Electricity Market Analysis, EG2060 L3-L4

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Economic model of consumption

The cost side of consumption consists of direct costs as:

- **Investment costs** (e.g. buy a new fridge)
- **Cost of electricity**
- **Maintenance cost** (e.g. change bulbs in offices)
- **Operation cost** (e.g. persons connecting and/or disconnecting load)

Economic model of consumption

In addition to consumption costs there are

- Taxes
- Subsidies
- Grid tariffs

Economic model of consumption

The value side of consumption consists of:

- **Possibility to use** (prepared to pay to have an equipment available even if it is not used)
- **Use of equipment** (consumers are prepared to pay for electricity, but different levels depending on time of day/season etc, and time frame, since it takes some time to change behavior)

Three examples of price sensitive loads

1. Test with high prices for households in a part of Sweden
2. Questionnaire concerning disconnection of part of consumption for households in Denmark
3. Industry bidding concerning extreme situations in Sweden

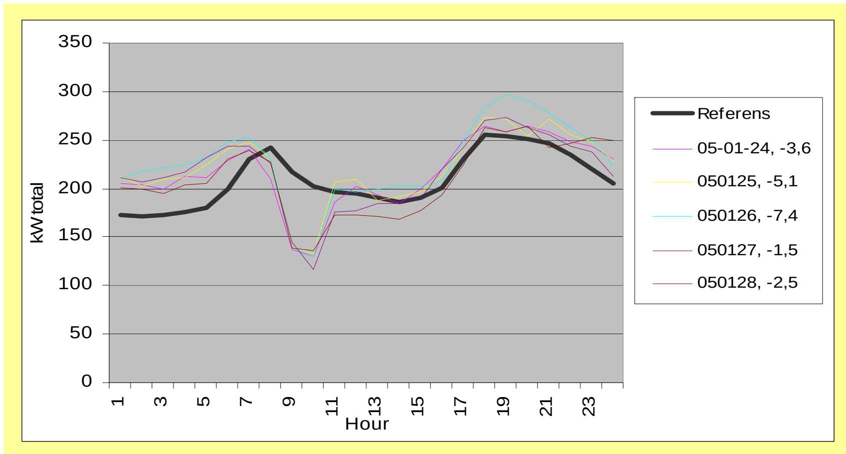
Critical peak pricing Tests with households using electrical heating

- Customers were offered lower prices for the whole year except for 40 hours with very high prices
- Customers to be alerted 1 day ahead of high prices via sms or e-mail
- No further technology was used besides hourly metering and the use of sms and e-mail
- 43 households, customers to Skånska energi participated the winter 2004 and 53 in the winter 2005. In addition 40 households, customers to Vallentuna energi participated in the winter 2005

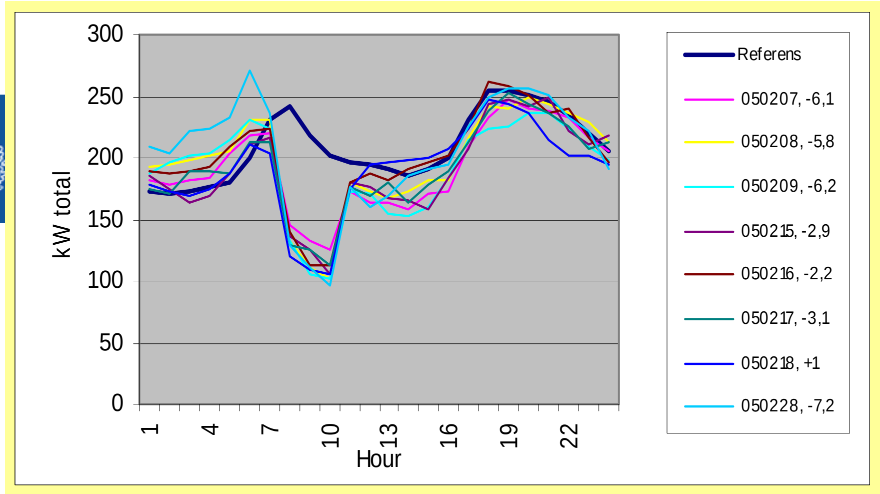
Critical peak pricing Results from test with households using electrical heating

- More than 50% of the total load was reduced during times of high prices
- No tendency of weakening results during test period
- Even customers with no substitute to electric heating shows ability for a substantial reduction
- Power reduction not significantly higher when the highest prices were alerted

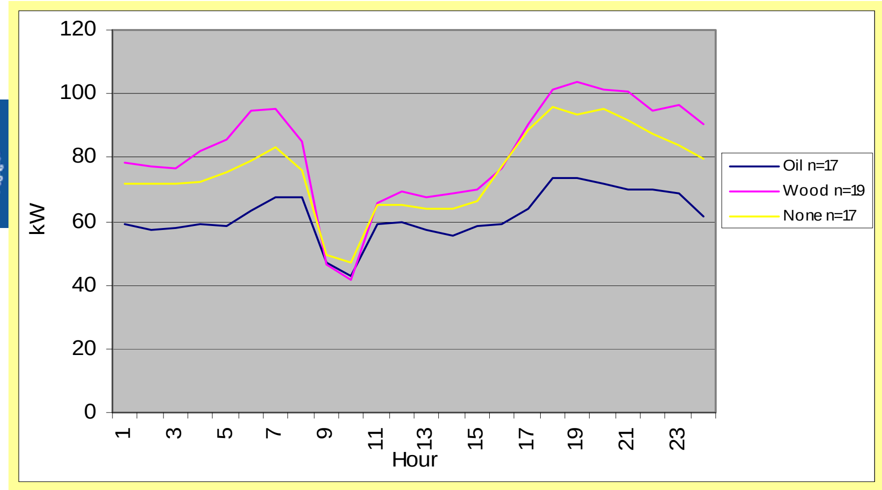
Skånska Energi - phase 1 High price 8-10, n=53



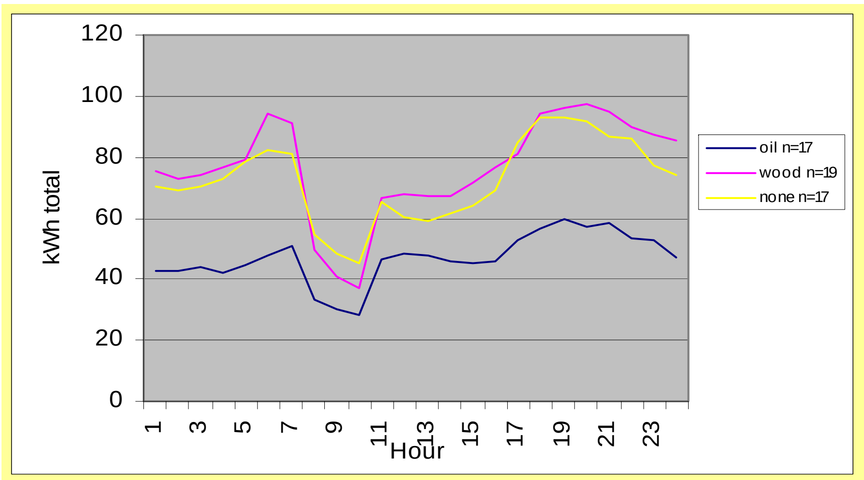
Skånska Energi – phase 2
High price 7-10, n=53



