

Long-term market reactions to changes in demand for NaOH

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www.lca-net.com, 2006-10-19

Executive summary

NaOH (sodium hydroxide or caustic soda) is a by-product of the chlorine-alkali process. As this process is determined by the long-term demand for chlorine, changes in demand for NaOH does not affect the output of NaOH from this process.

An analysis of the NaOH market reveals that long-term changes in demand for NaOH will affect the least essential uses of NaOH, i.e. those uses where NaOH can readily displace sodium carbonate (soda ash). A long-term increase in demand for NaOH will thus be met by an increased use of sodium carbonate for those uses where NaOH is not essential, e.g. in pulp and paper, water treatment, and certain chemical sectors where it is used as a neutralising agent. Likewise, a long-term decrease in demand for NaOH will lead to increased displacement of sodium carbonate.

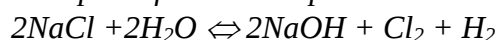
In the current market situation, where there is a global increase in demand for chlorine, the continuously increasing output of NaOH is adequate to cover the applications where NaOH is essential, and a marginal increase in NaOH demand will therefore not lead to a need to produce NaOH from the alternative process route (the caustification process, where NaOH is produced from lime and soda). If there is a further increase in demand for NaOH for essential applications, without a simultaneous increase in demand for chlorine, the caustification process will again be able to play a role as a marginal production route for NaOH, as has been the case previously.

To model the current long-term market reaction to a decreased demand for NaOH in a life cycle assessment, we thus recommend using the derived decrease in sodium carbonate supply. Sodium carbonate is currently produced from NaCl and CaCO₃ in the Solvay process (in Europe), and in addition directly from naturally occurring ores (trona) or brines (USA). The displaced sodium carbonate supply may therefore depend on the location and transport costs. The Solvay process is still the dominating process globally, implying that the output from the naturally occurring sources are not globally competitive, and that a decrease in NaOH demand will primarily affect the Solvay process. Sources for environmental data for the Solvay and the trona mining processes are identified.

1. Background

The issue of market reactions to changes in NaOH demand is treated in Weidema (2003): [Market information in life cycle assessment](#), p. 94 (our highlighting):

The joint production of chlorine and sodium hydroxide is one of the classical examples of allocation problems. The chloralkali process yields three coproducts:



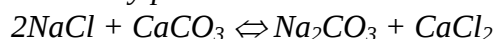
Hydrogen is produced in relatively small quantities (27 g for every kg of chlorine) providing approximately 3% of the world market for hydrogen. The main production route for hydrogen is steam reforming of natural gas and this will probably also be the preferred process to meet an increase in demand for hydrogen. As hydrogen does

not fulfil the first condition, it cannot be the determining co-product. In addition, it can be noted that the value of the hydrogen is approximately 5% of the total income for the chloralkali process, which means that it does not fulfil the last condition either. In practice, the chloralkali process is the exclusive production route for chlorine, which cannot be easily stored and is typically sold locally. Sodium hydroxide is a more flexible product that can be stored and transported over long distances. **Sodium hydroxide can be substituted by soda ash directly or by sodium hydroxide produced by caustification of soda ash, thus providing both a floor and a ceiling on the price of this co-product (van Santen 1998a).**

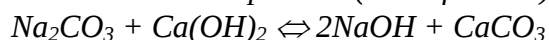
Chlorine and sodium hydroxide are produced in approximately equal quantities by the chloralkali process and their share in the total income for the process is approximately the same. However, during the last 10 years there has only been one short period in 1990/1991 where the price of sodium hydroxide was so high that it could by itself provide adequate revenue to change the production volume (Beal 1995). Based on this analysis of the market situation, it is concluded that long-term decisions on capacity adjustments are based on the existence of local, stable demands for chlorine, making chlorine the determining co-product for the chloralkali process when applied in LCAs with a long time horizon.

On p. 105, Weidema (2003) continues:

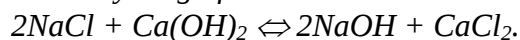
In Europe, the co-production of chlorine and sodium hydroxide involves a displaced production of sodium hydroxide [...], which can be identified as the combination of the Solvay process:



and the lime-soda process (caustification):



with recycling of the calcium carbonate, giving net process:



Caustification is not a commercial process, but it is used by industry (Kirk-Othmar 1978, van Santen 1998a).

More recent market information can be found at

http://aida.ineris.fr/bref/brefca/bref_gb_gen.htm

2. Identification of soda ash production or caustification as the substituted process

In the above quote from Weidema (2003) it is suggested that Sodium hydroxide can be substituted either by soda ash directly or by sodium hydroxide produced by caustification of soda ash. We found it extremely difficult to find data on the caustification process, even when contacting directly the industry sources. We finally found that this is simply because the process has generally been phased out, since it is quite costly and therefore not competitive as long as there is an ample supply of NaOH from the chlor-alkali process. In the last decade, this supply has been ensured by a globally increasing demand for chlorine.

