New market based price regulation on combined heat and power in Denmark

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Abstract

Major economic risks can become reality when local co-generation plants (L-CHP[1]) meet the full market penetration with new market based price regulation. Co-generation produces more than 50% of the national electricity consumption and half of the production is generated from L-CHP. The new price regulation is assumed to take action in 2004.

The paper will present an analysis of a market based price regulation on the L-CHP-sector. The paper will spotlight on L-CHP in district heating systems supplying heat for domestic purposes.

When smaller and medium sized CHP sell electricity they are paid an average price of 46 Euro per MWh. The return of selling electricity shall primarily cover the expenditure of buying gas for electricity production and writing off investments cost of a CHP-plant. With the framework of today it is a fact that the plants (in average) are only slightly competitive compared to individual heat production plants.

When CHP meet market conditions there is a high risk that electricity prices will be reduced significantly (prices of 20 – 30 Euro per MWh) for a longer period. Significantly reduced electricity prices will result in dramatically increased heat prices. If no action is taken there will be a potential risk that heat consumers in the smaller and medium sized cities together must pay an extra bill of 200 million Euro each year. It corresponds to an average increase of the heating bill of 300 – 500 Euro per year for an average house. This is far from acceptable. There will also be a high risk that companies with industrial CHP will permanently convert to heat only boiler and only use their CHP occasionally because CHP plants might not be cost-effective when electricity prices are low. These effects can cause a significant increase of the national CO_2 emission.

Introduction

Denmark has achieved a great deal in its energy policy through close government involvement in the energy sector. Combined heat and power production and heat networks are well developed and an extensive gas network has been developed very quickly. Energy efficiency policies have been effective and renewables, notably wind, have been developed successfully. It is a fact that there is a commitment to achieve ambitious targets for reduction of greenhouse gas emissions.

On the 1 January 2003 full access for all consumers to the electricity market was introduced and from 1 January 2004 full access to the gas market will be introduced. The overall aim is to improve security of energy supply, to protect the environment, and to promote competition in order to reduce energy costs.

In Denmark local combined heat and power plants (L-CHP) together with wind turbines and other renewable energy plants produce approximately 40 percent of the total

1. mainly supplies heating for domestic purpose (district heating in smaller cities) and industrial purpose.

Table 1. Main types of Local combined heat and power plants.

Local combined heat and power plants	District heating	Apartments and other similar buildings	Industrial and retail sector	Total
Numbers of plants	287	217	159	663
Electricity generation (GWh)	5 953	314	2 239	8 506
Percent of total capacity	70	4	26	100

Table 2. Three-Time Tariff 1. The Period of 2002 - Approved by the EU Commision.

Euro/MWh			
Low price (weekend and night)	High price (day)	Peak price (day)	Average
28	60	75	46

electricity consumption. At present the consumers are obliged to buy environmentally friendly production at state-regulated prices. Therefore the consumers are only allowed to buy approx. 60 percent at free market conditions.

State-regulated time tariffs on electricity imply that L-CHP does not operate the electricity production with respect to market prices. Occasionally there will be periods with low electricity prices where the L-CHP production will cause commercial and socio-economic losses and risk of supply security due to electric overflow.

It is the intention to abolish the obligation to purchase power from renewable energy production and from L-CHP plants. An economic model that reduces the risk on selling electricity and buying natural gas on market conditions will be proposed because it is necessary to preserve the large investment especially for L-CHP in the district-heating sector and to protect the environmental benefits achieved. It is the intention to launch the new framework by in 2004.

Present Situation for Local Cogeneration Plants

The total number of local CHP plants in Denmark is 663 with a total electricity capacity of approx. 2 GW. Local CHP can be categorised for following purposes:

- District Heating (fuel: mainly natural gas, some plants use biogas)
- Industrial (fuel: mainly natural gas)
- Small plants, for example installed in apartments for heat supply (fuel: mainly natural gas)

The total electricity production from these 663 L-CHP was 8,5 TWh (corresponding to 25 percent of the national electricity consumption), see Table 1. Far most of the L-CHP plants have been established from middle of the 90ies.

LOCAL CHP IN DISTRICT HEATING SYSTEMS

L-CHP in district heating systems constitute nearly 300 plants with a total capacity of approx. 1,3 GW. More than 200 of these plants have a capacity of less than 5 MW and the 15 largest plants produce more than 33 percent of the electricity production. 240 of the L-CHP in district heating systems use natural gas. Other L-CHPs use waste, biogas and other biofuels.

Economics

The present economic framework for L-CHP is regulated mainly by three conditions:

1. The L-CHP in district heating network and the small CHP-plants are driven as non profit corporations.
2. Electricity Act, which specifies obligations to buy electricity from CHPs and specifies the method for calculating the three time tariffs, which is based on the avoided cost principle.
3. Energy and CO_2 tax plus grant towards running costs for environmental friendly electricity generation.
4. A gas market into transition to market conditions.

