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Electricity Use in the Swedish Carpentry Industry

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ABSTRACT

Because of its large magnitude, industrial electricity consumption deserves attention. Therefore the electricity demands of three carpentry factories in Sweden have been studied. The results show that major savings of electricity can be achieved and that opportunities exist to shift necessary activities so they occur during periods of lower unit-price tariffs. The owner or director of each factory is only rarely a specialist in energy issues and usually does not know how much can be accomplished in saving money in these ways. Nevertheless a short period (a few days) of monitoring, in each of the three factories studied, showed that it would be highly profitable to install larger capacitors for cutting the reactive power: the payback period for such a measure is about a year. Further measurements of the electricity demand revealed that one of the factories used, at maximum, only about one-third of its subscribed power, i.e. the predeclared maximum peak power that the subscriber thinks will be needed. Thus, changing the supply contract or distribution agreement could save at least 25% of the electricity costs each year, and this would be achieved without reducing the expenditure by a single kWh of energy. In addition, even a small carpentry factory has several systems that are energized by electricity, e.g. all the motors for the carpentry machines, the wood-chip transportation equipment and the wood-drying apparatus, and so many opportunities exist to achieve real energy savings.

ABBREVIATION

SEK Swedish kroner (1 US$ = ~7 SEK)

THE PROBLEM

In Sweden, there has long been a national desire to reduce energy consumption. At first, the emphasis was laid on achieving heat thrift, but when a national referendum resulted in the decision to phase out the use of nuclear-electric plants, the main interest turned to lowering the electricity demand. The situation in Sweden is somewhat unique because there are many single-family houses heated unfortunately by dissipations in electrical resistors. Research has therefore previously been focused preponderantly upon devising economically viable, energy-saving measures for residential buildings. However, only a small proportion of the total amount of electricity used in Sweden is devoted to space heating and to the provision of domestic hot water. Most of the electricity is employed in industry. If the nuclear plants were turned off, there would be a severe shortage of electricity, which, in the short term, would have to be satisfied by new fossil-fuelled generators. Inevitably unit prices for electricity will rise. Even without the presently proposed phasing out of nuclear power, unit prices for energy are becoming higher. By the construction of the Baltic cable between Scania, in the south of Sweden, and northern Germany, Sweden will probably export electricity but also import 'Mediterranean unit prices'. This will lead to severe cost increases for Swedish industries.

In the Linköping Institute of Technology, a new discipline, 'wood technology', has been introduced; one specialist interest in this is the energy use associated with woodworking facilities. Emphasis is laid on the manufacture in factories of, for example, furniture, window frames, doors and cabinets. This investigation deals with the reduction of electricity costs in such carpentry industries.

CASE STUDY 1

A small factory, Rydsnäs Snickerifabrik AB with 10 employees, is sited about 100 km and 220 km south of Linköping and Stockholm respectively. (The factory lies in a rural region and, therefore, the local authority has shown interest in fostering such industrial activities in order to improve local employment prospects.) The company specialises in the manufacture of ceiling boards for houses. This commercial expertise has unfortunately been underutilised recently because of the economic depression suffered in Sweden. However, staircases are also built in the factory, and to a large degree, exported to Germany; this aspect of the business is thriving.

Our first monitoring procedure was to scan regularly the existing electricity meter. Part of the electric supply system was replaced only a few years ago and a modern meter was then installed: this facilitated obtaining the pattern of electricity use. Our scanning (at 10 min intervals) of the meter resulted in this information being stored in registers (see Table 1).

The owner explained that the mean 9kW consumption at night (see Table 1) was expended in water heating for domestic purposes, ventilation fans, refrigerators, etc., that operate day and night. The reactive power is very low, so only a small amount of inductive electric-motor load occurred during the night. The cost of this electricity is about 30 000 SEK each year or about 25% of the total annual cost paid to the utility. Thus switching off equipment that need not be run at night can contribute significantly to achieving cost reductions. However, studying the electricity demand during normal working hours is even more interesting (see Table 2).