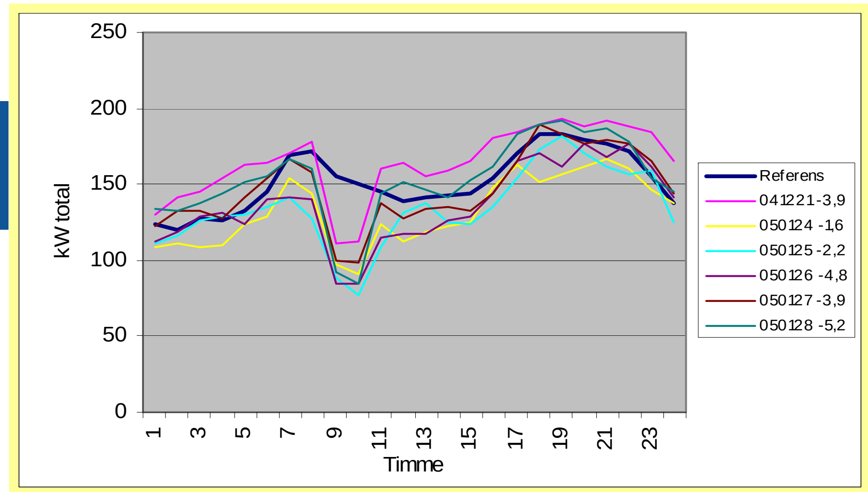
Skånska Energi - phase 1
High price 8-10, substitutes



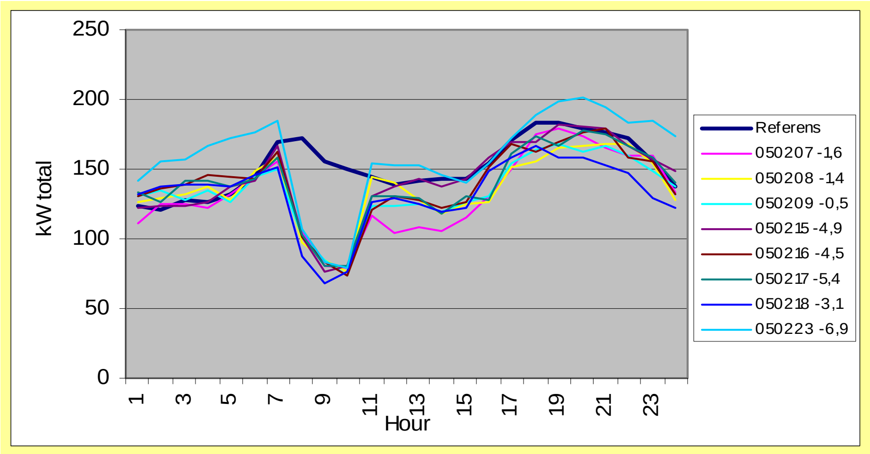
Skånska Energi - phase 2
High price 7-10, substitutes



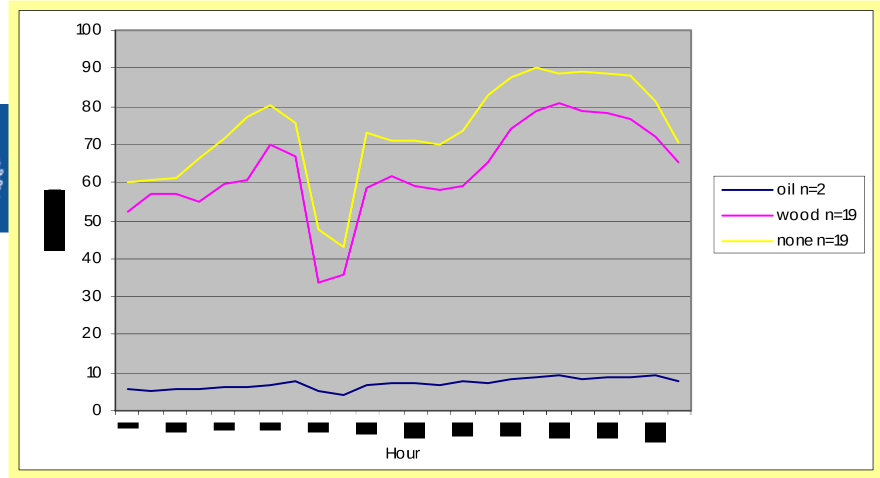
Vallentuna Energi - phase 1
High price 8-10, n=40



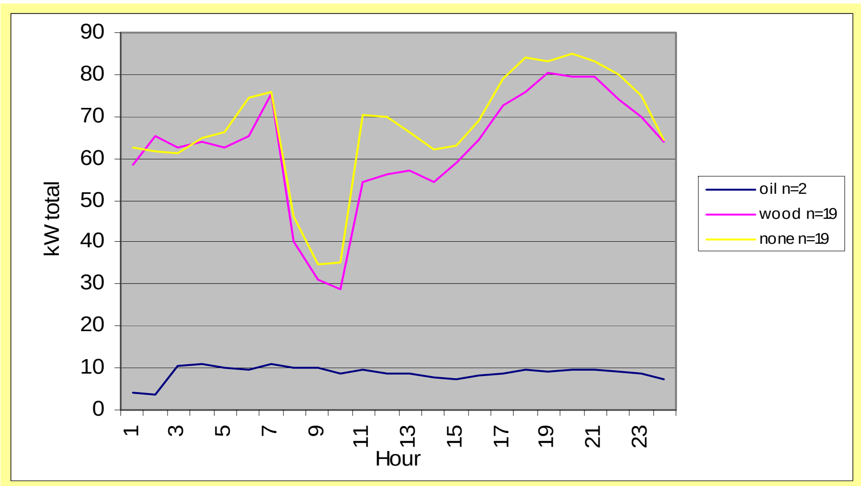
Vallentuna Energi - phase 2
High price 7-10, n=40



