THE COVARIATION OF HEATING LOAD AND SOLAR ENERGY PRODUCTION WITH THE ELECTRICITY PRICE VARIATIONS IN DENMARK

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Abstract

There are large variations of the electricity price from hour to hour in Denmark. This is much dependent on the large fraction of wind power in the electric grid (already about 20% with an expansion to 40% planned). The electricity prices are very low when the wind power production is large. Simple plotting of the electricity price versus heating load and solar radiation, indicate that there can be a positive match when using electricity as a backup source in a solar combi system. The electricity is used to charge the auxiliary part of the storage, in low cost periods. This also gives a demand side management effect for the electric grid. If enough auxiliary storage capacity and smart forecast based control is introduced in the combisystem, this match can be further used to increase the utilization of renewable energy sources, in an economical way. Presently the final customer electricity prices are variable only for a few customers on trail, but it is expected to become more and more common in Denmark.

1. Introduction

Electricity cost data from the Nord Pool electricity stock exchange and climate data from the DTU Byg climate station, has been used to analyse the covariation with climate related energy flows in a solar combisystem.

It is well known that the electricity demand and therefore the electricity price, is higher during the day than during the night. The demand increases during the day when for example offices, shops, schools, hospitals and industry need electricity during working hours. This gives a positive match with available solar radiation, se examples in figure 1. Therefore Solar Photovoltaics (PV) and solar thermal systems can help to reduce the need for daytime peak load electricity production in the grid. This can be created both by injecting PV electricity into the grid and also by reducing the electric load in the grid to auxiliary electric heaters.

Perhaps not so often thought about, is that the heating load of a house also has a positive match with the electricity price. The heating load is largest in the night when the outdoor temperature is low. The house also have a minimum heating load during daytime, when solar radiation heating through the windows of the house, is largest and the outdoor temperature is highest, see figure 2.

It is also well known that the wind power production is larger in the winter period, when the heating load is larger. This should give an extra value for wind and solar energy in combination even if these sources cannot be relied upon hour by hour. By utilizing weather forecasts both for planning of the electricity production and load adaptation in the grid, the fraction of renewables can be increased without the need for extra electrical storage capacity in the grid. This paper is aiming at describing some of these relations in a more quantitative way on a local level for a house.

The covariations have been analysed for the use of low cost electricity as backup energy in a solar combisystem.

During long periods in the summer half year, the solar heating system will heat the whole tank including the auxiliary part, especially during daytime, when the electricity price is high. No electricity at all, will be used for heating and hot water during this period.

