ENVIRONMENTAL FOOTPRINT COMPARISON TOOL

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

ENERGY

EFFECTS OF DECREASED WATER USE ON ENERGY USE

Energy Use at Mills

Kraft Mills | Mechanical Pulp Mills | Paper, Board, Tissue and Pulp Machines | Recycling and Deinking Mills

Overview

Nygaard compared the energy requirements among the major pulping types. His results, shown in Table W2, illustrate that kraft and TMP/CTMP consume approximately equivalent amounts of energy. The majority of energy for kraft pulping is used for process heating while the majority of energy for TMP/CTMP is for electrical energy to drive refiners. Deinking facilities have approximately 25% of the energy requirements of kraft and TMP/CTMP mills.

Table W2. Total Energy Consumption for Different Pulp Facilities Excluding Paper Machines (Nygaard 1997)

	Electrical Power(kWh/adt)	Process Heat(kWh/adt)	Total(kWh/adt)
Kraft	560	2500	3060
TMP/CTMP	3000	200	3200
Deinked pulp	600	220	820

Energy Balance at Kraft Mills

The overall energy balance has been estimated for a bleached kraft mill and is given in Table W3 and Table W4. The bleaching sequence for the simulated mill is ODE$_O$DEpD. Electrostatic precipitator (ESP) dust is assumed to be purged to maintain the chloride levels at or below 20 g/L NaCl in the white liquor. The corresponding overall water balance for the bleached kraft mill is given in Table W5 and Table W6. For mills that internally recycle water used in some or all process operations, the energy balance shifts considerably. For these configurations that use a “closed-cycle” concept, water consumption, defined as the portion of water removed from the local watershed or ecosystem that is not directly returned to the immediate environment in the form of liquid discharge from a mill, carries with it a much larger percentage of the overall energy leaving the system.

Table W3. Energy Sources to a Bleached Kraft Mill (Gleadow et al. 1997)

	Recent design (GJ/adt)	Closed-cycle (GJ/adt)
Energy sources		
Recovery boiler (BLS)	20.7	22.3
Power boiler (bark, wood waste, fuel)	11.1	11.1
Lime kiln (fuel)	2.0	2.0
TOTAL	33.8	35.4

Effects of Decreased Water Use on Energy Use

Energy Use at Mills

Table W4. Energy Sinks from a Bleached Kraft Mill (Nygaard 1997)

	Recent design< (GJ/adt)	Closed-cycle (GJ/adt)
Energy rejection (sinks)		
Power (exported)	3.8	3.6
Process cooling	9.1	20.2
Effluent cooling	5.0	-
Clear water by-pass	0.5	-
Loss with effluent	4.0	-
Pulp dryer hood	3.5	3.5
Recovery (evaporation of SBL)	1.9	2.0
Lime kiln losses	2.0	2.0
Other losses*	4.0	4.0
TOTAL	33.8	35.4
Internal flows		
Electricity		
Generated	6.7	6.9
Consumed	2.9	3.3

* Other losses: soot-blowing, washer-hood losses, space heating, miscellaneous uses, and unspecified losses.

Table W5. Water Input to a Bleached Kraft Mill (Nygaard 1997)

	Recent design (m3/adt)	Closed-cycle (m3/adt)
Water to mill		
Fresh water	67.7	9.1
In wood	2.0	2.0
In chemicals	0.2	0.1
Recycle	-	16.6
TOTAL	69.9	27.8

Table W6. Water Output from a Bleached Kraft Mill (Nygaard 1997)

	Recent design(m3/adt)	Closed-cycle (m3/adt)
Water from mill		
Mill effluent	61.9	-
Recycle	-	16.6
Evaporation	7.9	11.1
Primary sludge	0.1	0.1
TOTAL	69.9	27.8
Consumptive Use (%)	11.4	40.3

Bruce summarized steam and electricity usage by department for a number of kraft mills from the around the world (Tables W7 and W8).

Table W7. Department Steam Consumption (GJ/adt) (Bruce 1998)

	Softwood							Hardwood	
Department	Typical 1980	Model Mill	Recent Mill Designs						
			A	B	C	D	E	F
Steam & Chemical Recovery	4.9	1.2	3.3	1.7	2.6	1.6	1.1	0.9
Pulp Drying	4.4	2.3	2.7	2.7	4.5	3.1	4.1	3.0
Evaporation and Stripping	4.1	3.3	3.9	4.2	5.4	4.2	3.8	3.0
Digesting, Washing, Screening	4.1	1.8	2.3	2.0	3.3	3.2	1.9	2.2
Bleaching	3.5	0.0	2.8	0.4	0.6	0.4	3.4	0.6
Recausticizing & Kiln	0.5	0.0	0.4	0.3	0.0	0.0	0.0	0.3
Woodroom	0.3	0.0	0.0	0.0	0.0	0.2	0.4	0.4
Chemical Preparation	0.3	0.1	0.3	0.4	0.4	0.3	0.2	0.3
O_2 Delignification	0.0	0.4	1.3	0.5	0.2	0.2	0.3	0.0
Totals	22.1	9.1	17.0	12.2	17.0	13.2	15.5	10.7