TABLE 1
Representative scan for the middle of a Saturday night, i.e. 19 March 1994: Midnight ≡ 00:00 ≡ 24:00 hours

Time (h:min)	*Active power (kW)*	*Reactive power (kVA)*
00:10	8·7	0·3
00:20	7·5	0·0
00:30	11·1	0·9
00:40	7·5	0·0
00:50	9·3	1·5
01:00	10·5	1·2
01:10	8·1	0·0
01:20	9·9	0·6
01:30	7·8	0·0
01:40	9·9	0·3
01:50	11·4	1·5
02:00	8·4	0·0
02:10	7·8	0·0
02:20	8·4	0·0
02:30	8·7	0·3
02:40	10·8	1·5
02:50	8·1	0·0
03:00	8·7	0·0

TABLE 2
Electricity use in the Rydsnäs Carpentry AB factory during the early morning of Monday 21 March 1994

Time (h:min)	*Active power (kW)*	*Reactive power (kVA)*
06:10	9·6	0·6
06:20	10·8	0·6
06:30	10·5	0·0
06:40	10·2	0·0
06:50	12·3	0·3
07:00	34·8	17·7
07:10	49·5	32·1
07:20	54·6	42·3
07:30	57·9	47·4
07:40	55·5	43·5
07:50	54·3	41·0
08:00	57·6	47·4
08:10	55·5	57·3
08:20	57·3	45·9
08:30	54·6	38·1
08:40	57·0	45·6
08:50	54·0	40·8
09:00	56·7	43·5
09:10	57·3	42·3
09:20	54·3	39·6
09:30	52·5	38·4
09:40	27·0	7·2
09:50	26·7	9·0
10:00	21·6	2·1

From Table 2, it is apparent that the main production activities at the factory start at about 7 a.m.: the electricity use increased from 12·3 to 34·8 kW between 06:50 and 07:00. Simultaneously, the reactive power rose because several electric motors had been started. Electric lighting, provided by fluorescent tubes, may also contribute to this. We can see that the active power demand remains fairly constant (at about 55 kW) as long as manufacturing is proceeding. The reactive power at 09:30 hours, is somewhat lower than the real, or active, part, the value for cos ϕ being about 0·77, where ϕ is the phase lag. The electricity supply utility fines the factory owner if the reactive part is excessive, and it is therefore desirable to make cos $\phi \geq 0{\cdot}95$.[1] Compensation for the phase lag, because of the impedances of the motors, is achieved by the presence of a capacitance, which is already installed but obviously of too small a magnitude in the present case. At 09:30, the workers start breakfast and so

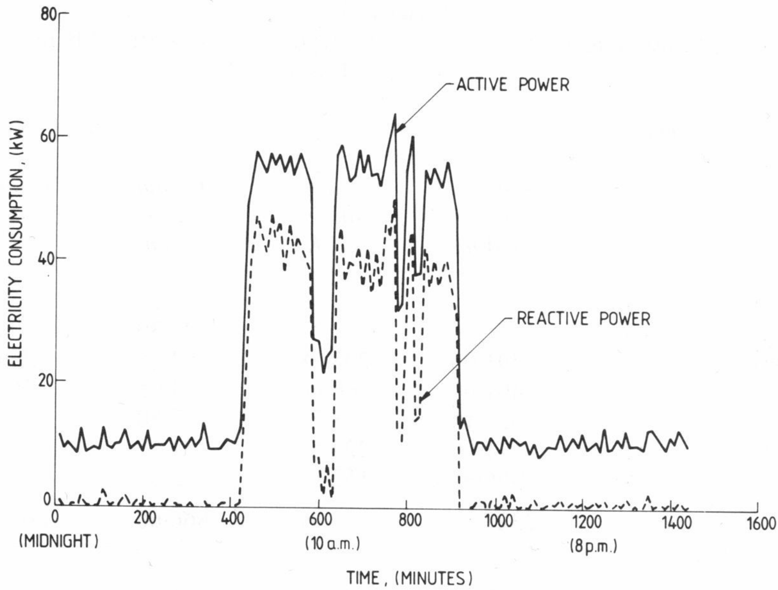

Fig. 1. Electricity supplied to Rydsnäs Carpentry AB during 21 March 1994.

some equipment is switched off. In Fig. 1, the electricity demand for the whole day is shown: approximately 10 kW is needed during the night, while about 55 kW is used during normal working hours. The peak load of 64·2 kW occurred just before the lunch break. The electricity supply utility, Smålands Kraft AB, charged 430 SEK/ kW as the power fee.