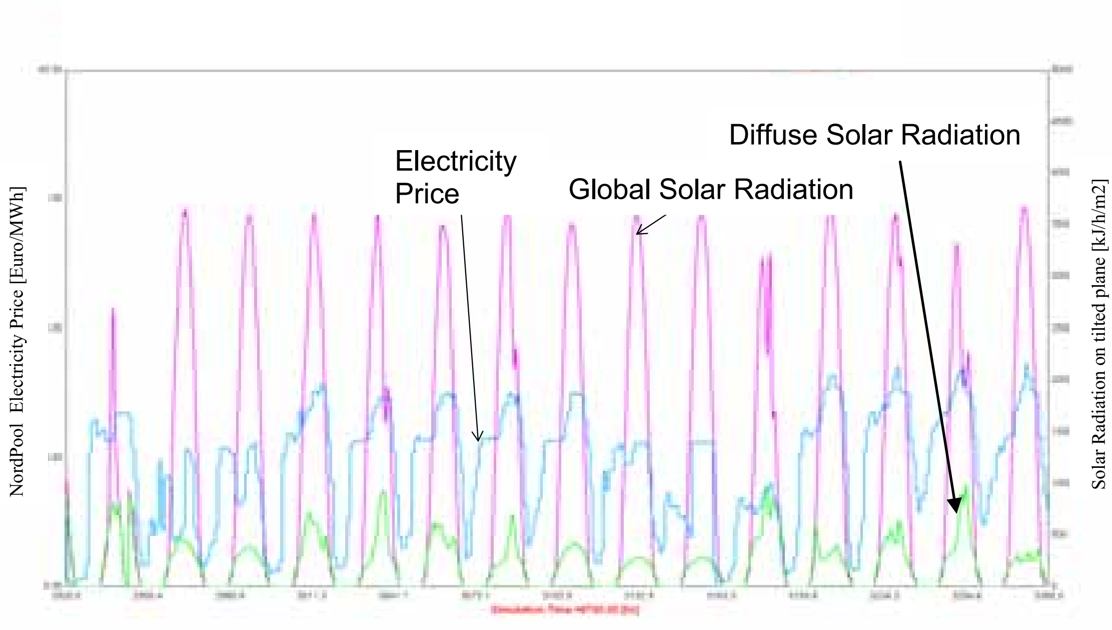

Figure 1. Covariation of electricity price and solar energy, indicating that distributed solar energy (both PV and Solar Thermal) could be used to relieve load from the grid and save energy cost for the house owner. A tendency to a weekly pattern can also be seen in the electricity prices with lower values in the weekends when the demand is lower for industry and offices.

The heating load is lower during daytime than during nights, as the ambient temperature is higher and because solar energy through windows will add to the internal free heating. At the same time the electricity prices are higher during the day. This will give a positive match when using electricity as a backup source.

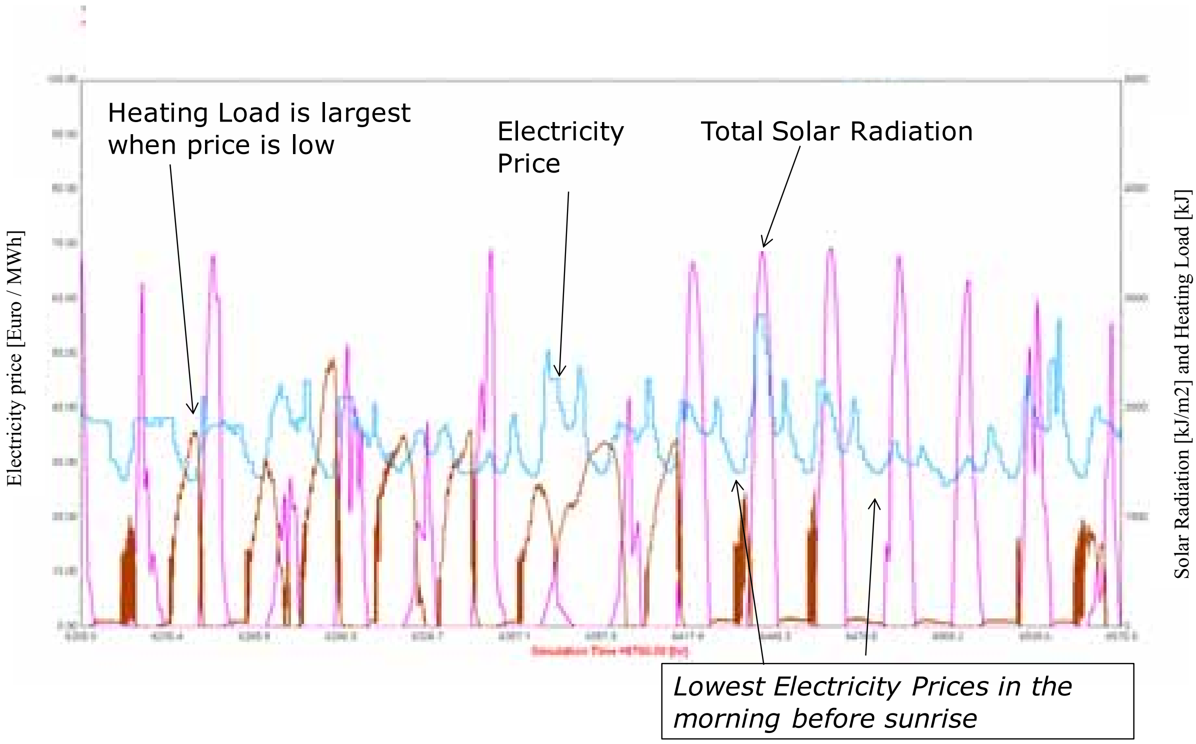

Figure 2. Heating load and electricity price for two weeks in the late winter 2008. There is a tendency to a favourable match.