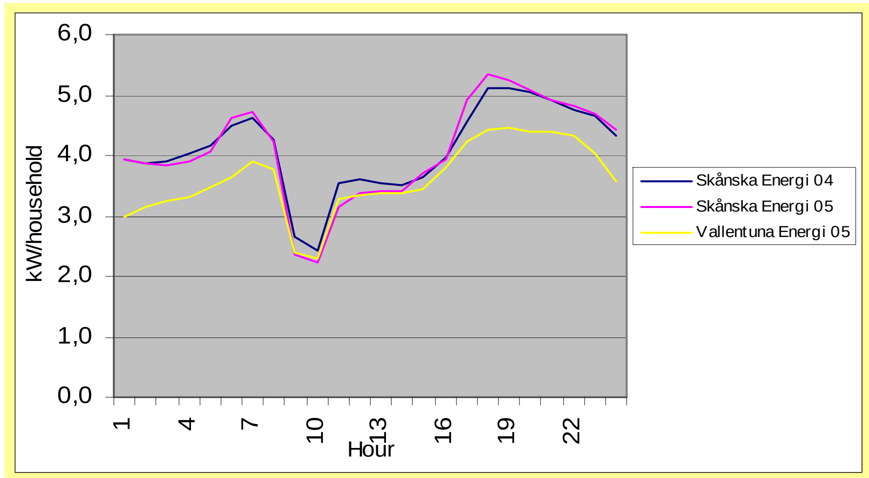
Vallentuna Energi – phase 1
High price 8-10, substitutes



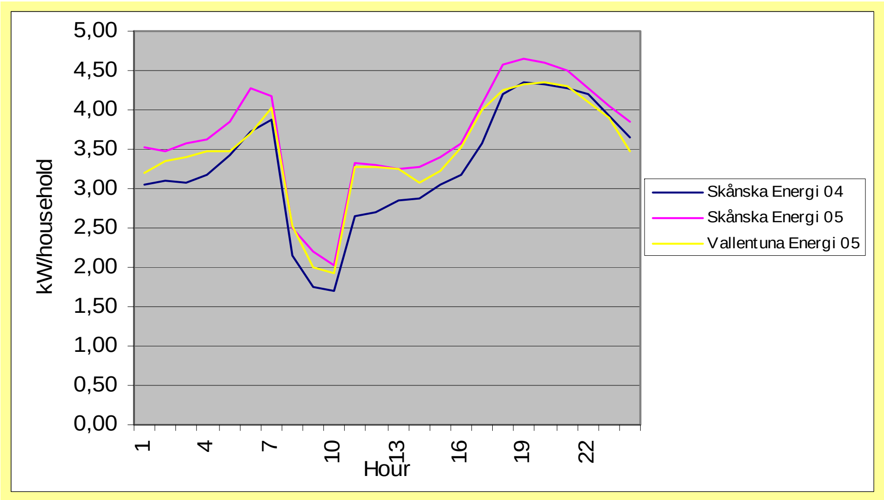
Vallentuna Energi - phase 2
High price 7-10, substitutes



Comparison Skånska energi 2004, 2005 and Vallentuna energi 2005 – Phase 1



Comparison Skånska energi 2004, 2005 and Vallentuna energi 2005 – Phase 2



Some important issues - 1

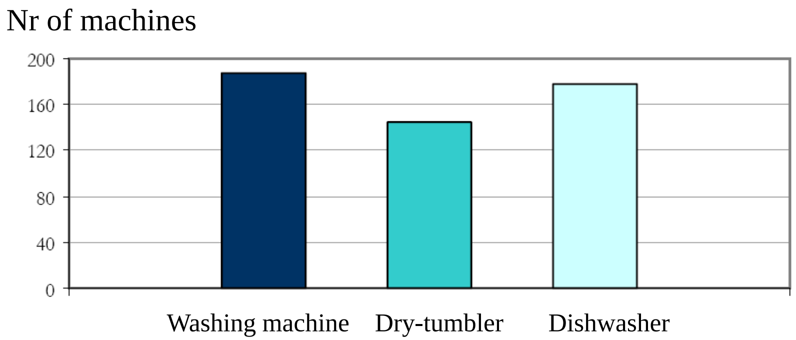
- The decrease has to be measured (in this test all participants had hourly measurements)
- The consumers must get the price (in this test all consumers got the price the day before via SMS)
- The interest to react depends on when they get the price

Consumers price sensitivity – 2 Households in Denmark

- Flexible electricity consumption has potential to become an important step towards achieving an economically efficient electricity supply. One way to obtain flexible electricity consumption is to establish agreements with private consumers regarding power-cuts during periods of peak consumption. Whether these agreements are economically efficient depends on how big a welfare loss the consumers experience during controlled power-cuts. This loss has so far not been estimated; hence the objective of this report is to indicate the level of such welfare loss.
- This rapport aims to analyze and quantify the private consumer's preferences for a number of characteristics relating to "controlled power-cuts" of washing machine, dish-washer and dry-tumbler respectively. These characteristics are decisive factors in determining loss of utility the consumer associate with the power-cuts.

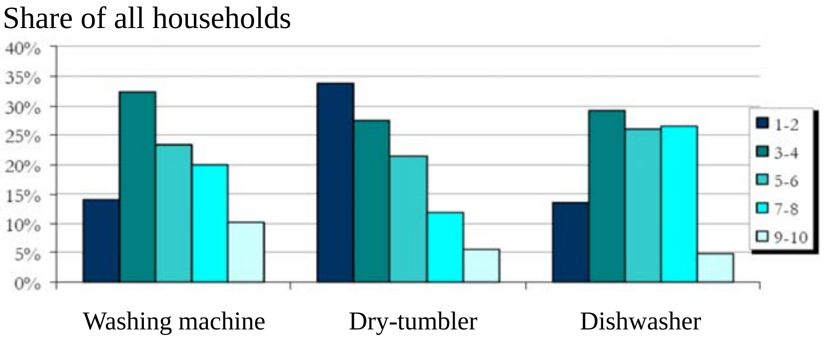
Households in Denmark

- Results of a questionnaire:



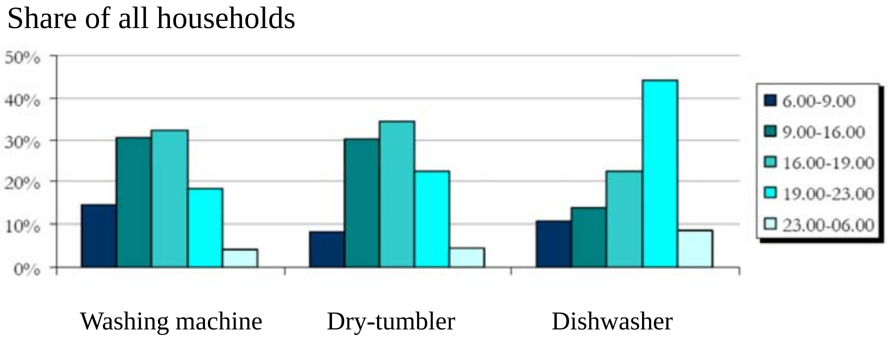
Households in Denmark

- How many times/week are they used



Households in Denmark

- At what time of the day are they used in week days



Households in Denmark

- **Results:** Needed compensation (DKK/year) for different types of contracts.

