COST PREDICTIONS FOR DRYING GRAIN WITH AMBIENT AND SOLAR-HEATED AIR IN CANADA

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The costs of drying wheat and corn (maize) with ambient and solar-heated air in the major grain-growing regions of Canada were predicted using a computer simulation model. In most cases of ambient air drying, the cost of electricity was the lowest component while the highest component was the cost of the drying equipment. The overdrying penalty was nearly twice the cost of electricity needed for drying wheat. The predicted mean cost of drying wheat with ambient air was about 20% higher in the humid region of Manitoba than in the semiarid and subboreal regions of Saskatchewan and Alberta. The cost of drying corn with ambient air was 35% higher in southern Ontario than in Manitoba. Adding a solar collector with a solar collector coefficient of 5°C increased the drying cost in 83% of the sets of conditions and locations simulated, but if the overdrying penalty were removed this figure would decrease to 40%. An equation to predict drying costs for different cost parameter values was developed.

INTRODUCTION

Solar grain drying has been found to be technically feasible in Canada (Brad et al. 1977). Before this method of grain drying is widely accepted, however, it must be shown to be economically feasible. Thus this study was undertaken to predict the costs of drying wheat and corn (maize) with ambient and solar-heated air in the major grain-growing regions of Canada.

METHOD

The drying of wheat and corn was simulated using the equilibrium drying model of Thompson (1972) modified by Fraser (1979). The drying of wheat was simulated using measured weather data from three locations across the Canadian prairies where 96% of all wheat produced in Canada during the 10-yr period 1969–1978 was grown (Canada Grains Council 1979). Edmonton, Swift Current, and Winnipeg were chosen because solar data were available for these stations and because they are located in the three main climatic regions of the Canadian prairies (Putman 1954). The drying of corn was simulated for London and Winnipeg, representing the two provinces where 91% of the corn produced in Canada is grown (Canada Grains Council 1979). To determine average economic performance the simulated drying results for 10 or more yr were averaged.

Initial moisture contents were 16, 20 and 24% for wheat and 20, 24 and 28% for corn. Harvest data ranged from 15 Aug. to 15 Oct. for wheat and from 15 Sept. to 15 Nov. for corn.

Solar collectors were characterized by the parameter, solar collector coefficient (SC) which was defined by Pierce and Thompson (1979) as: "the average 24-h temperature rise, °C, that a solar collector will produce when receiving 4183 J/cm^2 (1000 langleys) of solar radiation per day". Drying with two solar collectors having solar coefficients of 5°C and 10°C and drying with ambient air, solar coefficient of 0°C, were simulated.

In all simulations, a 1.1°C temperature rise in the air was added to account for heat added at the fan motor. With this limitation, power requirements for the motor are linearly related to airflow rate, and allowable grain depths decrease with increasing airflow rates (Fraser 1979). The airflow rates used for each set of conditions and locations were the predicted minimum rates that would dry the grain without spoilage in every one of the years simulated (Fraser 1979).

Continuous fan operation was simulated for the fall drying period until the wettest layer of grain was dry (14.5% for wheat and 15.5% for corn) or until the average ambient temperature for 1 wk was less than 0°C, provided this was after 1 Nov. for wheat or 1 Dec. for corn. Continuous operation was resumed after the winter period ended when the average weekly air temperature rose above 0°C, provided that this was after 31 Mar. The fan was not operated continuously during the winter because drying did not occur. Fan operation of 4 h/wk was simulated during the winter to cool the grain.

The operating energy cost was calculated from the energy input to the fan assuming a combined efficiency for motor and fan of 50%. The cost of electricity was set at $0.01/MJ ($0.036/kWh).

A penalty cost for overdrying was calculated from the average final moisture content of the grain and with the grain price set at $130/t. Overdrying occurred when bottom layers of grain were dried more than was required, i.e. below 14.5% for wheat and 15.5% for corn. Removal of this moisture results in better keeping quality but also results in less money being received when the grain is sold because it is sold on a wet-mass basis.

