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Impact analysis of the Spanish electric energy market liberalization on Chlor-alkali industry

Rubén Aldaco*, Raquel Onandía , Angel Irabien
Departamento de Ingeniería Química y Química Inorgánica, Universidad de Cantabria, Spain
aldacor@unican.es

A sodium chloride solution is decomposed electrolytically to generate gaseous chlorine, sodium hydroxide and hydrogen. Electricity accounts for about 50 % of total production cost. In Spain, the Electrical Sector Act 54/1997 commenced the electric market liberalization, with the introduction into national laws the provisions contained in European Directive 96/92/EC. In July 2008, tariffs disappear for industry consumers. Hourly discrimination complement, given by tariffs, it has been an important energy costs optimization way for chlor-alkali industry and now it is not so evident the modulation advantage. This article tries to analyze impacts in chlor-alkali industry of this new electric market.

1. Electrical energy in chlorine production.

The growth of the chlor-alkali industry has been primarily dictated by market demand, environmental concerns and constraints, and energy prices, and will continue to be governed by these factors in the future. Chlorine and its co-product caustic soda are inevitably produced together in the electrolysis of brine. This electrochemical process leads to the generation of gaseous chlorine, dissolved sodium hydroxide and hydrogen. So, physically and chemically, the electric current is essential to the chlor-alkali reaction.

It could even stated that electricity is feedstock as well as energy source for the chlor-alkali production. Electricity accounts for about 50 per cent of total production cost. The energy indicator is weight-averaged across all producers and based on steam and electricity. The electrical energy consists of power used for electrolysis (transformers, rectifiers and cells) and as motor power. Steam is used principally for caustic soda evaporation but also for minor utility purposes.

Figure 1 shows the electric energy price impact on chlorine production costs in Europe. There is a linear relation.

As electricity is actually a raw material of the chlorine production process, the basic consumption corresponding to the electrochemical reaction cannot be reduced. Only the additional consumption can be optimised. Energy is used both as electricity and as heat.

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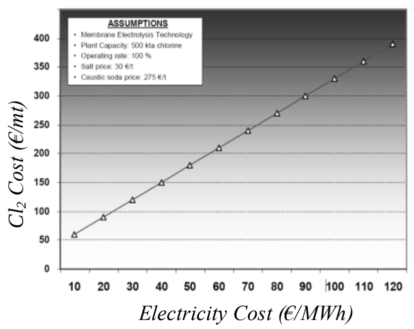

Figure 1: Impact of electricity costs on chlorine production costs in Europe.

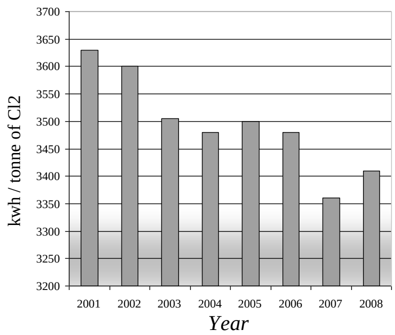

Figure 2: Western Europe Chlor-Alkali industry energy consumption.

About half of the energy expended is converted into the enthalpy of the products. The rest is converted into heat transferred to the air in the building and the products, which have to be cooled (BREF (12.2001)). The operation of a chlor-alkali plant is dependent on the availability of huge quantities of direct-current (DC) electric power.

The global trend is related to the progressive conversion from mercury to membrane technology and this is translated in a decrease of the energy consumption by this industry, as you can see in Figure 2.

2. European and specifically Spanish chlor-alkali industry situation.

The chlor-alkali process is one of the largest consumers of electrical energy. The chlorine production of a country is an indicator of the state of development of its chemical industry.

The total value of western European chlor-alkali sector production is 3 billion Euros. It is estimated that the turnover in 1995 generated by chlor-alkali related products amounted to some 230 billion Euros that is about 60% of the turnover of the west European chemical industry (SRI Consulting, 2010).

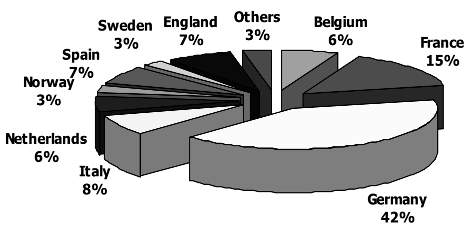

Figure 3: Western Europe Chlorine Capacity Distribution 2005

Electricity is a major cost factor in the production of chlorine, and the chlorine industry accounts for about 1 % of the total European energy consumption of 3,319 TWh with 11,522 kt of capacity.