In figure 3 the variation of the hourly electricity price during the day is shown for one year of data (Denmark East 2008). It can be seen that on the average (yellow line) the price is lowest in the late night/early morning and highest during mid day - afternoon. The extreme low prices occur only in the night/morning and the extreme high prices only during the day and evening.

Another way of presenting the variability is shown in figure 4 and 5 where the hourly values are plotted in time and size order (duration line). Both all year- and heating season data are shown in figure 5. It can be seen that the variability is almost independent of the season, so there is a basis for electricity cost reduction by smart system design and control during all seasons of the year.

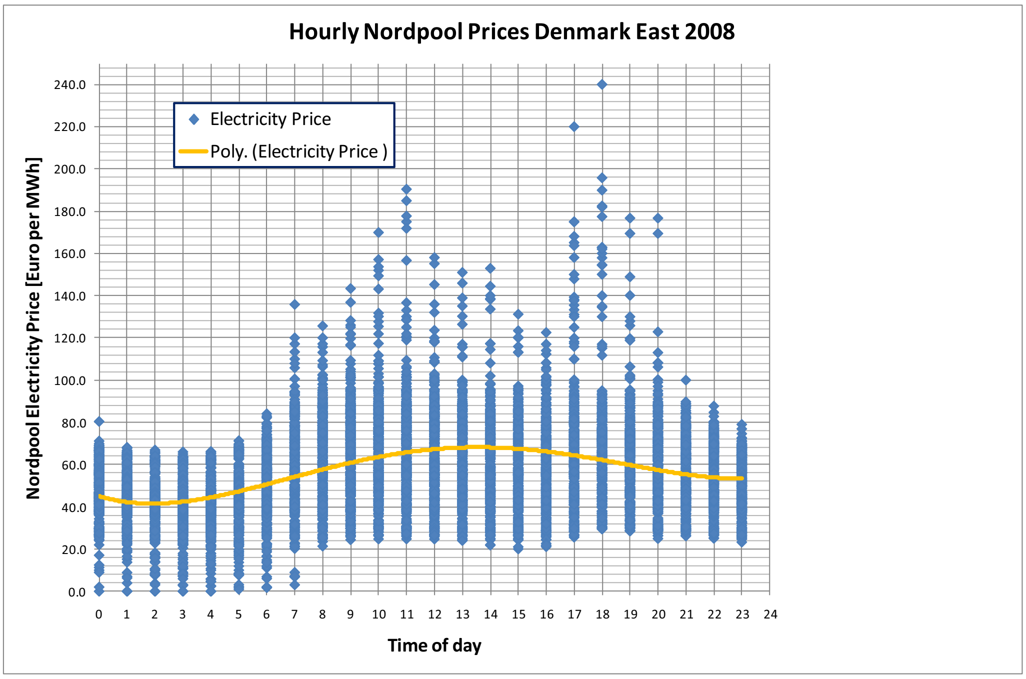

Fig 3. The variation of the hourly electricity price during the day (Denmark East 2008). It can be seen that on the average (polynomial curve) the price is lowest in the late night/early morning and highest during mid day - afternoon.

