ENVIRONMENTAL FOOTPRINT COMPARISON TOOL

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

ENERGY

EFFECTS OF DECREASED RELEASE OF CHLORINATED COMPOUNDS ON ENERGY USE

Energy Efficiency of Different Bleaching Sequences

Summing the energy content required to produce all chemicals used in the bleach plant allows a comparison of bleaching chemical electrical costs among various bleaching sequences. Comparisons of bleaching energy efficiency are best made among bleaching sequences with similar starting kappa number, final brightness value, and wood furnish.

Within the bleach plant, electrical energy is primarily used for chemical mixing and pumping of stock and filtrates. It is on the order of 30 kWh/ADt per bleaching stage (Dence and Reeve 1996).

Electricity demand in the bleach plant represents roughly 15% of the total electricity requirements at bleached kraft market pulp mills.

NCASI staff compared a number of laboratory bleaching studies reported in the literature to compare the electricity requirements of ECF, ECF-lite (ECF bleaching with low chlorine dioxide doses and increased use of oxygen or ozone), TCF, and chlorine-based (for a historical perspective) bleaching sequences. ECF-lite bleaching sequences are bleaching sequences using less than 10 kg/ODMT of chlorine dioxide (Chirat and Lachenal 1999). Only literature sources with complete measured chemical charge information were used. The bleach sequences examined and their reference sources are listed in Table C7. For complete chemical charge information, the reader is referred to the individual literature references shown in the last column of the table.

Electricity requirements for a number of chemicals used in the bleach plant were not considered in the electricity calculations. TCF sequences use chelants such as EDTA or DTPA for chelation of transition metals prior to hydrogen peroxide and ozone bleaching, and use magnesium sulfate ($MgSO_4$) in hydrogen peroxide bleaching as a bleach agent stabilizer. Many mills also use $MgSO_4$ to minimize pulp degradation in oxygen delignification stages. These costs were not considered and are expected to be small. Sulfuric acid is commonly used in both ECF and TCF sequences for pH control. The electrical costs of sulfuric acid addition were not considered because of its low cost and because sulfuric acid addition numbers are often not reported in the literature.

The overall electrical requirements for TCF sequences are quite dependent upon the estimated ozone and hydrogen peroxide electricity requirements. If the values of 13.4 kWh/kg and 0.75 kWh/kg for ozone and hydrogen peroxide, respectively, are used (the lower range for these chemicals), TCF sequences are comparable to ECF sequences for electricity requirements if only the electricity needs for the bleaching chemicals are considered. That trend is shown in Figure C9.

The chlorine-based sequences fall in the same range as ECF sequences. Even though chlorine gas is less expensive to produce than chlorine dioxide, chlorine-based sequences, in general, require higher sodium hydroxide charges in subsequent extraction stages, increasing their overall electrical requirement.

TCF sequences tend to have more bleaching stages than ECF sequences. If an average value of 30 kWh/ADmt per bleaching stage (for pumping and mixing) is factored into the calculation, ECF sequences have lower electrical consumption, as shown Figure C10.

The difference appears more dramatic if values for the electrical energy required to produce ozone and peroxide are taken from the upper end of their reported range. If values of 19.9 kWh/kg and 3.5 kWh/kg for ozone and hydrogen peroxide, respectively, were used (the higher range for these chemicals), TCF sequences, on average, would appear to require 50% more electricity than ECF sequences. That outcome is represented in Figure C11. Figure C12 incorporates the additional electrical power required for pumping and mixing.

To the extent that electrical energy efficiency is sought in the bleaching of kraft pulps, ECF bleaching would generally appear to be the option of choice, especially in comparison with longer TCF sequences, although there are exceptions. The overall energy efficiency of bleached kraft pulp production, however, requires integrated consideration of prior delignification accomplished in pulping.

