Calculation of Drying Costs

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Yves Fortin

Faculté de foresterie, de géographie et de géomatique

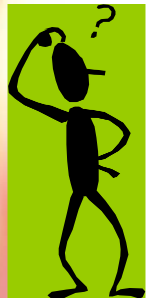
Université Laval

Contents

- Introduction
- Energy consumption
- Drying cost components
- Excel spreadsheets
- Case studies
- How to reduce drying costs
- Conclusions

Introduction

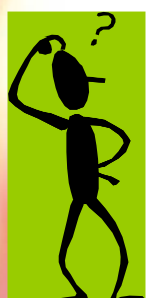
Why to calculate drying costs?



- to help choosing a new drying installation
- to determine the real cost of drying for an existing intallation
- to determine custom drying rates
- to determine actions to take to reduce drying costs

Introduction (cont?)

How to determine drying costs?



- Feaseability study (capital investment decisions): net present value of investment (NPVI: capital outlays – cash inflows), internal or discounted rate of return (IRR or DRR) (ref. Engalichev and Eddy 1970)
- Calculation of the various cost components: calculation of drying costs at a given time, not taking into account cash inflows and time value of money (Goulet and Ouimet 1970, McMillen and Wengert 1978, Hukka 2001, Chanrion *et al*. 1989)

INTRODUCTION (cont')

The calculation of drying costs involves first the calculation of energy consumption

INTRODUCTION (cont')

Kiln drying is a very demanding energy process

Balsam fir drying from 100% to 15%: 100 MBF, 2''x4''x8'

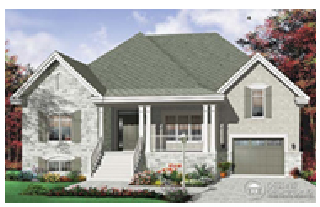
56 000 kg H_2O → 1.09 kWh/kg H_2O

61 040 kWh (208 millions BTU)

1-year bungalow consumption:

100 millions BTU

N.B. 1 kWh= 3 421 BTU



Energy consumption Excel spreadsheet
Input data

- ✓ Wood species and lumber dimensions
- ✓ Geometry of kiln and lumber stack
- ✓ Characteristics of equipment
- ✓ Initial and final moisture contents
- ✓ Conditions of exterior climate
- ✓ Drying schedule
- ✓ Drying curve

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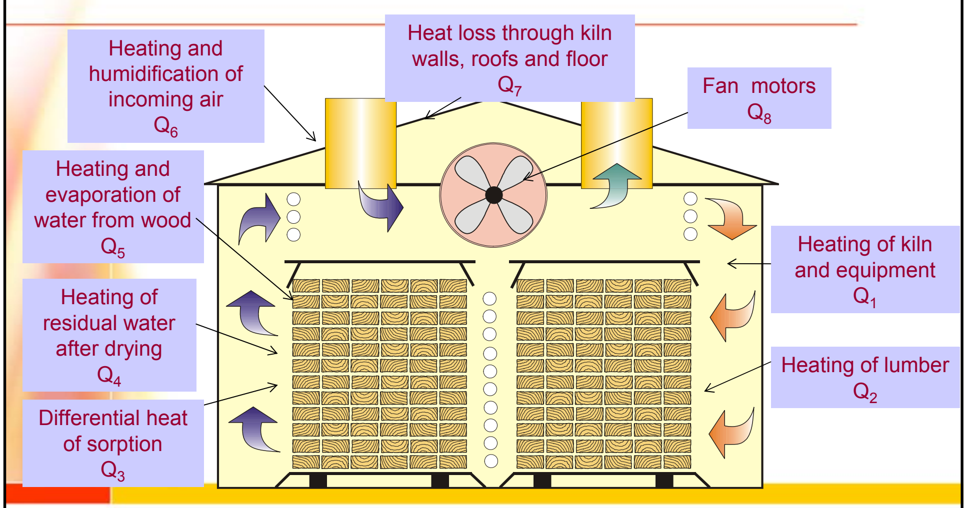
Energy consumption Excel spreadsheet
Sources of energy consumption (at the kiln only)



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Drying cost Excel spreadsheet
Input data

- ✓ Geometry of kiln and lumber stack
- ✓ Characteristics and costs of kiln and storage equipment
- ✓ Initial and final moisture contents
- ✓ Kiln operation capacity and number of kilns
- ✓ Process efficiency
- ✓ Labor salaries
- ✓ Kiln startup factor (1.2 -1.5)
- ✓ Other various costs and rates (stickers, fuel, taxe and interest rates, etc.)