Times/year => Length	2-3 times	12 times	30 times
15 minutes	256	409	419
1 hour	334	487	497
3 hours	556	709	1120

Some important issues - 2

- The decrease has to be measured (in this test the idea was to send signals, but the result in unclear since the use is stochastic)
- The consumers must get the price (in this test the idea was to have a contract with yearly payment)
- The interest to react depends on when they get the price (here already in advance)

Reserves in Sweden 2008-09
Consumers accepted to reduce consumption

Company	MW
Stora Enso AB	90
Holmen AB	85
Befesa ScanDust AB	17
Rottneros Bruk AB	31
INEOS Sverige AB	30
Göteborg Energi AB	+ 49
TOTAL	**301**

Reserves in Sweden 2009-10
Consumers accepted to reduce consumption

Company	MW
Stora Enso AB	210
Holmen AB	215
Befesa ScanDust AB	17
Rottneros Bruk AB	23
INEOS Sverige AB	30
Göteborg Energi AB	74
AV Reserveffekt	+ 64
TOTAL	**633**

Reserves in Sweden 2010-11
Consumers accepted to reduce consumption

Company	MW
Stora Enso AB	150
Holmen AB	215
Befesa ScanDust AB	19
Rottneros Bruk AB	25
INEOS Sverige AB	30
Göteborg Energi AB	74
AV Reserveffekt	+ 70
TOTAL	**583**

Reserves in Sweden 2011-12
Consumers accepted to reduce consumption

Company	Area	MW
Stora Enso AB	3-4	210
Höganäs Sweden AB	4	25
Rottneros Bruk AB	3	27
INEOS Sverige AB	3	30
Göteborg Energi AB	3	23,5
AV Reserveffekt	3-4	+ 46
TOTAL		**362**

Reserves in Sweden 2012-13
Consumers accepted to reduce consumption

Company	**Area**	**MW**
Stora Enso AB	3-4	210
Höganäs Sweden AB	4	25
Rottneros Bruk AB	3	27
Befesa Scandust AB	4	18
Vattenfall AB	3-4	92
Göteborg Energi AB	3	25
AV Reserveffekt	3-4	+ 67
TOTAL		**464**

Reserves in Sweden 2009-10
Consumers accepted to be disconnected

Contract details:

- There is a bidding process where the cheapest offers are accepted and receives a certain fixed payment per year (in reality for the period Nov-16 to March-15). Payment is according to bid (SEK/MWh).
- The bids are since January 2009 placed on Nordpool spot. (Earlier they were placed on the regulating market where they had to be available within 10 minutes. But some bids required information up to 16 hours ahead of activation.) They are only used if all other bids are accepted.
- When bids are used they are paid according to contract, but TSO is paid according to Nordpool rules.
- At least hourly measurements are required, but shorter Δt is of interest.

Some important issues - 3

- The decrease has to be measured.
- The consumers must get the price (in this case the bids are called when the prices are competitive)
- The interest to react depends on when they get the price (in this case they are prepared)

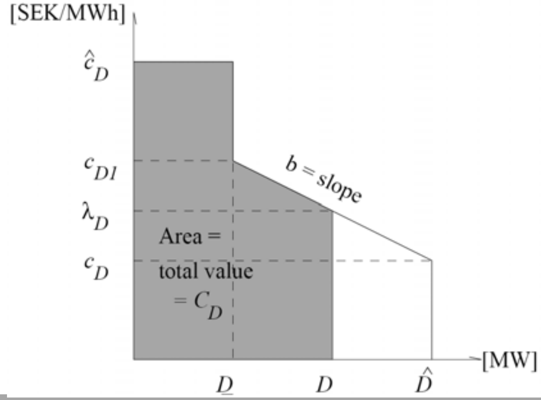
Outage costs ≠ price sensitivity
forced outage ≠ voluntary reduction

Consumer type	SEK/kW (X)	SEK/kWh (Y)
Household	2	4
Farming	10	35
Service	34	169
Minor industry	15	60
Larger industry	29	32

- Table from Sweden, 2003
- Interpreted in "Network performance model" as 70-110 SEK/kWh
- In proposition 2005/06:27 "Reliable grids": disconnections 12-24h. Household consumers: 150-300 SEK/h, industry 15-30 SEK/h.

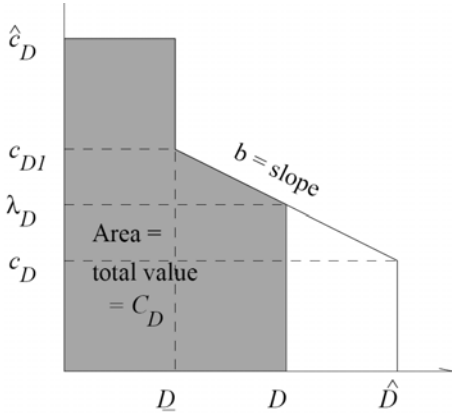
Model of consumption

- For a certain period (e.g. MWh/h)
- For a certain time frame (e.g. 12h ahead)
- Shows the consumer evaluation of certain load levels, i.e. what the consumers are prepared to pay for



Consumption value

- Consumption in interval $\underline{D} \le D \le \hat{D}$
- b = slope in [MW/SEK/MWh]
- Consumer value at demand D = area below curve:



$$\begin{aligned} C_D &= \hat{c}_D\underline{D} + (D-\underline{D})\frac{c_{D1}+\lambda_D}{2} = \\ &= \hat{c}_D\underline{D} + (D-\underline{D})\left[\frac{\hat{D}}{b} - \frac{D+\underline{D}}{2b} + c_D\right] = \\ &= k_{D0} + k_{D1}D + k_{D2}D^2 \end{aligned}$$

where

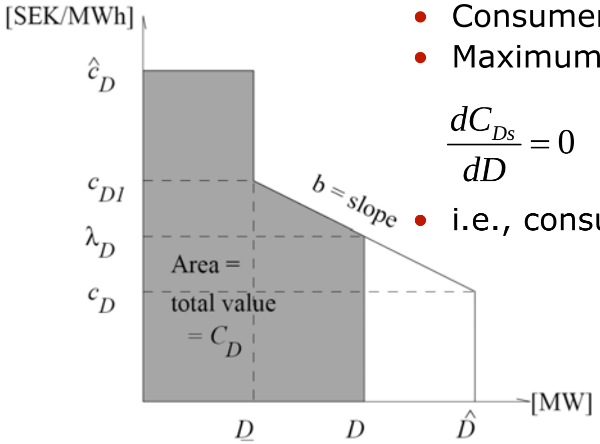
$$\begin{aligned} k_{D0} &= \underline{D}\left[\hat{c}_D - \frac{\hat{D}}{b} + \frac{\underline{D}}{2b} - c_D\right] \\ k_{D1} &= \frac{\hat{D}}{b} + c_D \\ k_{D2} &= -\frac{1}{2b} \end{aligned}$$

Consumer surplus

- λ_D = power price (SEK/MWh)
- Consumption in interval $\underline{D} \le D \le \hat{D}$
- Consumer surplus: $C_{Ds} = C_D - \lambda_D D$
- Maximum surplus:

$$\frac{dC_{Ds}}{dD} = 0 \quad \Rightarrow \quad \lambda_D = \frac{dC_D}{dD} = \frac{\hat{D}-D}{b} + c_D$$