On the manufacturing front, the chlor-alkali industry continued to shift away from the mercury cell technology accounting for about 38% of total chlorine production. The more energy-efficient membrane technology accounted for just above 45% of 2007 European chlorine capacity (Baquedano, 2008).

Table 1: Spanish Chlor-alkali capacity distribution.

Company	Mercury (kt)	Membrane(kt)	Total (kt)	Cap. Distribution
Electroquímica de Hernani		15	15	1,9%
Electroquímica del Noroeste	34		34	4,4%
Ercros	411	55	466	53,2%
Química del Cinca	31		31	4,0%
Solvay Química	281		281	36,4%
Total spanish capacity			822	

The total capacity of the nine chlorine-producing plants currently operating in Spain is 772,000 tons a year. This represents 7% of the overall capacity of the countries of Europe, which is around 10 million tons a year. Almost 98 % of production capacity in Spain is based in mercury technology.

3. Energy consumption Comparison

The fixed costs for personnel, taxes, insurance, repairs, and maintenance are about the same for all three available technologies. Of the variable costs, the expense for salt, precipitants, and anode reactivation are roughly the same. The difference among the three processes shows up in the consumption of energy, as electricity and steam.

Table 2: Energy Consumption: Comparison between Cl_2 production technologies.

	Mercury	Diaphragm	Membrane
Theoretical Voltage (V)	3.15	2.19	2.19
Current density (KA/m^2)	8-13	0.9-2.6	3-5
Cell Voltage (V)	3.9-4.2	2.9-3.5	3-3.6
NaOH Concentration (%)	50	12	33
Specific Consumption (ACkWh/t Cl_2)	3,360-10	2,720-1.7	2,650-5
Motive Power (ACkWh/t Cl_2)	200	250	140
Total elec. consumption (ACkWh/ t Cl_2)	3,560	2,970	2,790
Steam in NaOH conc.(ACkWh/t Cl_2)	0	610	180
Total energy consumption (ACkWh/t Cl_2)	3,560	3,580	2,970

The voltage is increased with increasing distance between the anode and the cathode. The energy required to liquefy chlorine is not included in the Table 2. It should be noted, however, that chlorine from membrane cells might need to be liquefied and evaporated to remove oxygen (O_2) and carbon dioxide (CO_2).

The energy required to liquefy and evaporate 1 t of chlorine is about 200 kWh. Electrical energy use is lower in the membrane technology. The power costs are lower, even allowing for the steam requirements and brine purification. Increased current density reduces the capital costs of an installation because the production per unit cell capacity is higher.
However, there is a trade-off in that higher current densities mean higher power consumption, and the unit cost of electricity can be a factor when determining the appropriate trade-off between capital cost and power consumption BREF (12.2001).

4. Electric market liberalization

The production of electricity energy in Spain, before to liberalization, was based on a system of "merit order" which supposed that the regulator determined what installations had to function to supply demand in every time period. Likewise, the retributive system of electricity companies was a regulator mechanism cost plus which established the settling of a price which allowed covering the service cost of the electricity enterprises and a return rate. In this context, electricity enterprises had incentives to secure the electricity supply in all time periods (García et al., 2005).
Following the aim of a common market, the deregulating of the national electrical sectors, in Spain the Electrical Sector Act 54/1997 commenced it, with the introduction into national laws the provisions contained in European Directive 96/92/EC, concerning common rules for the internal market in electricity. The Royal Decree 2019/1997 of 26 December considers such a market as the joint of purchase and sale trade transactions of energy related with the electricity energy supply. The electricity market began to function the first of January 1998 where every day is shaped in twenty-four hourly periods. In July 2008, the tariff system disappears and industry must go to the pool to buy energy in the liberalised market. The economical management of Spanish electric market is made by OMEL (Operador del Mercado Ibérico de Energía) and the technical management by REE (Red Electrica de España) .

5. Electric Spanish daily market

The electricity market is the set of transactions arising from the participation of the market agents in the sessions of the daily and intraday markets and from the application of the System Technical Operation Procedures. Market participants are companies authorised to participate in the electricity production market as electricity buyers and sellers. The purpose of the daily market is to handle electricity transactions for the following day through the presentation of electricity sale and purchase bids by market participants. The market operator matches electricity power purchase and sale bids. The price in each hour will be equal to the price of the last block of the sale bid of the last production unit whose acceptance has been required in order to meet the demand that has been matched. The market operator (OMEL) matches electricity power purchase and sale bids, obtains the hourly production and demand schedule on the network.