This utility charges a time-of-use tariff for electricity for part of the year. During normal working days between 06 : 00 and 22 : 00 hours each day, from October to April, the charge is 0·415 SEK/kWh. At 22 : 00 hours, the cost is reduced to 0·308 SEK/kWh, which remains applicable until 06 : 00 a.m. Saturdays and Sundays are likewise low-tariff periods. From May until September, the unit price is decreased further to 0·215 SEK/kWh irrespective of the time of day.

It is apparent from Table 3 that the major cost is incurred as a result of using electricity during high-tariff periods. The consumption remained fairly stable from week to week. Surprisingly the total weekly cost for the low-rated segment varies as a percentage more than that for the high-rated segment. There are 30 weeks of the year for which the unit electricity price during each period of 24 h varies and 22 weeks for which it is constant. Assuming that the electricity use for the considered week as indicated in Table 3 represents the average behaviour throughout the year, the factory must pay 39 855 SEK during the period October to April inclusive and 16 436 SEK for the rest of the year. Hitherto the maximum

TABLE 3
Electricity demands and direct costs for the Rydsnäs Carpentry AB factory for one week during March 1994

Day	Date in March	Unit high-tariff period		Unit low-tariff period	
		Amount used (kWh)	*Charge made (SEK)*	*Amount used (kWh)*	*Charge made (SEK)*
Saturday	19	—	—	213·25	65·68
Sunday	20	—	—	227·30	70·00
Monday	21	491·05	203·78	83·25	25·64
Tuesday	22	401·60	166·66	84·95	26·17
Wednesday	23	527·15	218·76	77·80	23·96
Thursday	24	541·00	224·51	84·55	26·04
Friday	25	366·95	152·28	95·50	29·41
Total		2327·75	965·99	866·60	266·90

power demand has been about 70 kW and so, using the power fee of 430 SEK/kW, the total cost amounts to 30100 SEK. However, the factory owner must also pay for the reactive power; the price of this is 100 SEK/kVA for the part that exceeds half the real power need. In our case, this results in a further charge of 2800 SEK. In addition, there is a constant standing charge of 8000 SEK each year. In total, this amounts to 97 000 SEK. However, the total cost paid to Smålands Kraft AB, the electricity supplier, during 1993 was 33 000 SEK higher. This arose because the company incurred a power fee charge of 64 000 SEK for the permitted use of 150 kW, rather than the maximum of 70 kW actually employed. By persuading Smålands Kraft AB to recognise this and by being thrifty with the use of power, this factory could reduce its annual bill for electricity by at least 25%.

CASE STUDY 2

This concerns the Klintland AB factory, Linköping, which manufactures chairs from wood.

The electricity demand (see Fig. 2 and Table 4) is scanned only every hour: hence the resulting lines look smoother than the corresponding ones of Fig. 1. This factory is much larger than that studied as Case Study 1. The maximum power demand, about 350 kW, occurs at ~11 a.m. Unfortunately much of the equipment in the factory is not turned off during the periods when the employees take lunch or are at tea

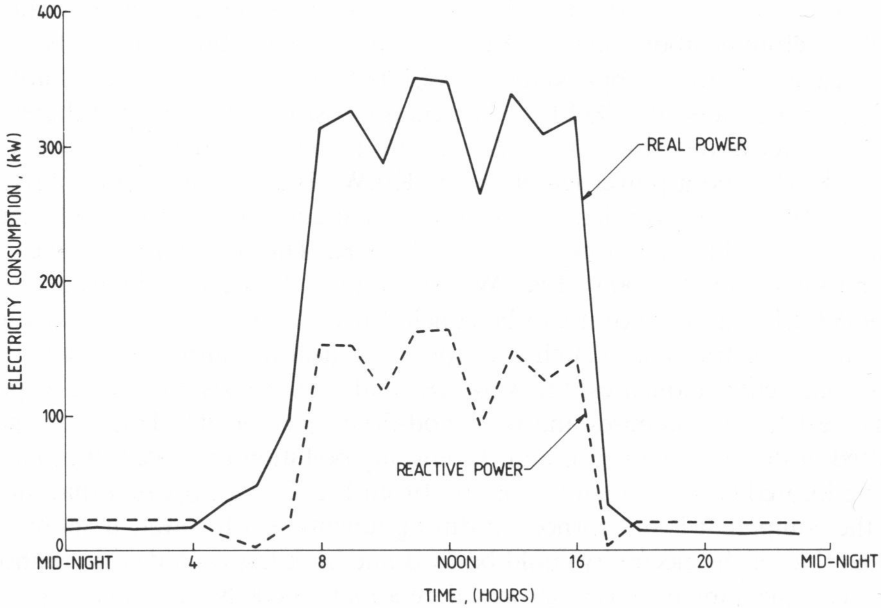

Fig. 2. Electricity demand at Klintland AB, Linköping, during 19 September 1994.