Table C7. Bleach Sequences from Literature Used in the Electricity Calculations

Bleaching Sequence	Classification	Pulp Type	Kappa into Bleach Plant	Final Brightness (ISO %)	Reference
C_DEHDED	C, lab	Northeastern softwood kraft pulp	25.3	90.3	Histed & Nicolle 1976
CEDED	C, lab	Softwood kraft pulp	25	85	Ruhanen & Dugal 1982
C_DEDED	C, lab	Black spruce kraft pulp	30.6	90.6	Liebergott et al. 1984
C_DE_ODED	C, mill	Eucalyptus	17	90.5	Walsh et al. 1999
C_DE_ODED	C, mill	Softwood kraft pulp	21.3	91.4	Wilson et al. 1999
D(EP)DED	ECF, lab	O_2 delignified softwood and hardwood kraft pulp	12.1	90.1	Rautonen et al. 1996
D(EP)DED	ECF, lab		12.1	90.0	Rautonen et al. 1996
DEDED	ECF, lab		13.2	89.1	Rautonen et al. 1996
DEDED	ECF, lab		18.4	89.4	Rautonen et al. 1996
OD(EOP)DD	ECF, lab	Eucalyptus	18.2	90.0	Colodette et al. 1999
(OQ)(OP)(ZE)DD	ECF-lite, lab	Eucalyptus	18.2	90.0	Colodette et al. 1999
$DEoD_1ED_2$	ECF, lab	O_2 delignified softwood kraft pulp	12.7	88.4	Toven & Gellerstedt 2003
DEOQ(PO)	ECF-lite, lab		12.7	87.5	Toven & Gellerstedt 2003
$(DZ)EoD_1ED_2$	ECF-lite, lab		12.7	87.5	Toven & Gellerstedt 2003
(DZ)EoQ(PO)	ECF-lite, lab		12.7	87.7	Toven & Gellerstedt 2003
DEopD	ECF, mill	Hardwood	19	90.4	Pryke et al. 1999
DEopD	ECF, mill	Softwood	34	88.7	Pryke et al. 1999
DEopD	ECF, mill	Hardwood	7.5	90+	Herbert 1999
DEopDD	ECF, mill	Softwood	14	90+	Herbert 1999
QOQPZPP	TCF, lab	O_2 delignified softwood and hardwood kraft pulp	7.2	89.4	Rautonen et al. 1996
QOQZQPZP	TCF, lab		7.2	90.6	Rautonen et al. 1996
QOQPZP	TCF, lab		9.1	89.6	Rautonen et al. 1996
QPZPZP	TCF, lab		12.1	88.8	Rautonen et al. 1996
QZPZP	TCF, lab		12.1	88.5	Rautonen et al. 1996
QPZPZP	TCF, lab		13.2		Rautonen et al. 1996
QPQZPZP	TCF, lab		18.4	89.5	Rautonen et al. 1996
QOQPZPZPP	TCF, lab		18.4	88.2	Rautonen et al. 1996
QOQZQPZP	TCF, lab		18.4	88.9	Rautonen et al. 1996
QOQZPZP	TCF, lab		18.4	89.0	Rautonen et al. 1996
(OQ)(OP)(ZQ)(PO)	TCF, lab	Eucalyptus	18.2	90.0	Colodette et al. 1999
Z(EO)Q(PO)	TCF, lab	Softwood kraft	30	89.2	Ni & Ooi 1996

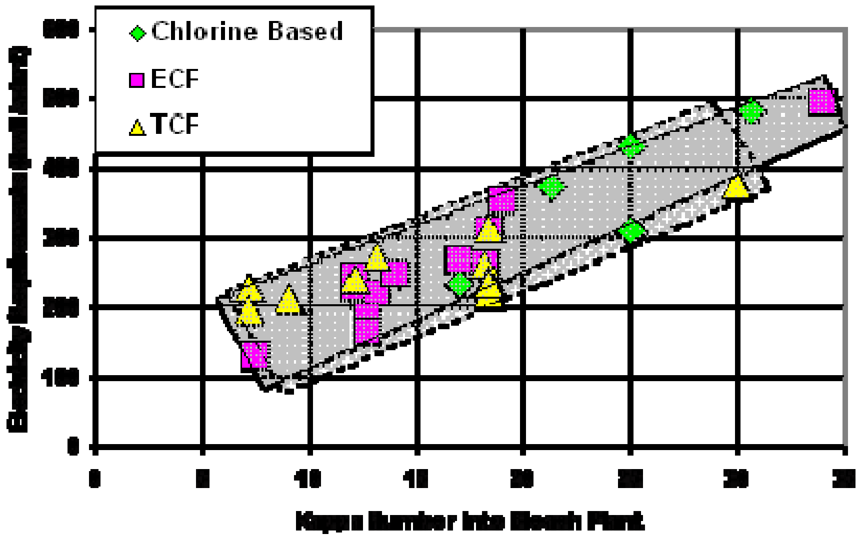

Figure C9. Electrical Energy Requirements for Bleaching Sequences When Only Considering Electricity Required for Chemical Production and Lower Electricity Values for O_3 and H_2O_2
[Dotted quadrangle encapsulates TCF sequences; solid quadrangle encapsulates ECF sequences]