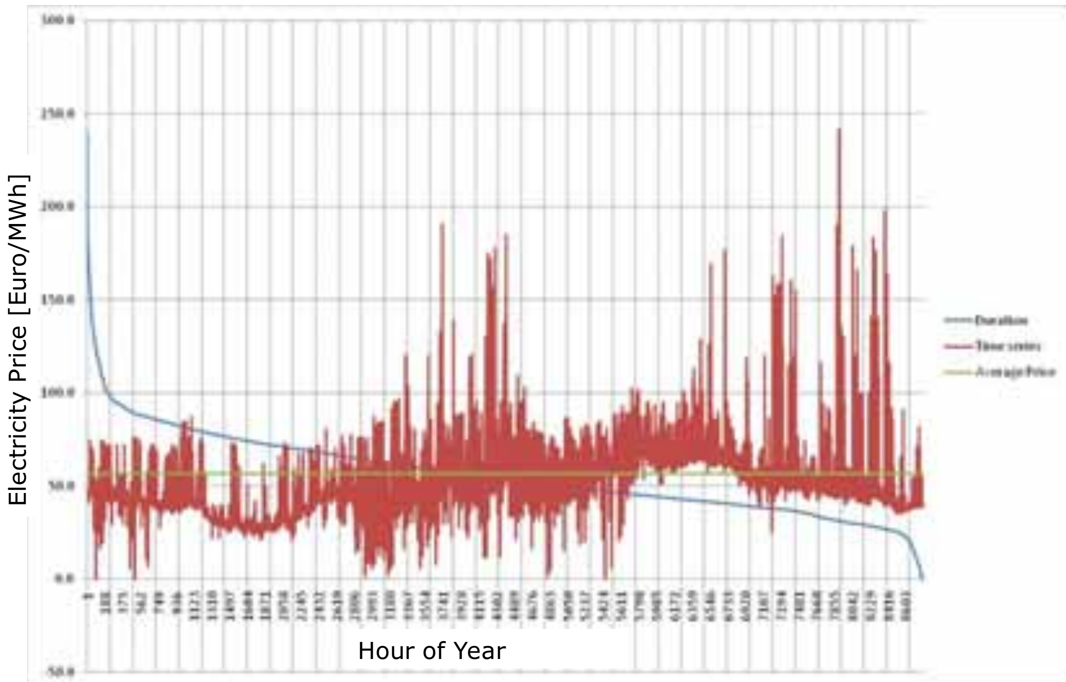

Fig 4. Electricity price variations for one year (2008 Denmark East). The horisontal line is the annual average price level. The scattered curve is the hourly prices over one full year. The duration curve is the hourly price sorted in size to give an indication of the distribution of prices over the year.

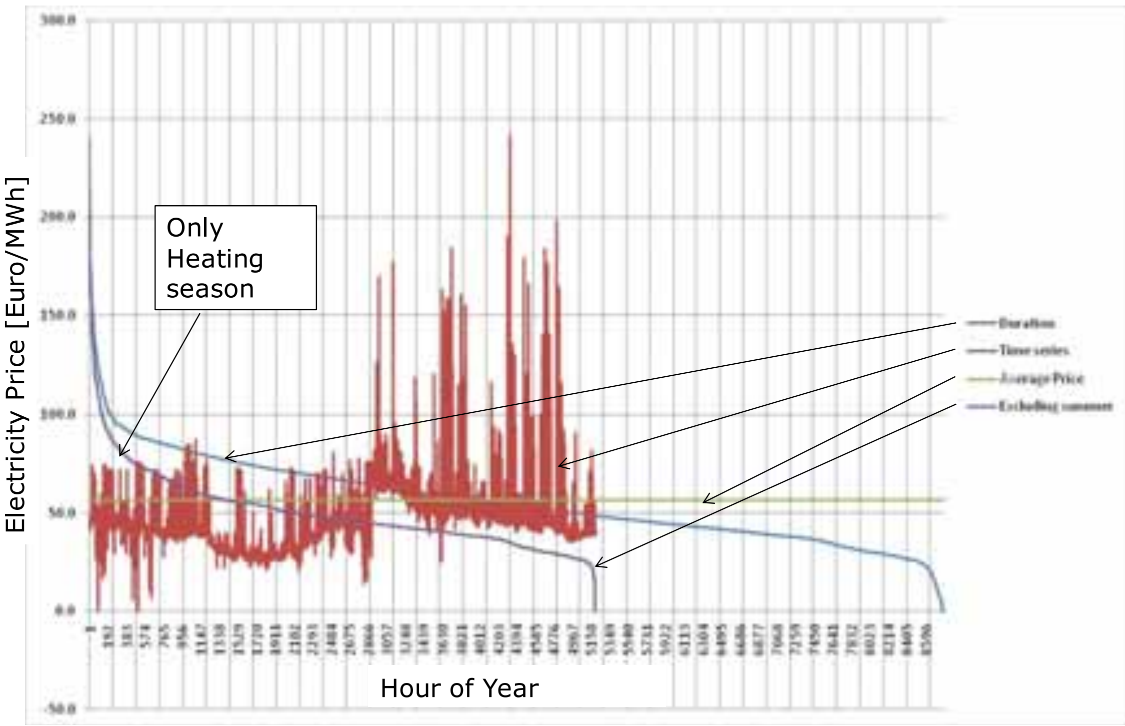

Fig 5. Electricity price variations for the *heating season* versus full year (2008 Denmark East). The horisontal line is the annual average price level. The scattered curve is the hourly prices only for the *heating season* and the upper duration curve is the hourly price sorted in size to create a distribution curve over the year. The lowest curve is the duration curve of the electricity price for the *heating season* only.