breaks. Interestingly, the reactive power exceeds the active part when the demand is very small. The high unit tariff for electricity, from November to March, Monday to Friday between 06 : 00 and 22 : 00 hours, is 0·442 SEK/kWh, and the low unit price for the other periods of those months is 0·245 SEK/kWh. During April, September and October, the unit price remains invariant at 0·21 SEK/kWh, while it is 0·143 SEK/kWh from May to August inclusive.

TABLE 4
Electricity demands and direct costs at the Klintland AB factory in Linköping for one week during November 1994

	At high unit tariff		*At low unit tariff*	
Day	*kWh*	*SEK*	*kWh*	*SEK*
Saturday	—	—	432·0	105·84
Sunday	—	—	451·2	110·54
Monday	2956·8	1306·90	272·0	66·64
Tuesday	2947·2	1302·66	233·6	57·23
Wednesday	3424·0	1513·40	320·0	78·40
Thursday	3211·2	1419·35	486·4	119·16
Friday	2872·0	1269·40	395·2	96·82
Total	15411·2	6811·71	2590·4	634·63

The electricity cost during each month between November and March will therefore be about 30 000 SEK. For April, September and October, the cost each month is approximately 15 120 SEK, while for each summer month, the cost is ~10 300 SEK. The energy cost for one year will therefore amount to about 240 000 SEK. There is also a subscription fee of 95 SEK/kW and a power fee of 189 SEK/kW. The company subscribes for a 450 kW peak power demand, so the annual cost for these tariff elements will, in total, be approximately 130 000 SEK. The total cost each year is therefore about 370 000 SEK. We know that the cost in February was ~39 000 SEK and hence it can be concluded that the factory unfortunately consumes electricity at a high rate for space heating during the winter. In many carpentry industries, the wood residuals (i.e. wastes) are burnt to provide heat for the premises and the wood-drying equipment. This is not permitted in this instance because of the ensuing pollution produced, the factory being located close to the town centre. From Fig. 2, it is apparent that much of the equipment is not turned off during lunchtime. However, it should be noted that, if the electricity could be used one hour less each day throughout the year, the annual energy bill would be about 25 000 SEK smaller.

At the Klintland factory, a powerful (100 kW) kiln had been installed for drying lumber before it is used in the factory. It is probable that turning off the power to the kiln for a few minutes (during peak power demand periods for the whole factory, e.g. see Table 5) would not jeopardise the quality of the resulting timber. The preagreed subscription for a peak demand of 450 kW is, in a large part, to ensure that sufficient power is always available for the kiln. However each kW not needed at peak conditions would be worth (189 + 95) SEK, and even more if the subscription limit is exceeded; thus a high potential for achieving savings exists. (The power fee is only of interest during high unit energy price conditions, whereas the subscription fee applies throughout the year.) If the limit is exceeded, the fee is doubled to 190 SEK/kW.

TABLE 5
The five highest electricity loads for the Klintland factory, Linköping, Sweden, between 17 September and 25 October 1994.

Date	*Time (hours)*	*Load (kW)*
18 October	12:00	433·6
4 October	10:00	414·0
18 October	13:00	412·8
27 September	10:00	406·4
21 September	14:00	404·8

The power fee is not charged during September and October; if it had been then the cost for the difference between the highest and the next highest load observed, namely 19·6 kW, would be 3700 SEK. If the manager knows that a peak is likely to occur, action can be taken to avoid incurring such a penalty (e.g. by temporarily switching off the kiln). Of vital interest is to be able to ascertain whether or not a peak power demand is likely to ensue in the next hour. However, in this respect, it should be appreciated that, if the power to the kiln is switched off for a considerable period, then the initial power surge subsequently, on re-energizing the kiln, may exceed the maximum limit stipulated by the subscription power and so be particularly expensive.

