD POOL PRICES

Average electricity price [SEK/MWh] per month in Nord Pool price area Stockholm



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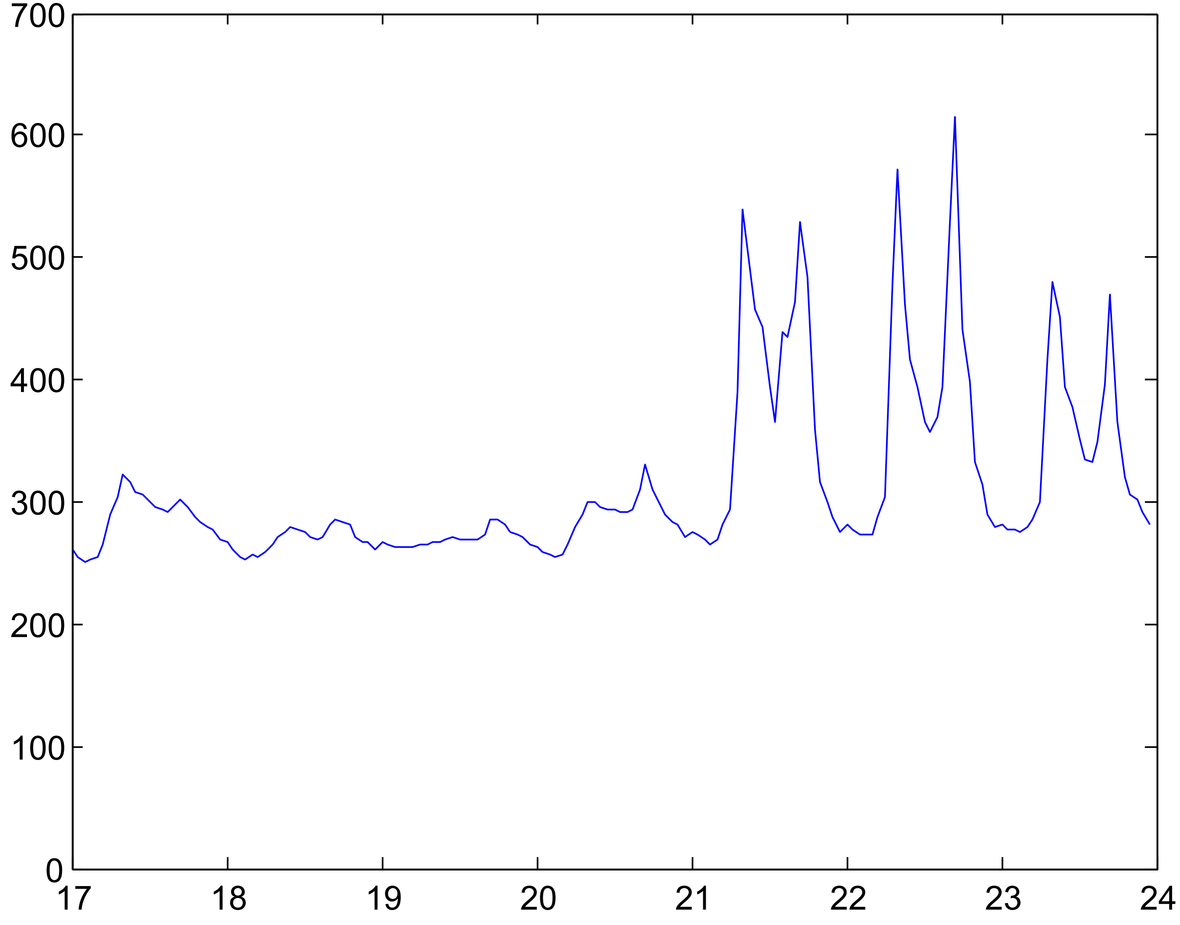
NORD POOL PRICES



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MARKET POWER

- Market power arises when a player has such a large market share that the actions of that individual player will affect the market price—the player is a price setter.
- A price setter can increase its own profits compared to the ideal market, but this will decrease the total surplus.
- It is illegal to exercise market power (but it is hard to prove that a player actually is using market power).

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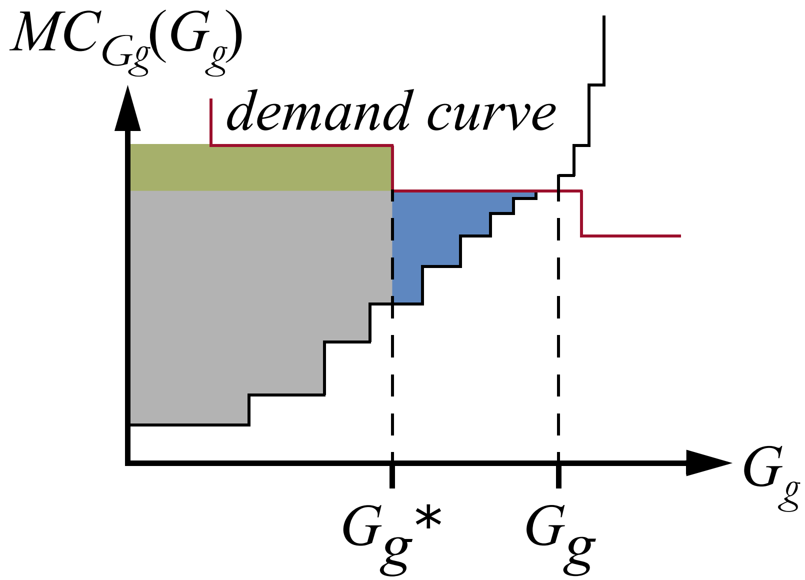
PRICE-SETTING PRODUCER

In the ideal market, the producer would choose the production level G_g, where the marginal costs of the company intersects the demand curve.

However, reducing the production to G_g* is profitable if the lost earnings (blue area) is smaller than the increased earnings (green area).



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