- i.e., consume so Price = Marginal Value

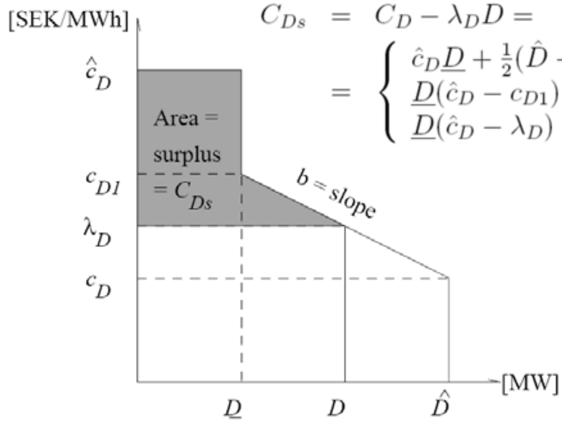


Consumer surplus at a certain price

Consumer surplus: $C_{Ds} = C_D - \lambda_D D$

$$C_{Ds} = C_D - \lambda_D D = $$

$$= \begin{cases} \hat{c}_D\underline{D} + \frac{1}{2}(\hat{D}-\underline{D})(c_D+c_{D1}) - \lambda_D\hat{D} & \lambda_D \le c_D \\ \underline{D}(\hat{c}_D - c_{D1}) + \frac{1}{2b}(D^2-\underline{D}^2) & c_D \le \lambda_D \le c_{D1} \\ \underline{D}(\hat{c}_D - \lambda_D) & c_{D1} \le \lambda_D \le \hat{c}_D \end{cases}$$



Total surplus

- The total surplus is the sum of producer surplus and consumer surplus:

$$C_{Ds} + C_{Gs} = C_D - \lambda_D D + \sum_{i \in I} (\lambda_G G_i - C_{Gi}) =$$
$$= C_D - \sum_{i \in I} C_{Gi} + \lambda \underbrace{\left(\sum_{i \in I} G_i - D \right)}_{=0 \text{ (eq. 1.17)}} = C_D - \sum_{i \in I} C_{Gi}$$

- i.e. total surplus = consumer value – producer cost

Total surplus maximization

- The total surplus is the sum of producer surplus and consumer surplus:

$$\frac{d(C_{Ds} + C_G)}{dD} = \frac{d(C_D - C_{Gtot})}{dD} = 0 \quad \Rightarrow \quad \frac{dC_D}{dD} = \frac{dC_{Gtot}}{dG_{tot}}$$

- i.e. maximal surplus is obtained when: marginal consumer value = marginal producer cost = price

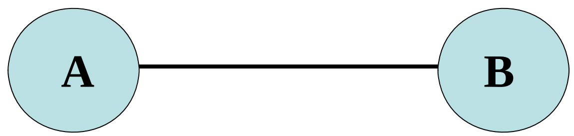
Total surplus example 1a

- D_A=300 MW, max 700 SEK/MWh
- G_A-max = 700 MW Cost 400 SEK/MWh

- D_{B1}=100 MW, max 700 SEK/MWh
- D_{B2}=100 MW, max 300 SEK/MWh
- G_B-max = 300 MW Cost 200 SEK/MWh

- G_A=300, D_A=300, G_B=200, D_B=200
- Max surplus – A: 300*(700-400)=90.000
- Max surplus – B: 100*(700-200)+100*(300-200)=60.000
- Total surplus: 150.000

Total surplus example 1b



- Higher surplus, but lower consumption!
- Low prod. in expensive unit.

- D_A=300 MW, max 700 SEK/MWh
- G_A-max = 700 MW Cost 400 SEK/MWh

- D_{B1}=100 MW, max 700 SEK/MWh
- D_{B2}=100 MW, max 300 SEK/MWh
- G_B-max = 300 MW Cost 200 SEK/MWh

- G_A=100, D_A=300, G_B=300, D_B=100
- Max surplus – A: 100(700-400)+200(700-200)=130.000
- Max surplus – B: 100(700-200)=50.000
- Total surplus: 180.000

Example 1.1

Example 1.1 *Assume that there are two power stations located in one area. The data for the power stations are shown in the table. The load is 310 MW, independent of the*

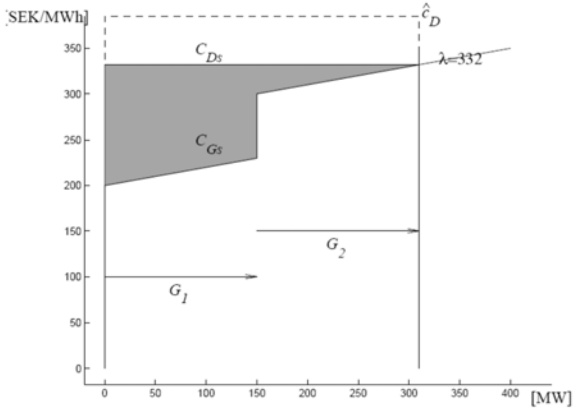
Unit	$\hat{G}_{in}$	c_{Gin}	a
i=1	150 MW	200 SEK/MWh	0,2 SEK/MWh/MW
i=2	250 MW	300 SEK/MWh	0,2 SEK/MWh/MW

Table 1.1. Data for example 1.1

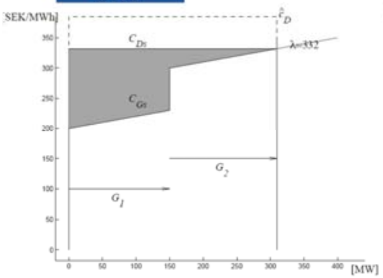
price. Calculate the price, the production in each unit per hour, and total operation cost

Example 1.1 – graphic solution

1. Draw the supply curve
2. Draw the demand curve
3. Calculate price



Example 1.1 – graphic solution



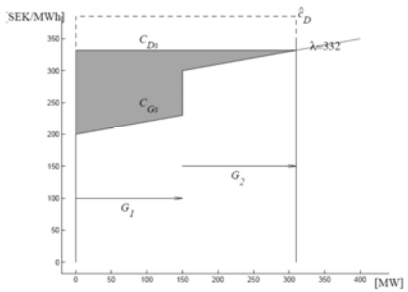
$$\lambda = c(G_2) = 300 + 0.2 \cdot 160 = 332 \quad \text{SEK/MWh}$$

$$C_{G1} = 200 \cdot 150 + \frac{0.2}{2} 150^2 = 32250 \quad \text{SEK/h}$$

$$C_{G2} = 300 \cdot 160 + \frac{0.2}{2} 160^2 = 50560 \quad \text{SEK/h}$$

$$C_{Gtot} = \sum_{i \in I} C_{Gi} = C_{G1} + C_{G2} = 82810 \quad \text{SEK/h}$$