Drying costs Excel spreadsheet
Cost components

- Fixed costs
  - ✓ Equipment, buildings and stickers (depreciation)
  - ✓ Interest on investment
  - ✓ Insurances (kilns, equipement, buildings, lumber)
  - ✓ Administration (office costs attributed to drying)
  - ✓ Taxes (land, buildings, lumber, yard facilities)
  - ✓ Interest on lumber inventory and land
  - ✓ Maintenance of yard and snow removal

Drying costs Excel spreadsheet

Cost components

- Variable costs
  - ✓ Labor (handling, stacking, kiln, boiler and forklift operators)
  - ✓ Energy (heat and electrical)
  - ✓ Maintenance of kilns and buildings
  - ✓ Forklift maintenance and use
  - ✓ Wood residues marketing value
  - ✓ Degrades

Drying cost Excel spreadsheet

- Global drying capacity

$$Drying\,capacity = \frac{\sum(V_i\, t_i)}{c_a\, n}$$

V_i = annual volume per species
t_i = drying time per species (days)
C_a = apparent coefficient of staking (= 1 for the reference thickness)
n = number of drying days per year

Drying cost Excel spreadsheet

- Drying process thermal efficiency

$$\mathrm{Eff}_{\mathrm{ther}} = \frac{h_{vap} + h_{sorp}}{\mathrm{N}}$$

h_{vap} = heat of vaporisation (kJ/kg$_{H2O}$ or BTU/lb$_{H2O}$)
h_{sorp} = heat of sorption (kJ/kg$_{H2O}$ or BTU/lb$_{H2O}$)
N = total energy to evaporate one 1 kg or 1 lb of water from wood) (kJ/kg$_{H2O}$ or BTU/lb$_{H2O}$)

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Drying cost Excel spreadsheet

- Annual heat consumption

$$C_c = \frac{D_b\left(M_i - M_f\right)VN}{100R} \qquad \text{(kJ or BTU)}$$

D_b = Green basic density of wood
M_i = initial moisture content (%)
M_f = final moisture content (%)
R = boiler efficiency

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Drying cost Excel spreadsheet

- Calculation approaches
  - ✓ group of species: gives an average drying cost only
  - ✓ one species and one size at the time:
    - can be done on the individual drying capacity basis
    - can be done on the global drying capacity basis by taking into account individual drying times and volumes and applying a correction factor to the cost components which are affected by the global capacity approach (existing installations)

Case study No 1: SPF medium size mill

- ✓ 75 millions MBF yearly production
- ✓ 2x4 commodities, 50% white spruce, 50% balsam fir
- ✓ Fir IMC: 115%; Spruce IMC: 60%; Target MC: 15%
- ✓ Drying time: 150 hrs for fir; 65 hrs for spruce
- ✓ Global drying capacity: 969 MBF (670 M bm for fir; 299 for spruce)
- ✓ 3 track-loaded kilns of 223 MBF for fir; 2 kilns of 150 MBF for spruce (individual capacity approach)
- ✓ 4 track-loaded kilns of 248 MBF each for the global capacity approach
- ✓ Cross-shaft fan arrangement
- ✓ Steam heated kilns (bark and sawdust residues)
- ✓ Conventional drying schedule
- ✓ Exterior air conditions: 41ºF (5ºC) and 70% RH
- ✓ Electricity cost: 0.135$/kWh
- ✓ 5-7% downgrading for each grade

Case study: white spruce individual capacity
Energy consumption and kiln efficiency sheet