By wise demand-side management, it should be possible to reduce significantly the peak load and hence lower the subscription fee accordingly. A detailed description of such load-limitation management procedures is given in Ref. 2. One effective measure that could be introduced into this carpentry factory would be to use a hot-water accumulator. The kiln dryer could be supplied with heat from such a hot-water storage system during what would otherwise be maximum power demand intervals for the factory, and electrically heated at other times. The heat accumulator would be charged using cheap-tariff electricity at night. The use of such an accumulator is described in detail in Ref. 3.

CASE STUDY 3

Our last example comes from the Klintland AB factory in Mjölby, Sweden, and is the largest of the three factories surveyed. In Fig. 3, results for the first working day of the monitoring series are shown. The power demand intermittently exceeds 500 kW. The maximum load observed during the series of tests was 564 kW at 13 : 00 hours on 17 October, 1994, i.e. it occurred in the middle of the day rather than during the morning as was previously presumed. Representative electricity costs for this factory are shown in Table 6.

The tariffs imposed at Mjölby are the same as those at Linköping. From November to March, for working days between 6 a.m. and 10 p.m., the unit price is 0·61 SEK/kWh, but from 10 p.m. to 6 a.m. it is only 0·22 SEK/kWh. During April, September and October, the unit price is reduced still further to 0·179 SEK/kWh, while it is 0·11 SEK/kWh from May to August inclusive.

There are 20 weeks of the year for which the unit tariffs used in Table 6 are applicable; the cost for such a period would be approximately 387 000 SEK. The total cost for April, September and October would be 75 000

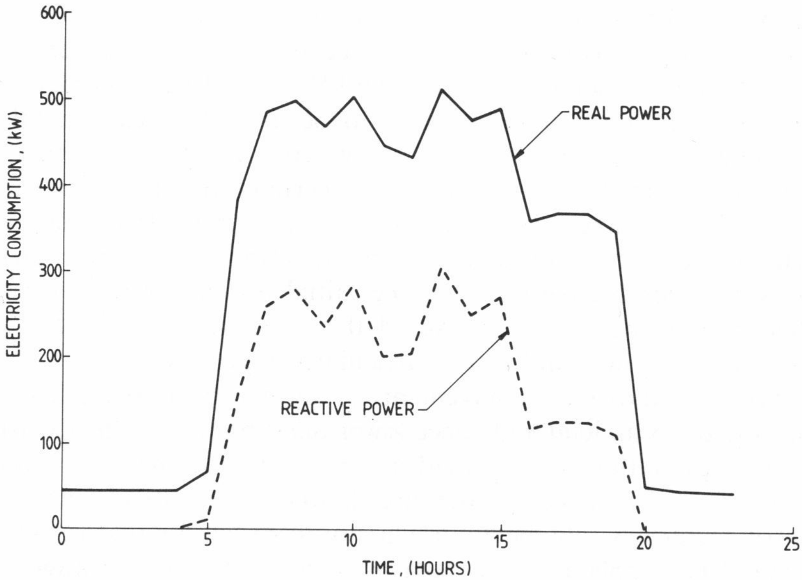

Fig. 3. Electricity demand at the Klintland AB factory in Mjölby during 13 September 1994.

SEK and the total cost incurred during the summer months amounts to 61 000 SEK. The total annual energy cost will therefore be about 523 000 SEK. There is also the subscription fee of 90 SEK/kW and the power fee of 105 SEK/kW. The latter elements add up to 106 000 SEK. A fixed charge of 6000 SEK is also applicable for each subscription. Thus the

TABLE 6
Electricity consumptions and associated direct costs for the Klintland AB factory in Mjölby during a typical week of November 1994

	At high unit tariff		*At low unit tariff*	
Day	*kWh*	*SEK*	*kWh*	*SEK*
Saturday	—	—	1173·3	258·13
Sunday	—	—	1171·9	257·81
Monday	6684·5	4077·24	556·4	122·41
Tuesday	6223·8	3796·51	749·8	164·96
Wednesday	6293·5	3839·04	437·7	96·29
Thursday	6227·1	3798·53	430·9	94·80
Friday	4544·8	2772·33	428·3	94·23
Total	29973·7	18283·65	4948·3	1088·63

total cost for one year is therefore approximately 635000 SEK. For 1993, the total amount actually paid to the electricity supply utility was 628 716 SEK, and so our approximate calculations are reasonable.