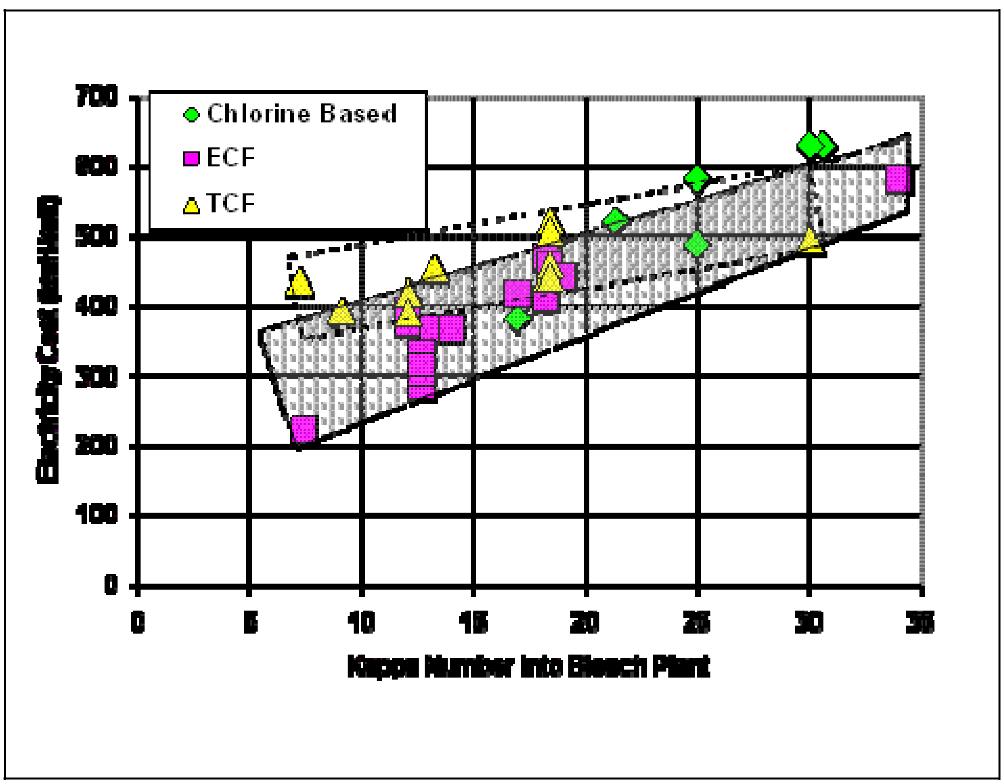

Figure C10. Electrical Energy Requirements for Bleaching Sequences When Including Electricity Required for Stage Pumping and Mixing and Using Lower Electricity Values for O_3 and H_2O_2
[Dotted quadrangle encapsulates TCF sequences; solid quadrangle encapsulates ECF sequences.]