Q_i	kJ	%	kJ	%	kJ/m³$_{app}$	kWh/kgH_2O
	Heat + Electricity		**Heat only**			
1	10 931 187	5.0	10 931 187	5.2	28 707	0.06
2	7 027 762	3.2	7 027 762	3.4	18 456	0.04
3	976 505	0.5	976 505	0.5	2 564	0.01
4	5 202 651	2.4	5 202 651	2.5	13 663	0.03
5	123 245 581	56.8	123 245 581	59.1	323 661	0.72
6	53 785 634	24.8	53 785 634	25.8	141 249	0.32
7	7 541 796	3.5	7 541 796	3.6	19 806	0.04
8	8 169 882	3.8	----			
Total	**216 880 999**	**100**	**208 711 117**	**100**	**548 105**	**1.23**

Corrected heat consumption (energy recovered from fans)
530 941
Apparent efficiency
0.58
Boiler heat consumption

MJ/m³$_{app}$	BTU/MBF
707.9	**1 583 597**

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Case study: white spruce individual capacity
Cost sheet

Cost component	Total annual drying cost $	$/m³	$/MBF	Percentage
Depreciation	198 479	2.34	5.52	15.89
Interest on investment	70 019	0.83	1.95	5.61
Insurances	32 262	0.38	0.90	2.58
Administration	42 426	0.50	1.18	3.48
Taxes	5 375	0.06	0.15	0.42
Interest on inventory and land	18 959	0.22	0.53	1.55
Yard maintenance and snow removal	15 000	0.18	0.42	1.18
Labor	195 000	2.30	5.42	15.31
Electrical energy	126 831	1.49	3.53	8.70
Forklift maintenance and fuel	41 750	0.49	1.16	3.28
Building and equipment maintenance	29 925	0.35	0.83	3.45
Wood residues marketing value	325 017	3.83	9.04	22.30
Drying degrades	148 068	1.75	4.12	12.14
Total	**1 249 110**	**14.72**	**34.74**	**100**

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Case study: white spruce global capacity

Cost sheet

Cost component	Total annual drying cost $	$/m³	$/MBF	Percentage
Depreciation	184 387	2.10	4.96	15.21
Interest on investment	64 078	0.73	1.72	5.29
Insurances	29 991	0.34	0.81	2.47
Administration	43 892	0.50	1.18	3.62
Taxes	4 094	0.05	0.11	0.34
Interest on inventory and land	18 615	0.21	0.50	1.54
Yard maintenance and snow removal	13 905	0.16	0.37	1.15
Labor	195 000	2.22	5.24	16.09
Electrical energy	108 695	1.24	2.92	8.97
Forklift maintenance and fuel	56 200	0.64	1.51	4.64
Building and equipment maintenance	27 300	0.31	0.73	3.20
Wood residues marketing value	312 535	3.56	8.40	25.79
Drying degrades	153 185	1.75	4.12	12.64
Total	**1 211 876**	**13.81**	**32.58**	**100**

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Case study: balsam fir individual capacity

Energy consumption and kiln efficiency sheet

Q_i	kJ	%	kJ	%	kJ/m³$_{app}$	kWh/kgH_2O
	Heat + Electricity		**Heat only**			
1	15 946 661	2.5	15 946 661	2.6	27 919	0.03
2	9 730 394	1.5	9 730 394	1.6	17 036	0.02
3	1 422 907	0.2	1 422 907	0.2	2 491	0.00
4	7 586 422	1.2	7 586 422	1.3	13 282	0.01
5	379 288 029	59.6	379 288 029	62.6	664 043	0.72
6	168 624 253	26.5	168 624 253	27.8	295 221	0.32
7	23 763 483	3.7	23 763 483	3.9	41 604	0.05
8	29 609 619	4.7	----			
Total	**635 971 767**	**100**	**606 362 148**	**100**	**1 061 596**	**1.16**

Corrected heat consumption (energy recovered from fans)

1 020 125

Apparent efficiency

0.61

Boiler heat consumption

MJ/m³$_{app}$	BTU/MBF
1 360.2	**3 042 647**

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Case study: balsam fir separate capacity