This conclusion is confirmed by Charles Fryer from Tecnon OrbiChem, one of the world's leading marketing consultancies specialising in the bulk chemicals petrochemicals and plastics industries, who in an e-mail to us (dated 2006-10-11):

“The production of caustic soda by the two processes you mention [i.e. the Solvay + soda-lime processes] is technically possible but generally reckoned to be uneconomic. Production of soda ash via the Solvay process costs around \$150 per ton. Then you need about 1.35 tons of soda ash to make 1 ton of caustic soda, so the raw material cost is about \$200 per ton, plus the cost of the lime. Then the conversion of soda ash to caustic soda, the lime-soda process, requires a cost of around \$150 per ton, so the caustic soda has a final cost of \$350 per ton. This looks okay today when caustic soda sells for around \$350-375 per ton in the USA and Europe, but prices in Asia are only \$250 per ton or less. Of course under certain circumstances the costs I have mentioned can be lower, especially in locations where energy is cheap. But it should be remembered that today prices for caustic soda are especially high, and during a recession they can fall to \$150 per ton or even less. At such times it is the return from sales of chlorine or chlorine derivatives that support the economics of the usual electrolytic route to chlor-alkali. Because of this the Solvay + Lime-soda route to caustic soda has been virtually abandoned in the world (there may still be some production by this route in India).”

NaOH has a large diversity of uses (Ref: <http://www.the-innovation-group.com/ChemProfiles/Caustic%20Soda.htm>):

- Direct application, mainly as a neutralising agent, 54 percent (pulp and paper 24 percent; soaps and detergents 10 percent; alumina 6 percent; petroleum 7 percent; textiles 5 percent; water treatment 5 percent; miscellaneous 43 percent);
- Organic chemicals, 35 percent (propylene oxide 23 percent; polycarbonate 5 percent; ethyleneamines 3 percent; epoxy resins 3 percent; miscellaneous 66 percent);
- Inorganic chemicals, 11 percent (sodium/calcium hypochlorite 24 percent; sulfur-containing compounds 14 percent; sodium cyanide 10 percent; miscellaneous 52 percent).

At least in the dominating use as a neutralising agent, NaOH can be substituted by other agents, especially soda ash.

Re. soda ash as a substitute for NaOH (caustic soda), U.S. Geological Survey, Mineral Commodity Summaries (Dennis & Kostick 1998) writes (our highlights):

*“Substitutes: **Caustic soda can be substituted for soda ash** in certain uses, particularly in the pulp and paper, water treatment, and certain chemical sectors. Soda ash, soda liquors, or trona can be used as feedstock to manufacture chemical caustic soda, which is an alternative to electrolytic caustic soda.” and “Domestic soda ash consumption for the first half of 1997 increased slightly compared with the previous year despite the low price of electrolytic caustic soda. However, caustic soda prices began to rise in July and continued through yearend **causing several customers to switch back to soda ash.**”*

FMC Industrial Chemicals, a soda ash producer, notes on their website:

*“**Soda ash provides a stable and predictable pricing alternative to caustic.** Soda ash can be used to replace caustic in many applications such as; pH adjustment, acid neutralization, pulp and paper, chemical production, or flue gas desulfurization. FMC has the knowledge and experience to assist you in the design and installation of a soda ash handling system to achieve a fast and low-cost transition from caustic soda to soda ash.”*

(Ref: FMC Industrial Chemicals (2006): Soda Ash; An Alternative Solution to Caustic Soda <http://www.fmcchemicals.com/Default.aspx?tabid=1512>)

3. Substitution rate of soda

The displacement rate of Sodium carbonate to NaOH is 1.325 kg Sodium carbonate to 1 kg of NaOH.

(Ref: <http://www.fmcchemicals.com/Portals/chem/Content/Docs/products/Sodaashapps.pdf>)

4. Production routes for soda

Sodium carbonate can be produced from the Solvay process (mentioned above).

Quoting Althaus et al. (2003), *the other relevant soda manufacturing process is the natural ash process. The so-called sources of natural ash are generally deposits of either Trona (sodium sesquicarbonate dihydrate) or nahcolite (sodium hydrogen carbonate), or brines containing soda or bicarbonate. These materials require to be separated from the impurities they are associated with in their deposits, and all have to be subjected to at least one calcining stage, to convert the material into sellable soda. Thus the materials require significant processing before they yield soda. This kind of process is principally used in the United States.*

The Solvay process is still the dominating process globally (see ESAPA 2004), implying that the output from the naturally occurring sources are not globally competitive, and that a decrease in NaOH demand therefore will primarily affect the Solvay process.

Nevertheless, we suggest that when relevant both soda production routes can be applied in a sensitivity analysis.

5. Environmental data for soda production

5.1. The solvay process

In the Ecoinvent database, the Solvay process can be found as *Soda, powder, at plant /RER/U*

The process is documented in Ecoinvent report no 8 (Althaus et al. 2003, p. 629). The main data source is *UBA (2001), a German report on the best available techniques (BAT) for soda production. This source presents data from 1999 from two German manufacturing plants: Solvay Soda Deutschland, located in Rheinberg and a production plant from the company Matthes and Weber, in Duisburg. The latter gave up the production at the end of the year 1999, but for the purpose of this study their data are also considered. Additional information is taken from Thieme (1993), KCL (2002) and Woode (1995). In this latter, each chapter is written by an industrial expert. The disadvantage of this source is that it does not mention the origin of the values reported.*

To be used for soda, all values of the Ecoinvent process shall be multiplied by 3, since the original data are allocated with 33% to Soda and 76% to calcium chloride. To

account for the by-product calcium chloride, the system shall be expanded to include its displacement. According to Weidema (2003), calcium chloride *can be used for de-icing and dust control because of its hygroscopic properties. However, it is not a very valuable product and part of it is deposited* (Moody 1969, Gerhartz 1985). Thus, the process to be displaced is the deposition of calcium chloride.

More recent data on the Solvay process is available in the form of a BREF note (ESAPA 2004).

5.2. Soda from natural ash

Data for soda ash production from trona are given in BCS Inc. (2002).

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