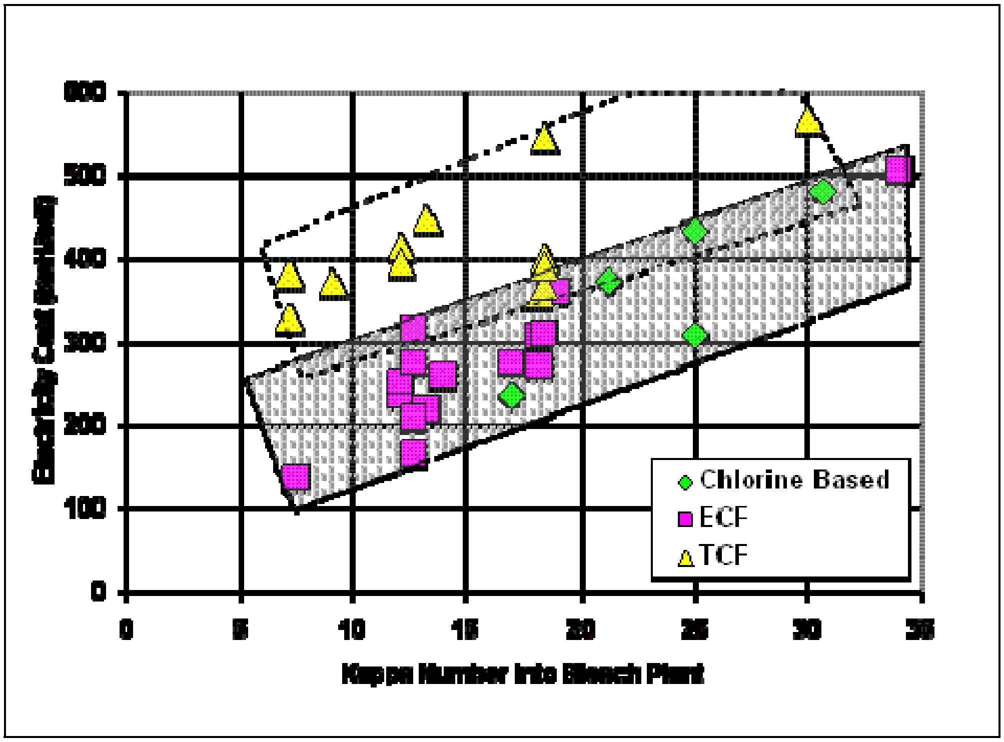

Figure C11. Electrical Energy Requirements for Bleaching Sequences When Only Considering Electricity Required for Chemical Production and Higher Electricity Values for O_3 and H_2O_2
[Dotted quadrangle encapsulates TCF sequences, Solid quadrangle encapsulate ECF sequences.]

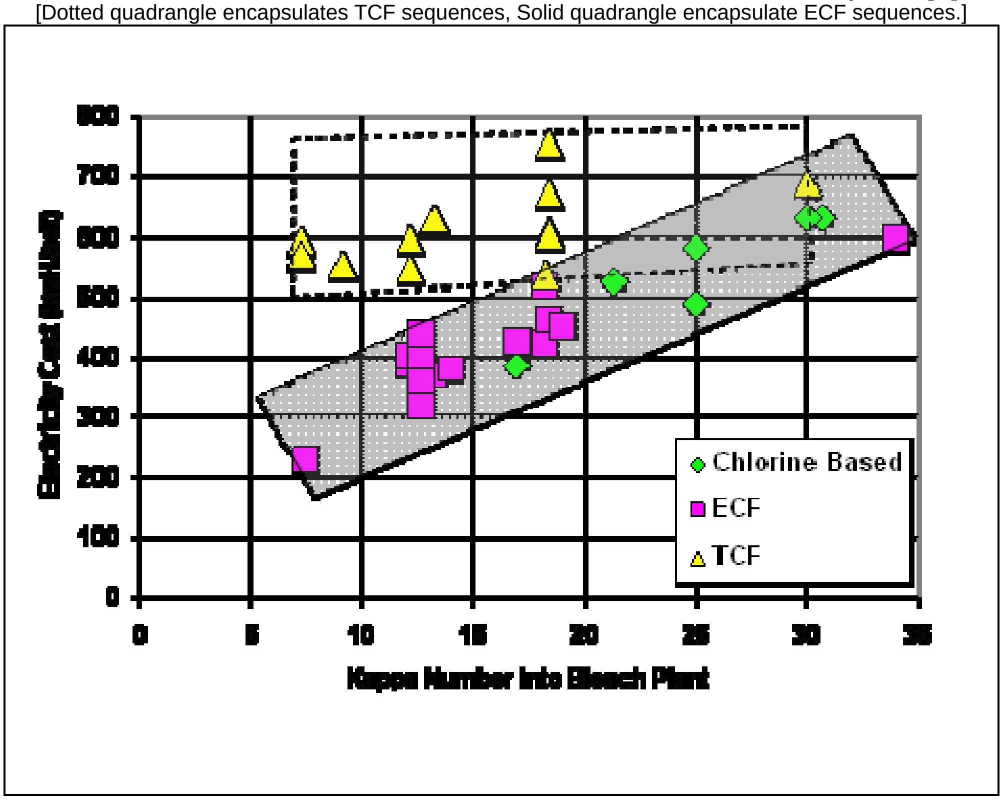

Figure C12. Electrical Energy Requirements for Bleaching Sequences When Including Electricity Required for Stage Pumping and Mixing and Using Higher Electricity Values for O_3 and H_2O_2
[Dotted quadrangle encapsulates TCF sequences, Solid quadrangle encapsulate ECF sequences.]

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