NOTES: Typical 1980 Mill is based upon a 1980 survey of 17 Canadian and 7 Nordic mills.
Model Mill is based upon a hypothetical mill designed for energy efficiency.
1. South American softwood mill designed in the 1990s
2. South American softwood mill designed in the 1990s
3. North American softwood mill designed in the 1990s
4. European softwood mill designed in the 1990s
5. North American hardwood mill designed in the 1990s
6. European hardwood mill designed in the 1990s

Table W8. Department Power Consumption (kWh/adt) (Bruce 1998)

	Softwood					Hardwood	
Department	Model Mill	Recent Mill Designs					
		A	B	C	D	E	F
Steam & Chemical Recovery	90	191	18	124	110	91	150
Pulp Drying	165	155	150	143	140	114	122
Evaporation and Stripping	35	125	75	98	30	125	28
Digesting, Washing, Screening, O_2 Delignification	125	168	181	180	205	156	156
Bleaching	55	124	33	132	110	92	94
Recausticizing & Kiln	60	30	61	23	25	14	19
Woodroom	55	24	43	37	20	68	28
Water & Effluent Treatment	40	68	108	56	40	85	45
Totals	625	885	669	793	680	745	642

NOTE: Model Mill is based upon a hypothetical mill designed for energy efficiency
1. North American softwood mill designed in the 1990s
2. North American softwood mill designed in the 1990s
3. Chilean softwood mill designed in the 1990s
4. European softwood mill designed in the 1990s
5. North American hardwood mill designed in the 1990s
6. European hardwood mill designed in the 1990s

References

Bruce, D. 1998. Benchmarking energy consumption and identifying opportunities for conservation. In *Proceedings of the 1998 84th annual meeting of the technical section of Canadian Pulp and Paper Association*. *Part B*. January 27-30 1998, Montreal, Canada.

Gleadow, P., Hastings, C., Barynin, J., Schroderus, S., and Warnqvist, B. 1997. Towards closed-cycle kraft: ECF versus TCF case studies. *Pulp & Paper Canada*, 98(4): T100-T110.

Nygaard, J. 1997. Energy aspects of mechanical pulp, chemical pulp and recycled fibres. In *Proceedings 1997 Tappi International Mechanical Pulping Conference*, 17-27. Atlanta, GA: Tappi Press.

Mechanical Pulp Mills

Overview

Nygaard compared the energy requirements among the major pulping types. His results, shown in Table W9, illustrate that kraft and TMP/CTMP consume approximately equivalent amounts of energy. The majority of energy for kraft pulping is used for process heating while the majority of energy for TMP/CTMP is for electrical energy to drive refiners. Deinking facilities have approximately 25% of the energy requirements of kraft and TMP/CTMP mills.

Table W9. Total Energy Consumption for Different Pulp Facilities Excluding Paper Machines (Nygaard 1997)

	Electrical Power (kWh/adt)	Process heat (kWh/adt)	Total (kWh/adt)
Kraft	560	2500	3060
TMP/CTMP	3000	200	3200
Deinked pulp	600	220	820

Energy requirements for mechanical pulp mills

Jackson and Wild summarized electricity and steam usage by department for a modern mechanical pulp mill (see Table W10). The numbers generated are for a 500 bdmt/d single-line TMP mill using a fiber supply consisting of 50% chips and 50% logs. Electricity for the refiner motors comprises approximately 81% of the total electricity usage.

Table W10. Overall Electrical Requirements for a Modern 500 bdmt/day TMP Mill (Jackson and Wild 1999)

Area	Pumps	Agitators	Screens	Blowers & fans	Mechanical drives	Refiner motors	Total	% of total
Material handling								
Chips	7			119	998		1124	
Logs	7			119	3010		3126	
Average	7			119	2004		2130	3.4
TMP								
Chip pretreatment	346	4		45	1751		2146	3.4
Mainline refining		224			566	37083	37873	60.1
Low consistency refining	93				4	2083	2180	3.5
Screening & cleaning	447	224	447				1118	1.8
Rejects treatment	432	652	298	30	875	10771	13058	21.1
Dewatering	186			30	37		253	0.4
Bleaching	596						596	0.9
Heat recovery	335						335	0.5
WW management	216						216	0.3
Effluent treatment	1006			745	112		1863	3.0
Total	3664	1104	745	969	5349	49937	61768	100
% of Total	5.9	1.8	1.2	1.6	8.7	80.8	100	

References

Jackson, M. and Wild, N. 1999. Mechanical pulp mills. In *energy cost reduction in the pulp and paper industry*, T.C. Browne, tech. ed. Montreal: Pulp and Paper Research Institute of Canada (Paprican).