Three time tariff – present situation

Today utility network companies are under the obligation to buy electricity production from L-CHPs at specific prices, principally based on the avoided cost of new utility production plants - the three time tariff. Normally the average price level of three-time tariff is higher than the average historical market price. The average price of three-time tariff is shown in Table 2.

Gas market

As in the electricity sector, liberalisation of the gas market necessitates the development of a framework for ensuring security of supply. The separation between gas grid and trade is in transition. Today the gas price is regulated by act to follow the oil price. When the gas sector is liberalised the gas price is expected to consist of a price for operating the gas transmission grid including gas capacity storing (not a part of market) and a market price for gas, which probably will follow the electricity market prices.

HEAT PRICES FOR CONSUMERS SUPPLIED FROM DISTRICT HEATING NETWORK

The typical range of annual heat prices is between 1 800 - 2 200 Euro for a typical residence supplied with heat from an individual natural gas or oil boiler. The annual average heat price for consumers connected to district heating network supplied by L-CHP is Euro in a typical residence, while the annual average heat price for the 25 percent most expensive is approx. 2 300 Euro in a typical residence.

The lowest price is typically found in older, bigger plants in larger cities. The highest price is typically found in new and small L-CHP. Table 3 shows annual heat prices for a

Table 3. Annual heat prices for a consumer connected to a district heating network supplied by L-CHP with an average annual heat consumption of approx. 18 MWh.

Average Heat Price	Lowest (Euro pr. Year)	Middle (Euro pr. Year)	Top (Euro pr. Year)
Share of plants	25 percent	50 percent	25 percent
Heat price	1 600	1 900	2 300

Table 4. Grant as a function of capacity and full load hour of operation of L-CHP.

Grant	Calculated as: Capacity * FP * (1 + a * (FT - FT_{fac}) / FT_{fac})
Fixed part (Euro/MW) (FP)	110 000
Full load factor (h) (FT_{fac})	4 000
(constant) (a)	0,7

standard consumer with an average annual heat consumption of approx. 18 MWh.

It is obvious that the heat production price of L-CHP would increase dramatically if the electricity sales price (alone) would drop to for example 200 DKK pr MWh compared with the present average sales price of 350 DKK/MWh. A significant increase in heat prices would be the result. A heat consumer supplied from L-CHP would see an average increase of approx. 4 000 DKK per year (530 Euro per year) due the fact that L-CHP are driven as non profit corporations.

Transition to Market Condition

The present situation implies some flexibility problems in the electricity market. Firstly, it will not be optimal to produce electricity when market prices are low. Secondly, there have been periods where it has been necessary to export electricity at prices close to zero, which corresponds to exporting environmental production at prices close to zero. In order to sustain the achieved environmental advantages and to protect district heating consumers (fair heat prices for district heating consumers) it is the intention to subsidize environmentally friendly production for a period.

The total imbursement for all L-CHPs (selling electricity to fixed three time tariffs – average price of 46 Euro/MWh) was approx. 400 million Euro in 2002. In addition, L-CHPs were subsidized by electricity grants of approx. 35 million Euro in 2002.

The average annual electricity price in 2002 in the same production hours was approx. 24 Euro/MWh. L-CHPs therefore risk to lose approx. 200 million annually if the electricity prices do not increase. However, when the demand for new electricity capacity increases on a long-term basis it is expected that the market electricity price will increase. On a long-term basis the investments costs in district heating network and L-CHPs will be reduced. Moreover the L-CHPs will be able to take the opportunity to operate as a power regulator in the market. Subsidies to L-CHP are therefore expected to be reduced over time.

SUBSIDY MODEL

The Danish Energy Authority has proposed a subsidy model and has analyzed the economy in L-CHPs under the different future market conditions. The main idea behind the subsidy model is ensure that the power producers act solely on market prices without disturbance from the subsidy. The model is carried out as a function of the electricity capacity and the annual operation hours. The calculation of subsidy is proposed to be based on historical information of the plants. Table 4 shows the proposed subsidy model.

Example: A L-CHP with an electricity capacity of 4 MW (supplying approx. 1 000 consumers with district heating) will acquire an annual subsidy of 517 000 Euro if the average operational full hour (FT) is 5 000 h.

Analysis of Heat Prices and emission of CO_2 under Market Conditions

To illustrate the effect of the subsidy model the present situation with the economy based on market prices can be compared with the new market subsidy scheme calculated with historic electricity prices of NordPool in 2001. It is assumed that co-generation will take place only when the market price is higher than a certain level (for example 24 Euro/MWh).