A depreciation cost was calculated for the drying equipment, i.e. drying floor, substructure, transition unit and fan. It was assumed that the bin structure should be charged against the cost of storage and not against the cost of drying. For a 5.7-m diameter bin, the drying equipment was found to cost about $2000. Assuming a 10-yr economic life, 10% interest rate and zero salvage value, the annual cost was $325/(bin · a).

The costs of the solar collectors, assumed horizontal with an average efficiency of 50%, were calculated at a rate of $1.00/(m^2 · a). This cost was chosen on the basis of an analysis by Schoneau and Besant (1976), who calculated total yearly costs to be $1.04/m^2, $0.89/m^2 and $1.49/m^2 for bare-plate, covered-plate and suspended-plate collectors, respectively.

RESULTS AND DISCUSSION

Cost of Drying with Ambient Air

Component costs

Of the three component costs (electricity, overdrying and depreciation) that

TABLE I. PREDICTED COSTS OF DRYING WHEAT WITH AMBIENT AND SOLAR-HEATED AIR AT EDMONTON†

				Wettest layer drying					Average drying	
Harvest date	MC‡ (%)	SC§ (°C)	Airflow rate (m³/(min · t))	Electricity cost ($/t)	Overdrying cost ($/t)	Drying equipment depreciation ($/t)	Collector depreciation ($/t)	Total drying cost ($/t)	Electricity cost ($/t)	Total drying cost ($/t)
15 Aug.	20	0	1.8	1.40	1.60	7.20	–	10.20	0.95	8.10
15 Aug.	20	5	1.6	0.70	2.30	6.70	0.66	10.40	0.57	8.00
1 Sept.	20	0	1.0	1.20	1.70	5.20	–	8.20	0.93	6.20
1 Sept.	20	5	0.9	0.85	2.20	4.90	0.37	8.40	0.73	6.00
15 Sept.	16	0	0.3	0.62	1.90	2.50	–	5.10	0.36	2.90
15 Sept.	16	5	0.2	0.45	2.70	2.00	0.06	5.20	0.24	2.30
15 Sept.	16	10	0.2	0.41	4.00	2.00	0.12	6.50	0.18	2.30
15 Sept.	20	0	0.9	1.30	1.80	4.90	–	8.00	0.94	5.90
15 Sept.	20	5	0.8	0.93	1.80	4.60	0.33	7.70	0.74	5.70
15 Sept.	20	10	0.7	0.79	2.10	4.30	0.58	7.80	0.64	5.50
15 Sept.	24	0	3.4	1.90	2.10	10.10	–	14.10	1.50	11.70
15 Sept.	24	5	3.1	1.40	2.60	9.60	1.30	14.90	1.10	12.00
15 Sept.	24	10	3.0	1.00	2.90	9.50	2.50	15.90	0.90	12.80
1 Oct.	20	0	0.9	1.20	2.00	4.90	–	8.10	0.98	5.90
1 Oct.	20	5	0.9	1.00	2.30	4.90	0.37	8.60	0.84	6.20
15 Oct.	20	0	0.8	1.00	3.00	4.60	–	8.70	0.91	5.50
15 Oct.	20	5	0.8	0.91	3.60	4.60	0.33	9.50	0.83	5.80

†Means of simulated results for the years 1967–1976. Costs and airflows are based on a tonne of wheat at 14.5% moisture content.
‡Initial moisture content at the start of drying, % wet-mass basis.
§Solar collector coefficient; 0°C means no solar collector. For all cases a 1.1°C temperature rise in the air was assumed to be added by fan motor heating.