2. Results

To quantify the potential for auxiliary cost reduction in a domestic combi system by using low electricity prices and advanced control, some calculations were made with a hot water plus heating load hour by hour for one year for a single family house.

Three different price levels were used. 1) The traditional fixed price set to the annual average level. 2) The actual price every hour from Nord Pool and 3) The minimum hourly price every 24 hour as an extreme potential if the auxiliary could be charged during only one hour per day at the lowest price.

Figure 6 shows an example of results from January for a house with 200 W/K transmission plus ventilation losses and 400 W of internal heat generation from persons and appliances and 100 l/day hot water load. No solar input.

It can be seen that the option 3 always is cheapest as expected and that the variable price alternative often comes on second place in hourly cost.

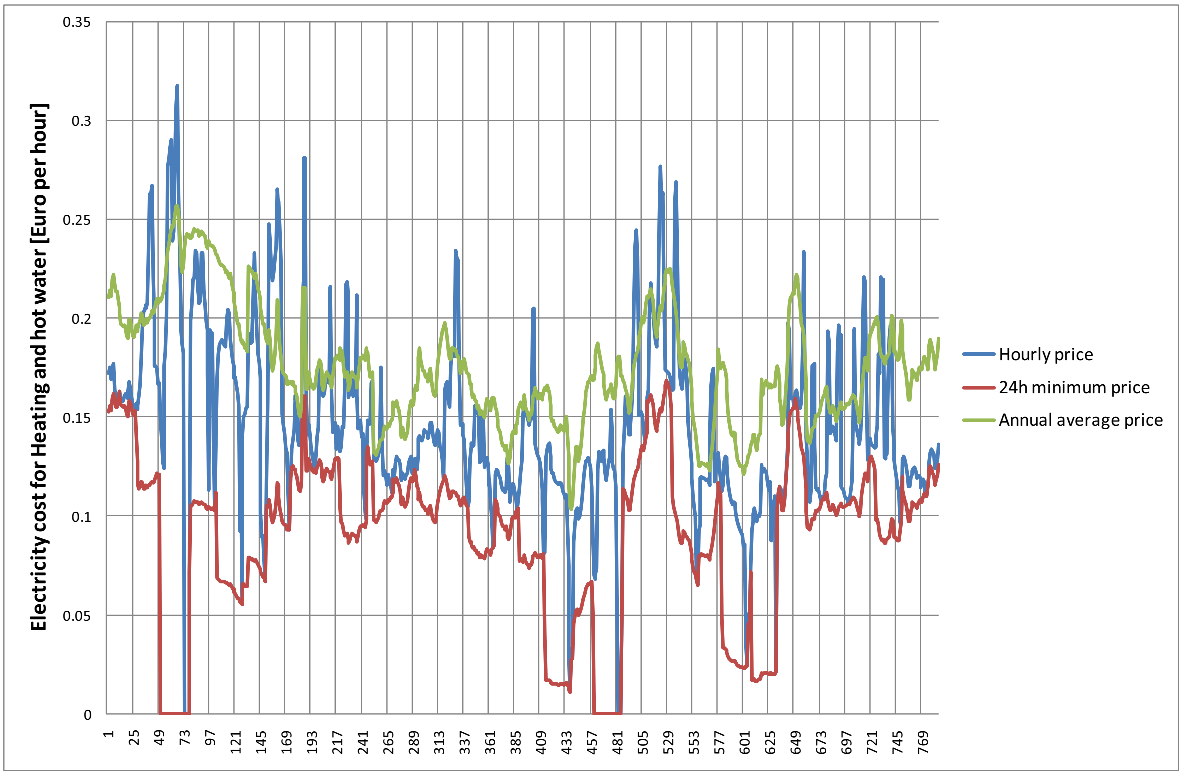

Figure 6. Electricity costs (on Nord Pool price level) for a house with 200W/K transmission + ventilation losses. 400W of internal heat from persons + appliances and 100 l/day hot water load. No solar input.