Example 1.1 – solution using optimization



$$\max Z = C_{Ds} + C_{Gs} = D(\hat{c}_D - \lambda) + \sum_{i \in I} (\lambda G_i - C_{Gi}) =$$

$$= D\hat{c}_D - \sum_{i \in I} C_{Gi} + \lambda \underbrace{\left(\sum_{i \in I} G_i - D \right)}_{=0}$$

$$= D\hat{c}_D - \sum_{i=1}^{2} \left[c_{Gi} G_i + \frac{a_i}{2} G_i^2 \right]$$

when

$$0 \leq G_1 \leq 150$$

$$0 \leq G_2 \leq 250$$

$$G_1 + G_2 = D$$

- Optimization variables: G_1 and G_2

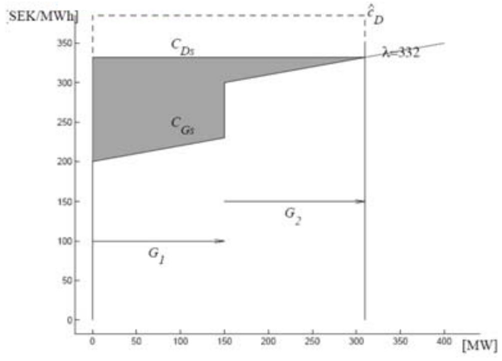
General approach

- **Graphic method** is illustrative for small examples
- In the course the requirement is to be able to make calculations with this method
- **Optimization method** is in reality required for solving larger systems with many constraints etc.
- In the course the requirement is to be able to interpret the results from this method, and to formulate them for higher grades.

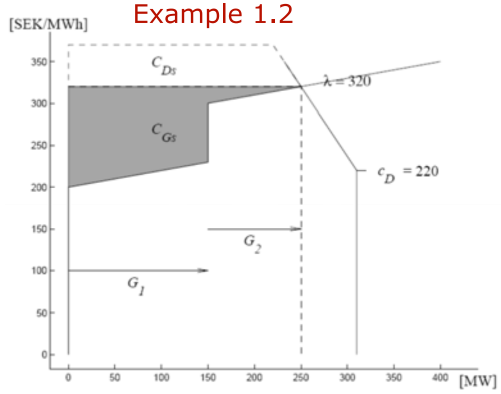
Example 1.2

Example 1.2 *Assume the same production system as above in example 1.1. The only difference here is that the load has a price sensitivity of b=0.6 when the price increases above 220 SEK/MWh. Calculate the price, the production in each unit per hour, and total operation cost.*

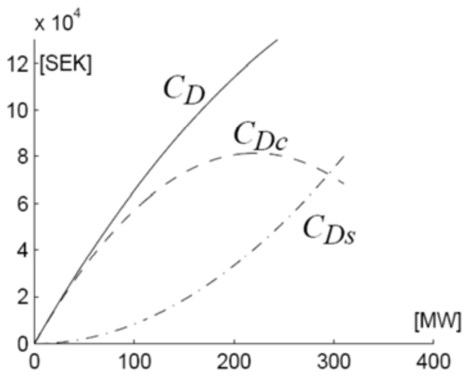
Example 1.1

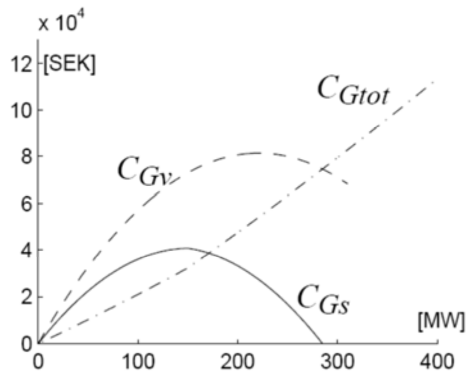


Example 1.2



Example 1.2





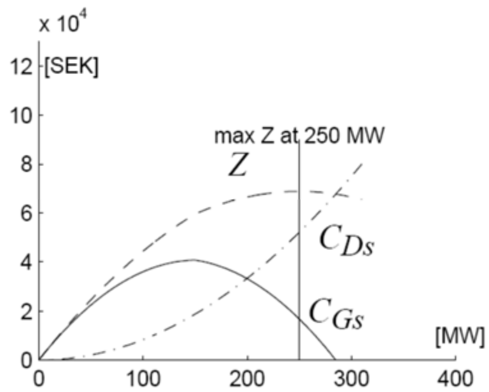
- C_D = **Consumer** value
- C_{Dc} = λD=Consumer cost (λ = price = marginal value)
- C_{Ds} = Consumer surplus

- C_{Gtot} = **Producer** cost value
- C_{Gv} = Producer revenue (price = marginal cost)
- C_{Gs} = Producer surplus

Example 1.2

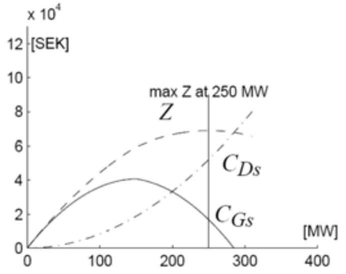
- C_{Ds} = Consumer surplus
- C_{Gs} = Producer surplus
- $Z = C_{Ds} + C_{Gs}$ = Total surplus

- Max(C_{Gs}) is not on the same load level (D) as Max(Z)!



Example 1.2

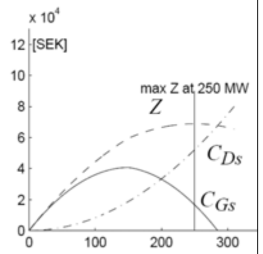
- So the question is why the producer should produce 250 MW (total maximum surplus) instead of 150 MW when this gives a lower surplus for the producer?
- There are two possible explanations:



1. **Controlled market** This implies that there are some rules for the producer that defines that they must operate the system in such a way to maximize also the benefits for the consumers. It could be, e.g., that the producers are owned by the consumers, or some regulations that the producers have to follow.

Example 1.2

- So the question is why the producer should produce 250 MW (total maximum surplus) instead of 150 MW when this gives a lower surplus for the producer?
- There are two possible explanations:



2. **Perfect competition** This assumption is based on that there are many companies with many power plants that compete on a market. Assume, e.g., that a total production (= load) of 150 MW is considered. At this level the marginal production cost and marginal consumer value are

$$\frac{dC_{Gtot}}{dC} = 300 + 0.2(150-150) = 300 \text{ SEK/MWh}$$

$$\frac{dC_D}{dC} = \left[\frac{310}{0.6} + 220\right] - \frac{2}{1.2}150 = 486 \text{ SEK/MWh}$$

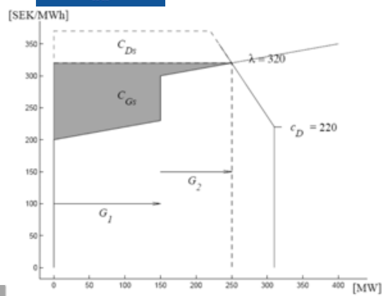
With the assumption of several producers this means that an increase of 1 MWh of production implies a possible prfit of 486-300 = 186 SEK. This means that it is profitable for a single producer to sell more, since there are consumers prepared to pay for this. This increase can go on until the marginal cost is equal to the marginal value for the consumers.