Nygaard, J. 1997. Energy aspects of mechanical pulp, chemical pulp and recycled fibres. In *Proceedings 1997 Tappi International Mechanical Pulping Conference*, 17-27. Atlanta, GA: Tappi Press.

Paper, Board, Tissue, and Pulp Machines

Total energy requirements for paper machines vary depending upon grade (see Table W11). In general, paper mills that have higher specific water consumption (i.e., water consumed per ton of paper product) will have higher energy consumption due to heating pulp stock and whitewater.

Table W11. Energy Requirements for Different Recycling and Deinking Process Steps (Williamson 1999)

	Steam consumption	Gas consumption	Electrical consumption	
Grade	(GJ/adt)	(GJ/adt)	(GJ/adt)	(kWh/adt)
Newsprint	3.4 – 5.5	-	1.2 – 2.3	420-630
Coated groundwood	5.1 – 5.6	-	2.0 – 2.9	550 – 820
Uncoated woodfree	4.3 – 7.2	-	2.0 – 2.4	550 – 670
Coated woodfree	3.7 – 7.7	-	1.6 – 3.2	440 – 900
Linerboard	3.4 – 8.8	-	1.8 – 2.4	515 – 660
Tissue	2.6 – 4.5	2.0 – 2.4	3.0 – 3.8	835 – 1050

The typical energy breakdown among process areas for a newsprint machine is given in Table W12.

Table W12. Typical Energy Consumption by Area for a Newsprint Machine (Schmidt 1981)

	Steam consumption	Electrical consumption	
Process Area	(GJ/adt)	(GJ/adt)	(kWh/adt)
Stock preparation	0.66	0.36	100
Forming, pressing	0.3	0.51	142
Drying, finishing	3.2	0.16	45
Auxiliary systems	-	0.15	42
Total	4.16	1.18	329

References

Williamson, P.N. (ed.). 1999. Paper, board, tissue and pulp machines. Chapter 7 in *Energy cost reduction in the pulp and paper industry: A monograph*. Montreal: Pulp and Paper Research Institute of Canada (Paprican).

Schmidt, K. 1981. Saving process energy in the papermaking industry. *Paper* 196(10): 20-26, 40.

Recycling and Deinking Mills

Overview

Nygaard compared the energy requirements among the major pulping types. His results, shown in Table W13, illustrate that kraft and TMP/CTMP consume approximately equivalent amounts of energy. The majority of energy for kraft pulping is used for process heating while the majority of energy for TMP/CTMP is for electrical energy to drive refiners. Deinking facilities have approximately 25% of the energy requirements of kraft and TMP/CTMP mills.

Table W13. Total Energy Consumption for Different Pulp Facilities Excluding Paper Machines (Nygaard 1997)

	Electrical Power(kWh/adt)	Process Heat(kWh/adt)	Total (kWh/adt)
Kraft	560	2500	3060
TMP/CTMP	3000	200	3200
Deinked pulp	600	220	820

Energy for Recycling and Deinking

Total energy requirements at deinking facilities will typically vary from 300 to 1000 kWh/adt depending upon the final product and process design (see Table W14).

Table W14. Energy Requirements for Different Recycling and Deinking Process Steps (Williamson 1999)

	Typical Energy Consumption (kWh/adt)	
Unit Operation	Electrical power	Steam energy
Pulping	62-74	0-400
Coarse screening	25-40	-
Flotation	38-90	-
Lightweight cleaning	15-29	-
Heavyweight cleaning	27-40	-
Fine screening	31-69	-
Washing/Thickening	17-19	-
Kneading/Dispersion/Bleaching	30-100	0-535

The typical energy breakdown among unit operations at a deinking plant is given in Table W15.

Table W15. Typical Energy Consumption by Unit Operation for a Deinking Plant (Williamson 1999)

Process Area	Temperature Limits	Steam Requirements1 (kg/adt)	(kWh/adt)
Pulping	25-45°C Chemi-mechanical process: 65-70°C	525-600	350-400
Flotation	45-55°C depending upon surfactant cloud point	-	-
Dispersion	90-110°C (Frictional temperature increase from a kneader 20-35°C)	215-325	140-200
Bleaching	Hydrosulfite or FAS: 60-65°C Atmospheric peroxide: 65-85°C Pressurized peroxide: 95-105°C	190-260 90-190 690-840	135-180 60-125 445-535

NOTE: Assuming direct heating saturated steam at a pressure of 3.5 bar, no heat loss, initial pulp temperature 25°C for pulping, 45°C for dispersion and bleaching.

References

Nygaard, J. 1997. Energy aspects of mechanical pulp, chemical pulp and recycled fibres. In *Proceedings 1997 Tappi International Mechanical Pulping Conference*, 17-27. Atlanta, GA: Tappi Press.

Williamson, P.N. (ed.). 1999. Paper, board, tissue and pulp machines. Chapter 7 in *Energy cost reduction in the pulp and paper industry: A monograph*. Montreal: Pulp and Paper Research Institute of Canada (Paprican).