TABLE II. PREDICTED COSTS OF DRYING WHEAT WITH AMBIENT AND SOLAR-HEATED AIR AT SWIFT CURRENT†

				Wettest layer drying					Average drying	
Harvest date	MC‡ (%)	SC§ (°C)	Airflow rate (m³/(min · t))	Electricity cost ($/t)	Over-drying cost ($/t)	Drying equipment depreciation ($/t)	Collector depreciation ($/t)	Total drying cost ($/t)	Electricity cost ($/t)	Total drying cost ($/t)
15 Aug.	20	0	1.2	0.62	3.30	5.80	–	9.70	0.49	6.30
15 Aug.	20	5	1.4	0.45	4.30	6.30	0.58	11.60	0.41	7.30
1 Sept.	20	0	1.0	0.69	2.30	5.20	–	8.20	0.59	5.80
1 Sept.	20	5	0.9	0.57	3.00	4.90	0.37	8.90	0.50	5.80
15 Sept.	16	0	0.3	0.55	1.70	2.50	–	4.80	0.23	2.80
15 Sept.	16	5	0.2	0.45	2.80	2.30	0.08	5.50	0.17	2.50
15 Sept.	16	10	0.2	0.40	3.40	2.30	0.17	6.30	0.12	2.60
15 Sept.	20	0	0.9	0.95	2.30	4.90	–	8.20	0.73	5.70
15 Sept.	20	5	0.8	0.75	2.80	4.60	0.33	8.50	0.61	5.60
15 Sept.	20	10	0.8	0.62	3.50	4.60	0.66	9.40	0.52	5.80
15 Sept.	24	0	3.2	1.40	2.60	9.80	–	13.80	1.20	11.00
15 Sept.	24	5	3.0	1.10	3.40	9.50	1.20	15.30	0.87	11.60
15 Sept.	24	10	2.8	0.81	4.10	9.10	2.30	16.30	0.77	12.20
1 Oct.	20	0	1.0	1.10	2.20	5.20	–	8.60	0.85	6.10
1 Oct.	20	5	0.9	0.88	2.20	4.90	0.37	8.40	0.69	6.00
15 Oct.	20	0	1.1	1.20	2.30	5.50	–	9.00	0.97	6.50
15 Oct.	20	5	1.1	0.97	2.70	5.50	0.45	9.60	0.79	6.70

†Means of simulated results for the years 1960–1974. Costs and airflows are based on a tonne of wheat at 14.5% moisture content.
‡Initial moisture content at the start of drying, % wet-mass basis.
§Solar collector coefficient; 0°C means no solar collector. For all cases, a 1.1°C temperature rise in the air was assumed to be added by fan motor heating.

make up the total costs for drying wheat, the lowest was the cost of electricity in 20 of the 21 sets of conditions and locations studied (Tables I–III). With the limitations placed on grain depth in this analysis, the mean cost of electrical energy was only 13% of the total drying cost. Substantial increases in the unit cost of electricity could occur with only a small effect on the total drying cost.

For the drying of corn, the mean cost for electricity was the lowest, 22%, at Winnipeg (Table IV), but at London it was second lowest, 26% (Table V). At London the lowest component cost was the penalty for overdrying.

The overdrying penalty for wheat averaged for the three prairie locations and seven sets of conditions was $2.06/t or nearly twice the cost of electricity, $1.22/t. This legally instituted penalty charge for drying grain to a lower, safer moisture content could be eliminated by buying and selling grains on a dry-mass basis instead of a wet-mass basis. Such a change could occur at little cost because most grain buyers already measure moisture content of the incoming grain.

At all locations and sets of conditions studied, the highest component cost was the cost of the drying equipment; 66% of the total cost of drying wheat, 48% for corn at Winnipeg and 61% for corn at London (Tables I–V). It is apparent that the choice of size and type of drying equipment is important and that the farmer should be given considerable information on dryer design and operation. By determining optimum grain depths and bin sizes, in-bin drying systems of lower cost than those presented in this paper may be possible.