Example 1.2 – graphic solution

$$\lambda = 300 + 0.2\cdot(D-150)$$

$$\lambda = \frac{310-D}{0.6} + 220$$

$$=> \begin{cases} \lambda = 320 \text{ SEK/MWh.} \\ D = 250 \text{ MW} \end{cases}$$



$$C_{G1} = 200\cdot150 + \frac{0.2}{2}150^2 = 32250 \quad \text{SEK/h}$$

$$C_{G2} = 300\cdot100 + \frac{0.2}{2}100^2 = 31000 \quad \text{SEK/h}$$

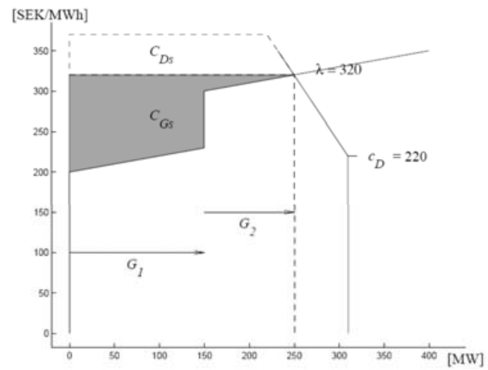
$$C_{Gtot} = \sum_{i\in I_n} C_{Gin} = C_{G1} + C_{G2} = 63250 \quad \text{SEK/h}$$

Example 1.2 – solution using optimization

$$\max Z = C_{Ds} + C_{Gs} = \left(\frac{310}{0.6} + 250\right)D - \frac{1}{2\cdot0.6}D^2 - \sum_{i=1}^{2}\left(c_{Gi}G_i + \frac{0.2}{2}G_i^2\right)$$

when

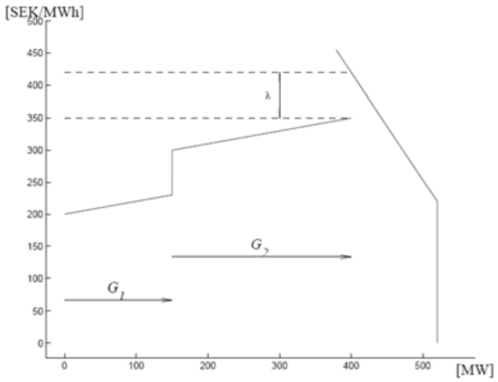
$$0 \le G_1 \le 150$$
$$0 \le G_2 \le 250$$
$$G_1 + G_2 = D$$



- Optimization variables: D, G_1 and G_2

On Capacity deficit -1

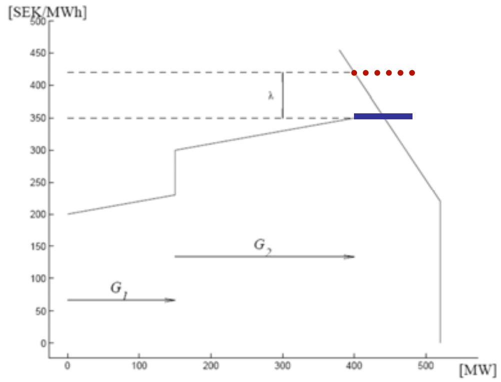
Example 1.3 *Assume the same production system as above in example 1.2. The only difference here is that the load has a base level of 420 MW. Calculate the price, the production in each unit per hour, and total operation cost.*



- There will be no price cross

On Capacity deficit -2

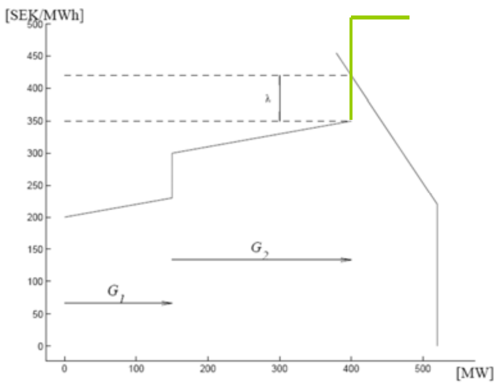
Example 1.3 *Assume the same production system as above in example 1.2. The only difference here is that the load has a base level of 420 MW. Calculate the price, the production in each unit per hour, and total operation cost.*



- There will be no price cross
- If the **consumers (…)** set the price, then it will be on their marginal value
- If the **producers** set the price, then it will be on their marginal cost
- In reality any price between these levels is possible

On Capacity deficit -3

Example 1.3 *Assume the same production system as above in example 1.2. The only difference here is that the load has a base level of 420 MW. Calculate the price, the production in each unit per hour, and total operation cost.*



- There will be no price cross
- Can be modeled as a deficit plant with extreme cost. Then the price is clearly stated as the consumer marginal value.
- The production in this plant will be zero unless the demand curve is vertical.

Assignments 3-4 - overview

- Aim of assignments:
  - Apply knowledge from lectures, each part in the lecture has corresponding questions
  - Evaluate whether a new power plant is profitable or not
  - Learn how to interpret the results from computer programs
  - Points to exam
- Performance:
  - Solutions have to be handed in individually! But cooperation is of course a good idea!
  - Individual data sheet corresponds to obtained number.
  - A computer program (Matlab) is available. This program simulate the operation of a 4-area system including several power plants, load in each area, transmission between areas etc.
  - The program can be run at KTH, e.g., in computer room, Teknikringen 33
  - Material available from http://www.kth.se/ees/utbildning/kurshemsidor/eps/EG2060/VT11-1?l=en_UK

Assignments 3-4 – data example 1

Individual data sheet nr 1

Production resources. Unit number as index.

Area	Owner	Hydro MW	Hydro storage cap. MWh	Hydro storage start MWh	Hydro inflow MWh/h	Coal MW	Bio MW	Natural gas	Gas turbine
A	O1	300_1	100	100	300	-	-	-	200_9
A	O2	-	-	-	-	-	400_5	200_7	-
B	O3	-	-	-	-	-	-	-	200_{10}
B	O4	-	-	-	-	500_3	-	200_8	-
C	O1	400_2	100	100	400	-	-	-	300_{11}
C	O2	-	-	-	-	-	500_6	-	-
D	O3	-	-	-	-	-	-	-	400_{12}
D	O4	-	-	-	-	600_4	-	-	-
Fuel SEK/MWh		180 (value end period 2)				200	300	400	800
[a] Cost incr. [SEK/MWh]/MW		0.1				0.1	0.1	0.1	0.1
Fixed cost SEK/h,MW		100				90	70	60	35
Emission kgCO_2/MWh		0				1000	0	440	700

Assignments 3-4 – data example 2

Transmission lines. Line number as index.