The three time tariffs gave in fact a socio economic surplus in 2001. Actually, the peak prices of the three time tariffs fitted rather well with the level of market prices. However, it seems obvious that L-CHPs generally will be able to optimise their production scheme according to the market signals. Draft calculations of the benefit by introducing market conditions show a total annual profit of approx. 10 million Euro. However, the advantages of price regulation through market signals depend very much on the level of electricity price. If the average level of market prices is quite high the profit will be small compared with the three-time tariffs and visa versa.

Based on the mentioned conditions it is possible to calculate the annual heat production costs from L-CHP plants. The results are shown in Figure 1.

Though the difference between the calculated future and the present economy is quite small for most plants, it is seen that some plants will profit and some will lose money. Figure 2 shows specific price changes in heat production costs as a function of full load-hours and the capacity of the plant. It is seen that L-CHPs with relatively few annual heat load hours and larger plants will benefit most from the capacity subsidy.

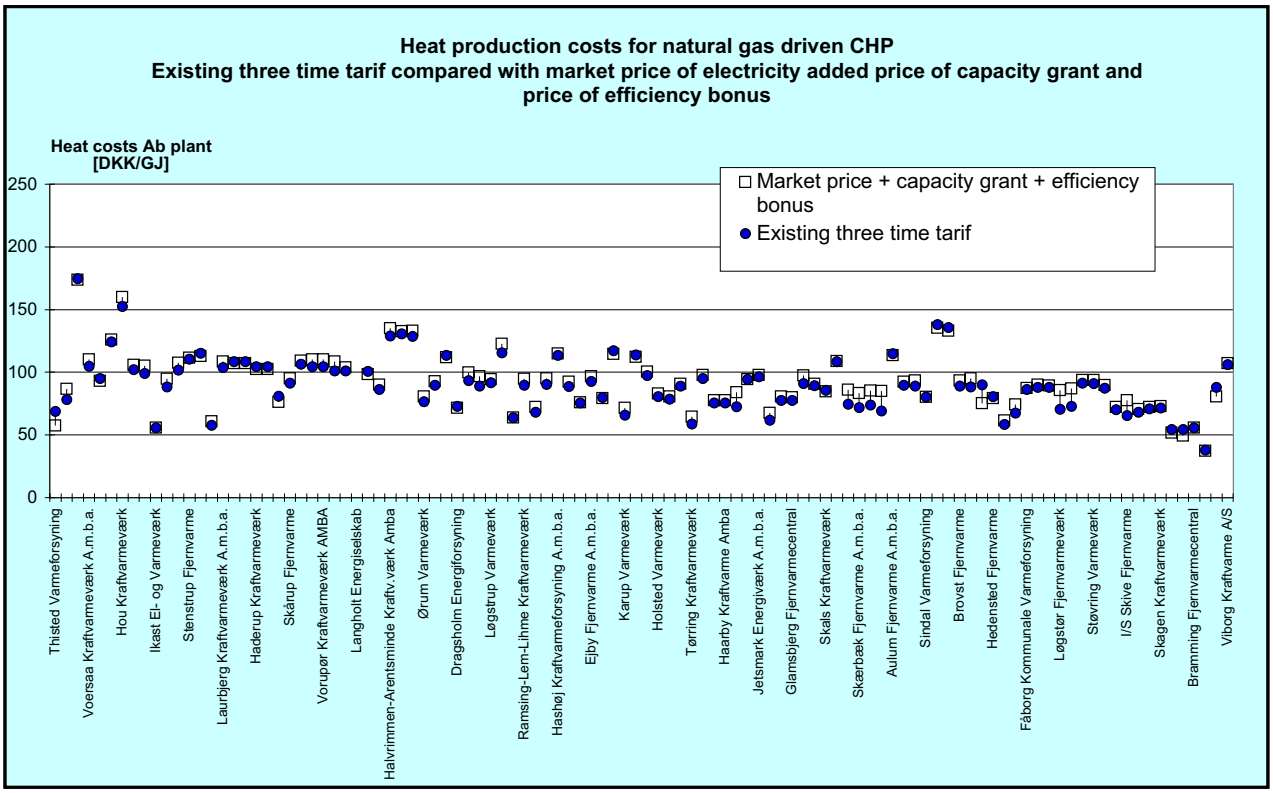

Figure 1. Heat Production price in selected L-CHPs*. The dark circle represents the present heat production price for a specific plant and the square represents the production price based on market price and the capacity subsidy. To compare the annual heat price for a consumer supplied by L-CHP an alteration of 10 DKK/GJ corresponds to 100 Euro in a typical residence.*

Table 5. Production shares, income from heat and electricity sale, alteration of production prices and alteration of CO_2 emission depending of the electricity price.