TABLE III. PREDICTED COSTS OF DRYING WHEAT WITH AMBIENT AND SOLAR-HEATED AIR AT WINNIPEG†

				Wettest layer drying					Average drying	
Harvest date	MC‡ (%)	SC§ (°C)	Airflow rate (m³/(min · t))	Electricity cost ($/t)	Over-drying cost ($/t)	Drying equipment depreciation ($/t)	Collector depreciation ($/t)	Total drying cost ($/t)	Electricity cost ($/t)	Total drying cost ($/t)
15 Aug.	20	0	3.0	0.90	1.80	9.50	–	12.10	0.64	10.10
15 Aug.	20	5	2.2	0.58	3.20	8.00	0.91	12.70	0.51	9.40
1 Sept.	20	0	2.4	1.70	1.90	8.40	–	11.90	0.96	9.30
1 Sept.	20	5	1.6	0.65	2.00	6.70	0.66	10.00	0.54	7.90
15 Sept.	16	0	0.4	0.82	1.80	3.00	–	5.60	0.47	3.50
15 Sept.	16	5	0.3	0.56	2.50	2.50	0.10	5.70	0.28	2.90
15 Sept.	16	10	0.2	0.47	3.20	2.40	0.18	6.20	0.18	2.70
15 Sept.	20	0	1.3	1.40	1.80	6.00	–	9.20	0.96	7.00
15 Sept.	20	5	1.2	1.00	2.20	5.80	0.50	9.50	0.72	7.00
15 Sept.	20	10	1.0	0.72	2.50	5.20	0.83	9.30	0.62	6.70
15 Sept.	24	0	7.5	2.90	1.80	15.80	–	20.50	2.30	18.10
15 Sept.	24	5	6.0	1.90	2.30	13.90	2.50	20.60	0.98	17.40
15 Sept.	24	10	5.5	1.20	2.70	13.30	4.50	21.70	0.78	18.60
1 Oct.	20	0	1.1	1.40	1.40	5.50	–	8.30	1.10	6.60
1 Oct.	20	5	1.0	1.10	2.10	5.20	0.41	8.90	0.86	6.50
15 Oct.	20	0	1.0	1.30	1.90	5.20	–	8.40	1.10	6.30
15 Oct.	20	5	1.0	1.10	2.50	5.20	0.41	9.20	0.91	6.60

†Means of simulated results for the years 1961–1970. Costs and airflows are based on a tonne of wheat at 14.5% moisture content.
‡Initial moisture content at the start of drying, % wet-mass basis.
§Solar collector coefficient; 0°C means no solar collector. For all cases a 1.1°C temperature rise in the air was assumed to be added by fan motor heating.

TABLE IV. PREDICTED COSTS OF DRYING CORN WITH AMBIENT AND SOLAR-HEATED AIR AT WINNIPEG†

				Wettest layer drying					Average drying	
Harvest date	MC‡ (%)	SC§ (°C)	Airflow rate (m³/(min · t))	Electricity cost ($/t)	Over-drying cost ($/t)	Drying equipment depreciation ($/t)	Collector depreciation ($/t)	Total drying cost ($/t)	Electricity cost ($/t)	Total drying cost ($/t)
15 Sept.	24	0	2.4	1.90	2.80	5.70	–	10.40	1.30	7.00
15 Sept.	24	5	2.3	1.10	3.80	5.50	0.95	11.30	0.97	7.50
1 Oct.	24	0	2.0	2.00	3.00	5.10	–	10.10	1.50	6.70
1 Oct.	24	5	1.9	1.60	3.40	5.00	0.78	10.70	1.20	7.00
15 Oct.	20	0	0.7	1.40	3.90	2.90	–	8.10	1.20	4.10
15 Oct.	20	5	0.6	1.10	5.40	2.60	0.25	9.40	1.00	3.90
15 Oct.	20	10	0.6	1.00	6.60	2.50	0.45	10.60	0.92	3.90
15 Oct.	24	0	1.6	2.50	3.00	4.50	–	10.00	2.10	6.60
15 Oct.	24	5	1.5	2.10	4.60	4.40	0.62	11.70	1.80	6.80
15 Oct.	24	10	1.4	1.80	5.30	4.20	1.20	12.50	1.60	6.90
15 Oct.	28	0	4.8	4.30	2.70	8.50	–	15.50	4.10	12.50
15 Oct.	28	5	5.4	4.00	3.90	9.00	2.20	19.20	2.90	14.20
15 Oct.	28	10	5.2	2.80	3.90	8.80	4.30	19.90	2.40	15.50
1 Nov.	24	0	1.7	2.20	3.50	4.70	–	10.30	2.10	6.70
1 Nov.	24	5	1.7	2.20	4.70	4.70	0.70	12.10	1.90	7.30
15 Nov.	24	0	1.7	2.30	3.90	4.70	–	10.90	2.20	6.90
15 Nov.	24	5	1.5	2.00	5.40	4.40	0.62	12.30	1.90	6.90