In the Mjölby factory, wood residuals are burnt to produce heat for the premises, the kiln dryer, etc. However, coping with all the saw dust, wood chips and offcuts in this way is a problem because it is not feasible to maintain combustion by feeding the stoves continually with such refuse alone. Also the factory lacks adequate dry-storage space for such refuse and thus large piles of it sometimes ensue outdoors. These unfortunately are exposed intermittently to inclement weather, so lowering the effective calorific value of this fuel. Thus negotiations have started to ascertain whether it is favourable to sell the combustible wastes to the district heating utility and buy back heat instead.

The power demanded versus duration at the specified power for the factory for one week is shown in Fig. 4. The peak demand is 533·6 kW; the mean load (during the normal working week of 40 h in Sweden) is 490 kW; but considerable power is still being used for periods of between 40 and 60 h per week. Thus significant opportunities for energy thrift exist.

The total electricity used during the week considered in Fig. 4 was 35 210 kWh. If the factory were in continuous production, day and night, the constant power demand would be 533.6 kW throughout the 168 h, which equals 89645 kWh. But the Mjölby factory used only 39·3% of that amount. If it were possible to implement a perfect load-management

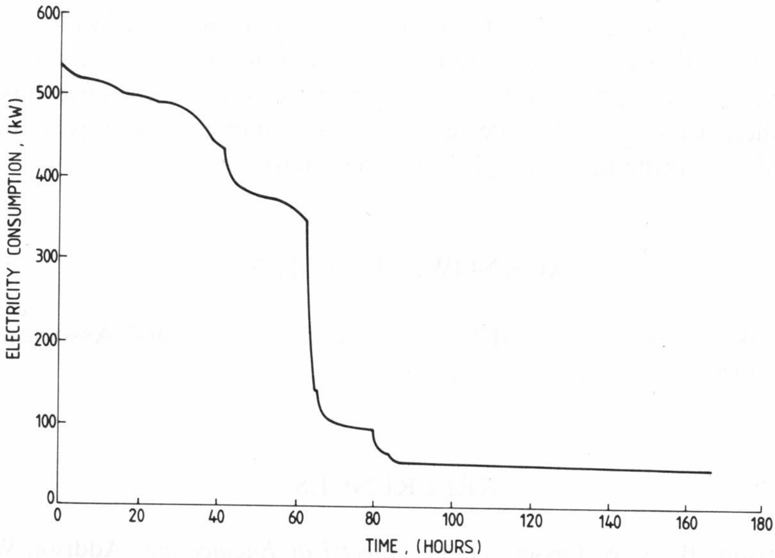

Fig. 4. Electricity demand in the Mjölby factory from 13 to 20 September 1994.

system, the maximum load would be 209·6 kW. This would reduce the total subscription and power fees to 38 776 SEK. Furthermore, one should plan to work less during the high-electricity-tariff hours and more in the low-tariff ones. During the five winter months, at present there are 400 high-tariff hours (at 209·6 kW demand) at a cost of 0·61 SEK/kWh, so equalling in total 51142 SEK. There are 440 low-tariff hours during the winter months and the associated cost amounts to 20289 SEK. During the spring and autumn, we have three months, i.e. 2184 active hours at 0·179 SEK/kWh, costing 81940 SEK and, during the summer, there are 2952 h at 0·11 SEK/kWh, which adds up to 68061 SEK. If the fixed cost of 6000 SEK per year is included, the total annual cost would become ~270000 SEK, which is less than half the original cost and this reduction could be achieved without a single kWh being saved. If working during the high-tariff hours could be avoided entirely, still more money could be saved. Of course, it is not possible to achieve all of this because other additional costs would be incurred (e.g. for working during unsociable hours), but it is an interesting challenge for the firm's future strategy.

CONCLUSIONS

The three carpentry factories studied showed similarities in their patterns of electricity use. All three had subscriptions based on time-of-use rates. This made it desirable to reduce dependence upon electricity of high unit price tariff, e.g. by use of heat accumulators. The subscription and power fees made it also desirable to reduce the peak loads incurred: each kWh so saved is worth about 100 SEK, or £10. A prima facie case has been established that considerable energy and financial savings could be achieved by simple measures, in the three factories.

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