6. Price Impact: Electrolysis Modulation

The Spanish electric market until July 2008 allowed the possibility of consuming electric energy following the tariff system defined by the government. There were available several tariffs, according to different conditions. In these tariffs, different complements existed, which could mean a charge or a discount in the final electric bill. These complements were applied in a separate way to the energy invoice. One of the most important ones was the hourly discrimination complement, which penalized or favoured energy consumption depending on the period of the day, or even in some cases depending on the month. This advantage, until this moment, encouraged logically that in order to optimize energy cost, to prepare production plans, assuring maximum production during hours with minimum prices, and minimizing production in more expensive energy hours. Table 3 shows an example of the hourly discrimination complement available in the tariffs.

Table 3: Example of tariff supplement for hourly discrimination: Type 4.

Period	Duration	Overcharge or discount
Peak	6 hours from Monday to Friday	+100
Plain	10 hours from Monday to Friday	-
Valley	8 hours from Monday to Friday and 24 h of week-end and special days	-43

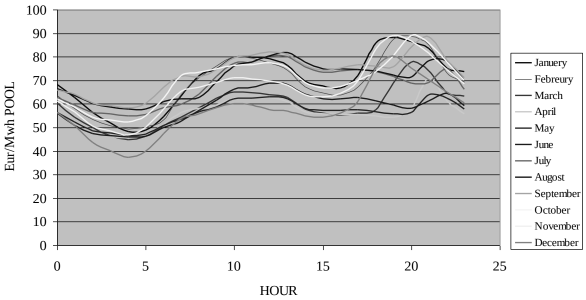

Figure 4: Monthly Daily Pool Price, 2008.

In the new market, it is not possible to find fixed prices, and it is necessary to present energy consumption plan before knowing final prices. Also due to the system to match bids and sales, this system generates different price for each hour, in each day. On the other hand, in case of not accomplishing energy prevision, this system has penalties. It makes very difficult to prepare economic forecast in whatever industry where energy is a variable cost, as in the chlor-alkali industry. In Figure 4, it is represented the average hourly price for the different months of the year from pool during 2008. From Figure it is possible to check the variability along the day. Besides, the irregular profile of the curves found in 2008, it looks like difficult to imagine, to follow the tendencies in order to optimize the energy price. It would mean important intensity changes which would have as a result, a loss of yield in the process. Each intensity variation is traduced in a

process destabilization. So actually, it is not so evident to modulate, trying to follow a prevision of the curves to optimize energy costs. All these modifications on Spanish electrical system have generated important impacts in chlor-alkali sector, not only about energy costs, but also in operational aspects.
Figures 5 and 6 show the different production distribution planned by mercury electrolysis before and after the electric energy market liberalisation, as an example of the tendency commented above.

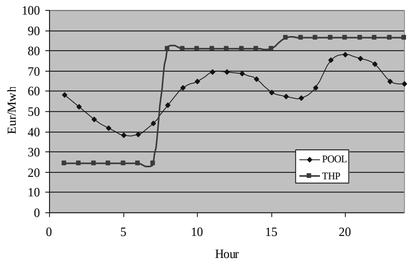

Figure 5. Electric energy price profile comparison: THP tariff-pool.

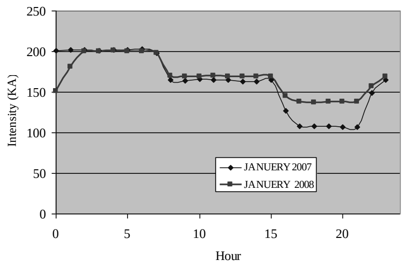

Figure 6. Cell-room intensity profile comparison, same production.

The system managed by OMEL required an important production planning each day, with the uncertainty about electric energy price. Previsions and the penalties in case of not accomplishment them, have meant an important loss of flexibility for the normal operation. In relation about energy price, it can be concluded that there is an important reduction in the modulation benefit that especially electrolytic process found in tariffs system. Regarding pool prices profile, it can be expected that modulation is going to be decreased for the sector, due to the loss of incentives introduced by tariff supplements. And this tendency is not only a result of price impact, but also a process difficulty. Each modulation step means a process destabilisation and looking to price profiles, it does not look so interesting and not so easy to follow the tendencies. Finally, it is expected that electric prices will change; taking into account that it is a supply and demand market. However, actually it is not so evident to recover the economical benefit for the chlor-alkali industry that modulation represented.

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