†Means of simulated results for the years 1961–1970. Costs and airflows are based on a tonne of corn at 15.5% moisture content.
‡Initial moisture content at the start of drying, % wet-mass basis.
§Solar collector coefficient; 0°C means no solar collector. For all cases a 1.1°C temperature rise in the air was assumed to be added by fan motor heating.

Climate

According to Putman (1954), Edmonton is in a subboreal region, Swift Current is in a semiarid region and Winnipeg is in a humid region. The mean cost of drying wheat in the subboreal and semiarid regions was $8.90/t while it was 22% more costly, $10.86/t, in the humid region. The cost of drying corn in warm, moist London where the average equilibrium moisture content of unheated ambient air for the harvest period 17 Sept. to 2 Dec. is 19.9% (Treidl 1974) was 35% higher than the predicted cost for Winnipeg where the average equilibrium moisture content is 1.5% lower. In general, electrical energy and drying equipment costs increase and the overdrying costs decrease from the semiarid region to the subboreal and humid regions of the prairies and to the warm, humid region of southern Ontario.

Initial moisture content

Increasing initial moisture contents by four percentage points, from 16 to 20% and 20 to 24% for wheat and from 20 to 24% and 24 to 28% for corn, can cause total drying costs to increase about 70% for the sets of conditions and locations studied (Tables I–V).

Harvest date

The most costly date to begin drying wheat on the prairies was the earliest harvest date studied, 15 Aug. (Tables I–V). The electricity cost is the lowest on this date but because of the higher ambient temperatures, drying must be

TABLE V. PREDICTED COSTS OF DRYING CORN WITH AMBIENT AND SOLAR-HEATED AIR AT LONDON†

				Wettest layer drying					Average drying	
Harvest date	MC‡ (%)	SC§ (°C)	Airflow rate (m^3/(min · t))	Electricity cost ($/t)	Over-drying cost ($/t)	Drying equipment depreciation ($/t)	Collector depreciation ($/t)	Total drying cost ($/t)	Electricity cost ($/t)	Total drying cost ($/t)
15 Sept.	24	0	6.2	1.90	1.10	9.80	–	12.80	1.50	11.30
15 Sept.	24	5	5.5	1.10	2.00	9.10	2.30	14.40	0.93	12.30
1 Oct.	24	0	5.0	3.30	1.90	8.60	–	13.80	2.10	10.70
1 Oct.	24	5	3.8	1.70	2.70	7.40	1.60	13.40	1.10	10.10
15 Oct.	20	0	1.0	1.80	2.30	3.50	–	7.60	1.50	5.00
15 Oct.	20	5	0.8	1.40	3.70	3.10	0.33	8.50	1.00	4.50
15 Oct.	20	10	0.8	1.20	4.00	3.10	0.66	8.90	0.89	4.60
15 Oct.	24	0	5.5	5.20	2.20	9.10	–	16.50	3.80	13.00
15 Oct.	24	5	3.8	2.90	2.80	7.40	1.60	14.60	2.40	11.30
15 Oct.	24	10	3.4	2.40	3.30	6.90	2.80	15.40	1.40	11.10
15 Oct.	28	0	18.0	7.80	2.10	18.30	–	28.30	5.50	23.80
15 Oct.	28	5	9.5	4.60	2.30	12.50	3.90	23.30	2.80	19.20
15 Oct.	28	10	8.2	2.70	2.90	11.50	6.80	23.80	1.60	19.90
1 Nov.	24	0	2.8	3.10	2.20	6.20	–	11.50	2.80	9.00
1 Nov.	24	5	2.6	2.70	3.70	5.90	1.10	13.40	2.30	9.30
15 Nov.	25	0	2.8	2.90	2.20	6.20	–	11.40	2.60	8.80
15 Nov.	24	5	2.6	2.50	3.80	5.90	1.10	13.30	2.30	9.30