Cost sheet

Cost component	Total annual drying cost $	$/m³	$/MBF	Percentage
Depreciation	385 410	4.56	10.76	19.31
Interest on investment	132 765	1.57	3.71	6.65
Insurances	62 245	0.74	1.74	3.12
Administration	42 268	0.50	1.18	2.12
Taxes	9 500	0.11	0.27	0.48
Interest on inventory and land	41 284	0.49	1.15	2.07
Yard maintenance and snow removal	15 000	0.18	0.42	0.75
Labor	217 500	2.57	6.07	10.90
Electrical energy	263 954	3.12	7.37	13.23
Forklift maintenance and fuel	41 750	0.49	1.17	2.09
Building and equipment maintenance	56 400	0.67	1.57	4.31
Wood residues marketing value	580 249	6.86	16.20	29.07
Drying degrades	147 514	1.75	4.12	7.39
Total	**1 995 838**	**23.61**	**55.72**	**100**

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Case study No 2: White pine mill

- ✓ 14.8 millions MBF yearly production ; boards 4/4
- ✓ IMC: 120%; Target MC: 7%
- ✓ Drying time: 240 hrs
- ✓ Drying capacity: 425 MBF
- ✓ 4 package-loaded kilns
- ✓ Steam heated kilns (dry residues: 60$/dry metric tonne)
- ✓ Conventional drying schedule
- ✓ Exterior air conditions: 41ºF (5ºC) and 70% RH
- ✓ Electricity cost: 0.135$/kWh
- ✓ Storage shed for dry lumber
- ✓ Top loading plates
- ✓ 7-10% downgrading for each grade

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Case study: white pine global capacity

Energy consumption and kiln efficiency sheet

Q_i	kJ	%	kJ	%	kJ/m^3_{app}	kWh/kgH_2O
	Heat + Electricity		**Heat only**			
1	11 162 850	2.2	11 162 850	2.4	44 602	0.03
2	6 197 180	1.2	6 197 180	1.3	24 761	0.02
3	2 921 826	0.6	2 921 826	0.6	11 674	0.01
4	2 414 420	0.5	2 414 420	0.5	9 647	0.01
5	294 379 506	58.2	294 379 506	62.7	1 176 211	0.72
6	130 276 285	25.7	130 276 285	27.7	520 527	0.32
7	22 259 545	4.4	22 259 545	4.7	88 939	0.05
8	36 592 941	7.2	----			
Total	**506 204 552**	**100**	**469 611 611**	**100**	**1 876 362**	**1.15**

Corrected heat consumption (energy recovered from fans)

1 759 394

Apparent efficiency

0.63

Boiler heat consumption

MJ/m^3_{app}	BTU/MBF
2 345.9	**5 247 608**

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Case study: white pine global capacity

Cost sheet

Cost component	Total annual drying cost $	$/m³	$/MBF	Percentage
Depreciation	345 260	9.91	23.40	17.99
Interest on investment	117 588	3.38	7.97	6.13
Insurances	65 957	1.89	4.47	3.44
Administration	104 475	3.00	7.08	5.44
Taxes	30 375	0.87	2.06	1.58
Interest on inventory and land	116 667	3.35	7.91	6.08
Yard maintenance and snow removal	15 000	0.43	1.02	0.78
Labor	240 000	6.89	16.26	12.50
Electrical energy	238 280	6.84	16.15	12.41
Forklift maintenance and fuel	41 750	1.20	2.83	2.18
Building and equipment maintenance	48 759	1.40	3.30	4.34
Wood residues marketing value	332 501	9.55	22.53	17.32
Drying degrades	222 880	6.40	15.10	11.61
Total	**1 919 492**	**55.12**	**130.08**	**100**

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How to reduce drying costs

- Air predrying
- Reduction of drying time (computer optimisation techniques)
- Increase the quality of drying (reduction of degrade losses)
- Install heat recovery systems
- Install variable frequency motor drives
- Improve the kiln maintenance
- Improve the air circulation in the kiln
- Improve the efficiency of the heating system

Conclusions

✓ The calculation of energy consumption and drying costs are two preconditions for the optimisation of the drying process.

✓ Investment costs, labor cost, energy cost, and degrade cost are the main cost components to which actions can be taken to reduce drying costs, although all other costs are important to consider.

✓ The reduction of drying cost should not, however, be at the expense of drying quality.

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Conclusions (cont')

- ✓ An increase of drying cost can even be justified with an increase value of the dried products (e.g. value-added products).
- ✓ For new installations, the calculation of drying costs must be made in combination with a financial feasibility study (more thorough analysis).

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Calculation of Drying Costs

Thanks for your attention

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