The annual auxiliary electricity cost for the three different price levels is shown in Fig 7. To the right (right bar) the traditional fixed price level is applied all year. To the left the actual variable price each hour at Nord pool level is used. In the middle an extreme case, if all auxiliary needed is charged during the cheapest hour every 24 hour.

This last case is the minimum cost that can be achieved with perfect forecasting and a large enough 24 hour storage capacity. This may be achieved in a real system, but then the extra system cost has to be balanced with the extra cost savings, so the optimum savings may be less extreme.

In percentage points the result is 10% lower cost just by introducing variable price but no advanced control or storage technology. By applying extreme forecast control and large enough storage, that use the lowest electricity price every 24 hour, a cost saving of 37% can be achieved.

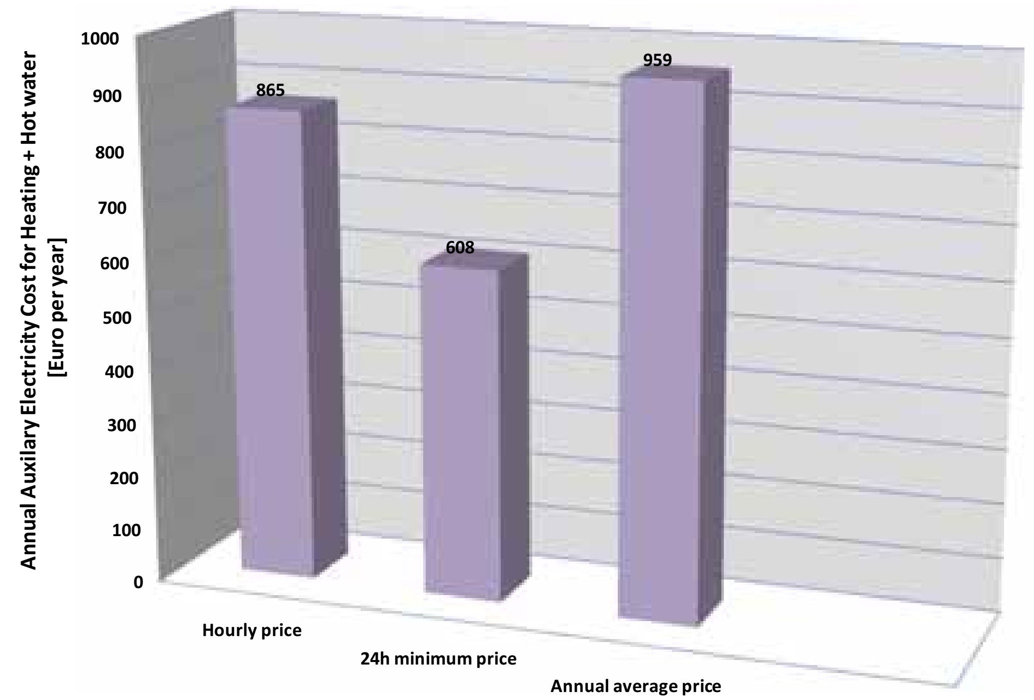

Fig 7 Annual auxiliary electricity cost for three different price levels and different control. To the right the traditional fixed electricity price all year. To the left the variable price each hour at Nord pool level. In the middle an extreme case if all auxiliary needed is charged during the cheapest hour during every 24 hour period.

3. Conclusion

The variations in electricity price hour by hour can be used both to reduce the cost for the final customer and also create a demand side management effect that will reduce the need for peak power plant operation in the grid.

Both solar radiation and heating load has a positive match with the electricity price variations during the day and would reduce the cost for the final customer without advanced forecast control, if only variable prices were introduced at the final customer.

In these simplified calculations an annual electricity cost saving of 10% can be achieved just by introducing variable price at the final customer.

By extreme forecast control and enough thermal storage capacity the cost savings is in the range of 37% compared to the traditional fixed electricity pricing (for the Denmark East area 2008).

Further savings can be achieved by introducing a well designed solar thermal system and of course a PV system when the PV system prices come lower and PV electricity is paid better in the grid.

References

[1] B. Perers, S.Furbo, E. Anderssen, J.Fan . Solar/electric heating system for the future energy system. ISES Solar World 2009 Congress Proceedings. Johannesburg 2009.