Line nr	from	to	Capacity [MW]	X [Ω]
1	A	B	50	10
2	A	C	-	-
3	A	D	60	10
4	B	C	70	10
5	B	D	-	-
6	C	D	80	10

Load and TSO data

Area	Load [MW]	Price sensitivity above 320 SEK/MWh [SEK/MWh,MW]	Transmission System Operator
A	500	0.2	TSO-1
B	600	0.2	TSO-1
C	700	0.2	TSO-2
D	800	0.2	TSO-2

Assignment 3-4
Simulation method: Optimization - 1

The market prices, production- consumption- and transmission- level are obtained by solving the following optimization problem:

$$Max\ z = \sum_{area\ n=1}^{4} \left\{ \left[\frac{\hat{D}(n)}{b(n)} + c_D(n) \right] \cdot D(n) - \frac{1}{2b(n)} D^2(n) \right\} - \sum_{gen.\ g=1}^{nunits} \left\{ c_G(g) G(g) + \frac{a(g)}{2} G^2(n) \right\}$$

$$-0.000000001 \sum_{all\ lines} \left[P_{pos}(l) + P_{neg}(l) \right]$$

Assignment 3-4
Simulation method: Optimization - 2

considering

$$for\ all\ areas = n : P_{net}(n) = \Big[\sum_{g \in [area\ n]} G(g) \Big] - D(n)$$

$$for\ all\ areas = n : P_{net}(n) = \sum_{l \in [linefrom(l)=n]} \left[P_{pos}(l) - P_{neg}(l) \right] - \sum_{l \in [lineto(l)=n]} \left[P_{pos}(l) - P_{neg}(l) \right]$$

$$for\ all\ generators = g : \quad 0 \le G(g) \le G_{\max}(g)$$

$$for\ all\ lines = l : \quad 0 \le P_{pos}(l) \le P_{\max}(l), \qquad 0 \le P_{neg}(l) \le P_{\max}(l)$$

$$for\ all\ areas = n : D(n) \le \hat{D}(n)$$

Assignment 3-4
Simulation method: Optimization - 3

It can be noted that the aim of the second row is to eliminate circulating flows, since no losses may cause this. When multiind=2, i.e. when the DC load flow method is applied for modeling transmission flows, then the following constraint also has to be included:

$$\textit{for all lines} = l: \quad P_{pos}(l) - P_{neg}(l) = \sum_{\textit{all areas}=n} M(l,n) \cdot P_{net}(n)$$

Where the matrix M is defined according to Compendium A, section 2.4.1

Assignment 3a

One price area, one period

First assume

- The consumers are not price sensitive, (except in Q2)
- There are no transmission limits,
- There are no costs for the emissions costs.

Set inflow = installed capacity for the hydro units. Remember that the impact of fixed costs is important.

Assignment 3a

Q1) Draw a figure (by hand is OK) with the supply and demand curves for the whole system including all four areas. Show the values for the price cross.

Q2) Same as Q1, but now assume that the consumers are price sensitive.

Q3) What will the system price be in your system (assume that operating cost of hydro is considered equal to the water value) based on

a. Marginal costing?

New 2010 — b. Formulate the mathematical problem which gives the requested result in Q3a

c. Mean cost pricing (for whole system) ?

Q4) Compare the answers between the two methods and explain differences and/or equalities.

Q5) Calculate the transmission between the regions (MWh) for the two different pricing methods. Explain differences and/or equalities.

Q6) Calculate the benefit (=income – total cost) for the different owners with the two pricing methods. Explain the result.

Assignment 3-4 simulation

- One simple example in MATLAB:

```
>> load data1
>> multiind=1 ;
>> transcap = 10000*ones([1,6]) ;
>> market
```

- multiind = 1 => use simple transmission limits
- This gives the generation, prices etc with (in reality) no transmission limits. Here "transcap" is changed, but all other variables can be changed in the same way.

Assignment 3-4 Data that can be changed
same as in DATAX.mat

gdata = a 4-column vector, with length=nr of units
- col-1: Installed capacity
- col-2: type: hydro-1, coal-2, bio-3, nat-gas-4, gas-turb-5
- col-3: area number (1-4)
- col-4: owner number (1-4)

fuelcost = a vector with the fuel costs for the 5 source types in [SEK/MWh]
fixedcost = a vector with the fixed costs for the 5 source types in [SEK/MWh]
emission = a vector with CO_2 emissions for the 5 source types in [kgCO2/MWh]
a1 = Incremental increase of production cost for all sources
hydrodata = Extra data for hydro system, same order as gdata, length=nr of hydro units
- col-1: unitnr
- col-2: reservoir cap in [MWh]
- col-3: start content in [MWh]
- col-4: inflow

linefrom = vector with start node of the 6 lines, Lines: AB AC AD BC BD CD
lineto = vector with end node of the 6 lines
transcap = vector with the capacity of the 6 lines
transx = vector with the reactance of the 6 lines
multiind = binary variable, [=1] => Multi Area Method, [=2] => DC Power Flow Method
multiind is not defined in data file, so it has to be defined.
cD1 = above this price in [SEK/MWh] the load is price sensitive
loaddata = load data where each row corresponds to the 4 areas
- col-1: load in MW for 2008
- col-2: another load level – not used!
- col-3: another load level – not used!
- col-4: price sensitivity coefficient b in MW/[SEK/MWh]

tso = vector with TSO number in each area.

Assignment 3-4
Output data

Output data for the MATLAB file market.m

G = generation in each generator, same numbering as gdata
P = transmission in each line
D = demand in the 4 areas
Lambda = electricity price in the 4 areas [SEK/MWh]
Gcost = operating cost for electricity in each generator (not fixed)

Internally defined data in file market.m

nunits = nr of rows in gdata, i.e., nr of units
gn = generator-area matrix: gn(g,k)=1 if unit g is in area k, gn(g,k)=0 otherwise
owner = generator-owner matrix: owner(g,k)=1 if unit g belongs to owner k.
expo = export-area matrix: expo(l,k)=1 if line l origins in area k
impo = import-area matrix: impo(l,k)=1 if line l ends in area k

Questions on demand

1. A "not price sensitive consumer" is prepared to pay 1000 SEK/kWh?
2. A "price sensitive consumer" can be disconnected without any information during the previous hour/day?
3. The "consumer surplus" at a given power price is
   - *a) higher for a consumer who is prepared to pay more?*
   - *b) independent of the price level?*
   - *c) independent on when the price is set?*

Questions on total surplus

1. "Total surplus" is the difference between consumer surplus and producer surplus?
2. "Total surplus" is the difference between consumer value and total production cost?
3. Minimization of total surplus gives as a result that price should be set according to marginal cost?
4. Prices based on marginal costs result in low consumer prices?
5. Interconnections lead to lower prices for consumers?