Electricity production	Electricity production	Electricity production	Electricity income	Heat prod. and sale		Alteration		
Scenarios L-CHP	Three time tariff (reference) 2001 (TJ)	Market model (TJ)	Share: market compared with reference (pct)	Reference (MDKK)	Market model (MDKK)	Heat production price (MDKK)	CO2 (tons/year) /percent of national emission	Average DKK/GJ
Nordpool price2001	18 642	17 117	92%	2 100	2 000	100	-	4
Nordpool price2001 **+ 4 Euro/MWh**	18 642	18 377	99%	2 100	2 300	-65	-150 000 -0,3 percent	-3
Nordpool price2001 **- 4 Euro/MWh**	18 642	13 377	72%	2 100	1 750	300	+800 000 1,5 percent	12

However, it does seem possible to introduce a new price system that both encourages power producers to optimize their co-generation and only introduces minor influence on the total economy and the heating bill. This statement is of course very dependent on the future structure on the gas market and the specific conditions on the L-CHP plants.

The annual production of L-CHP depends much on the variation in price of electricity and natural gas. In the calculation the gas price has been assumed not to fluctuate depending of neither the electricity price nor the amount of operation hours of the L-CHP. When the gas sector is liberalised the gas price is expected to consist of a price for operating the gas transmission grid including gas capacity storing (not a part of market) and a market price for gas. It may be expected that the unit price (Euro/Nm^3) for operating the gas transmission grid inclusive gas capacity storing will strongly depend on the annual load. If L-CHP only produces relatively few hours the unit price will be relatively high and vice versa. There may therefore be a large risk for significant low operation time if the average annual electricity price is low.

In order to illustrate the sensitiveness of the economy Table 5 shows the annual production load from L-CHP if the average level of electricity price was 4 Euro/MWh higher than in 2001 and 4 Euro/MWh lower than in 2001. It is seen that the share of heat production from L-CHP is very dependent of the electricity price. If the average level of the electricity price is 4 Euro/MWh lower than in 2001 the share of CHP production will decrease 20 percent compared with the present conditions (three time tariff). Because the heat

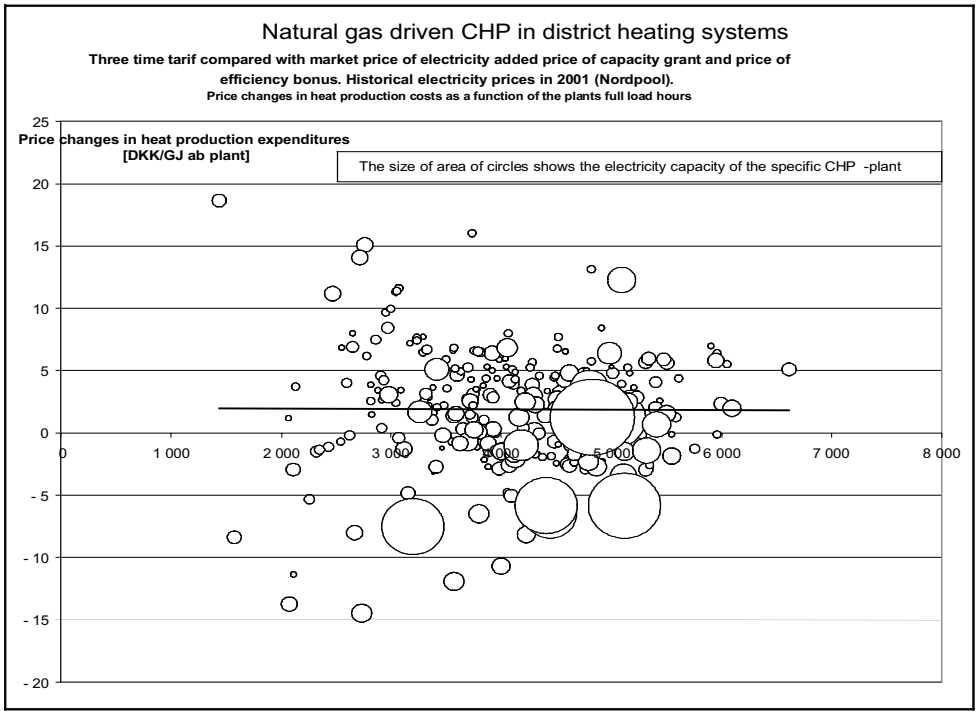

Figure 2. *Price changes in heat production costs as a function of full load hours and capacity of the plant.*

and electricity will be produced on separate plants the global CO_2 emissions will increase. The results are shown in Table 5.

Conclusion

A subsidy model for avoiding economic ruin in L-CHP has been analyzed under future market conditions. It is the idea to avoid disturbance from subsidies so electricity producers act solely on market signals.

Based on preliminary calculation it seems possible to introduce a new price system that both encourages power producers to optimise their co-generation with only minor influence on the total economy in the co-generation plants. This statement is much depending on the future structure on the gas market. There may be a large risk for significant low operation periods if the average annual electricity price is low. This might cause significantly increased CO_2 emission.

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