

# ENVIRONMENTAL FOOTPRINT COMPARISON TOOL

A tool for understanding environmental decisions related to the pulp and paper industry



## EFFECTS OF DECREASED RELEASE OF CHLORINATED COMPOUNDS ON ENERGY USE

### Electricity to Make Bleaching Chemicals

The electricity requirements, reported by a number of sources, necessary to produce the major chemicals used in bleach plants are summarized in Table C6.

**Table C6. Electrical Energy Requirements for Production of Chemicals in Bleach Plants (kWh/kg)**

Chemical	Formula	Mellroy and Wilczinsky 1999	Laxén and Henricson 1996	Folke et al. 1996	Dence and Reeve 1996	Paper Task Force 1995
Chlorine	Cl <sub>2</sub>	3		1.6	2.3 – 2.6	1.37*
Sodium hypochlorite	NaOCl			3.5		
Chlorine dioxide	ClO <sub>2</sub>	9.25 <sup>a</sup>	8.9	11		9.8
Sodium Hydroxide	NaOH	2.8 <sup>b</sup>	1.8	1.8	2.0 – 2.3	1.37*
Ozone	O <sub>3</sub>	19.9 <sup>c</sup>	10	14	13.4 <sup>d</sup>	11.9
Oxygen, cryogenic	O <sub>2</sub>	1.15		2.8	3	
Oxygen, PSA/VSA <sup>e</sup>	O <sub>2</sub>	0.4	0.4	2.8	2.65	0.39
Hydrogen peroxide	H <sub>2</sub> O <sub>2</sub>	0.75	0.61 – 3.85 <sup>f</sup>	3.5		1.69

<sup>a</sup> Based upon the R8 process.

<sup>b</sup> Based upon the use of oxidized white liquor (OWL) in the oxygen delignification stage and fresh caustic in extraction stages for the ODEopDED bleaching sequence.

<sup>c</sup> Ozone, 13 wt % O<sub>3</sub> in O<sub>2</sub>.

<sup>d</sup> From Gottlieb et al. (1994), Ozone, 6 wt % O<sub>3</sub> in O<sub>2</sub>, Electricity cost includes power of gas recycle system, O<sub>3</sub> generator power, and power for cooling needs (chilled water and cooling tower).

<sup>e</sup> A mill using only O<sub>2</sub> in the Eo stage would have cryogenic oxygen delivered on site. A mill with oxygen delignification would likely have a pressure swing absorption (PSA)/vacuum swing absorption (VSA) plant on site.

<sup>f</sup> The lowest estimate is based upon H<sub>2</sub> production by steam reforming, a slightly higher value is obtained using methanol cracking, and the highest estimate is based upon H<sub>2</sub> production by electrolysis.

\* The reasons for this value being low are not known.

Electricity requirement estimates reported by these published reference papers vary considerably for the primary ECF bleaching chemical ClO<sub>2</sub>, and the primary TCF bleaching chemicals, O<sub>3</sub> and H<sub>2</sub>O<sub>2</sub>. As much could be said for sodium hydroxide, which is common to both bleaching concepts. The relative cost and energy advantages of alternative bleach sequence configurations warrant scrutiny with regard to underlying estimates of electricity required for chemical manufacture.

**ClO<sub>2</sub> Manufacture:** Chlorine dioxide (ClO<sub>2</sub>) is the primary bleaching chemical used worldwide for final delignification and brightening of chemical pulps. Most mills in North America use purchased sodium chlorate to generate ClO<sub>2</sub> on site. The primary methods of generating ClO<sub>2</sub> at pulp mills are the Sterling R8/R10 process and similar Eka SVP-MeOH process. In 1992, 76% of the installed ClO<sub>2</sub> capacity in

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North America used one of these processes, where sodium chlorate is reduced to chlorine dioxide with methanol acting as the reducing agent (Stockburger 1992). The electrical energy required to produce chlorine dioxide is large (8.9 – 11.0 kWh/kg) because of the large energy requirements for the production of sodium chlorate. For example, in the R8 process, approximately 97% of the energy required to produce  $\text{ClO}_2$  is a result of the energy requirements to produce sodium chlorate. McIlroy and Wilczinsky's estimate of 9.25 kWh/kg is based upon the R8 process (McIlroy and Wilczinsky 1999); other authors do not specify a generation process.

**Ozone:** Ozone is produced by passing oxygen through a corona discharge, which has large electrical requirements (10.0 – 19.9 kWh/kg). With current technology, ozone yields from oxygen are low (6 to 13 wt. %). The differences in  $\text{O}_3$  electricity requirements among the authors tabulated above are most likely due to the concentrations of ozone being produced. It is known that the concentration of ozone production from oxygen is a function of applied voltage (Dence and Reeve 1996). The value reported by Gottlieb et al. (1994) of 13.4 kWh/kg is based upon an ozone production facility at a pulp mill and includes the most information regarding ozone production and auxiliaries.

**Caustic and Chlorine:** Sodium hydroxide and chlorine are commercially produced by the chloralkali process, which involves the electrolysis of sodium chloride solution with the anode and cathode separated by a membrane. For commercial production of sodium hypochlorite, the membrane is simply removed. Since the molecular weights of chlorine gas and sodium hypochlorite are similar, 71 and 74 respectively, their cost on a kg basis should be similar as well. It is unclear why there is a large difference in electricity requirements between chlorine gas and sodium hypochlorite reported by Folke et al. (1.6 kWh/kg vs. 3.5 kWh/kg respectively).

It has been reported that a chloralkali process with multi-layered membranes, zero gap, and cathode coatings has achieved a power consumption of 2000-2300 kWh/ton of sodium hydroxide at current densities of 2-4 kA/m<sup>2</sup>. This translates to 2.3-2.6 kWh/kg of  $\text{Cl}_2$  (Dence and Reeve 1996), values similar to the McIlroy and Wilczinsky reported value of 3.0 kWh/kg. McIlroy and Wilczinsky's values of 3.0 and 2.8 kWh/kg for  $\text{Cl}_2$  and NaOH are deemed representative because they are in fair agreement with the values reported elsewhere (Dence and Reeve 1996) and they consider the use of oxidized white liquor (OWL) as the alkali source for  $\text{O}_2$  delignification. The Paper Task Force (1995) value for caustic seems irregular, in comparison to these other reported values.

## References

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Stockburger, P. 1992. What you need to know before buying your next chlorine dioxide plant. In  
*Proceedings of the 1992 Tappi Engineering Conference*, 1085-1091. Atlanta, GA: Tappi Press.