†Means of simulated results for the years 1962–1973. Costs and airflows are based on a tonne of corn at 15.5% moisture content.
‡Initial moisture content at the start of drying, % wet-mass basis.
§Solar collector coefficient; 0°C means no solar collector. For all cases a 1.1°C temperature rise in the air was assumed to be added by fan motor heating.

completed rapidly before the grain spoils. This rapid drying requires larger fans and lower grain depths, thus increasing drying equipment depreciation. This pattern of drying costs could suggest that harvesting should be delayed. But Kabernick and Muir (1979) have shown that in the Red River Valley it is more economical to harvest early with large combines to reduce weathering damage to the grain and to allow sufficient time in the autumn to carry out seed bed preparations for the following year.

The cost of drying wheat starting on 15 Aug. could be reduced if the drying equipment was used to dry a second batch later in the autumn. The mean drying times and standard deviations, in parentheses, for harvesting on 15 Aug. were: Edmonton — 960(620)h, Swift Current — 650(300)h and Winnipeg — 380(320)h. Therefore, in many years a second batch of wheat could be started drying in late September at Edmonton, mid-September at Swift Current and early September at Winnipeg.

At Winnipeg the lowest-cost drying occurs at a harvest date of 1 or 15 Oct. for both wheat and corn, while at London, 15 Oct. is the most costly time to begin drying corn. The high cost for 15 Oct. at London probably was the result of high harvest temperature in some years requiring high airflow rates to prevent spoilage while in other cooler years there was insufficiently dry weather to complete drying in the autumn.

As a general relationship it was found that the total cost of drying was nearly directly proportional to the required airflow rate for drying wheat and corn on the prairies. The costs of drying corn at London varied somewhat from this relationship at the high airflow rates.

Cost of Drying with Solar-Heated Air

Adding a solar collector with a solar collector coefficient of 5°C increased the cost of drying wheat and corn at the four locations in 29 of the 35 sets of conditions simulated (Tables I–V). Adding a solar collector with a coefficient of 10°C instead of 5°C increased the drying costs in all but one of the 15 sets of conditions studied.

The electricity cost was reduced in every case by the addition of a solar collector. The equipment (excluding collector) depreciation was reduced in most cases because the required rate of airflow with a collector was less than without the collector. But in every case the warmer, drier air supplied through a solar collector increased the overdrying penalty. If the overdrying penalty was removed, solar drying would become less expensive than ambient air drying in 60% of the sets of conditions instead of in only 17% as it would be under the present regulations.

The average drying costs (overdrying penalty included) for all sets of locations and conditions increased 6% by adding a solar collector. The highest increase was 15% for corn at Winnipeg while at London the addition of a collector reduced average costs by 1%. If the overdrying penalty is omitted, the addition of a solar collector reduces costs for all locations by an average of 2% with the greatest reduction being 9% at London. Even with the overdrying penalty omitted, the addition of a solar collector to dry wheat at Swift Current and corn at Winnipeg results in cost increases.

Cost of Drying to an Average Moisture Content

One fan management procedure that can eliminate the overdrying penalty is to stop drying when the average moisture content of the bin of grain is equal to 14.5% for wheat and 15.5% for corn. Such a procedure requires close supervision and introduces an added cost (which was not included in this analysis) of mixing the grain immediately after drying is stopped. Besides eliminating the overdrying penalty, fan operating times are reduced. The average reductions in drying costs by drying to an average moisture content were 25% for ambient air drying and 30% for solar drying with a coefficient of 5°C (Tables I–V).

Comparison with Measured Results

Corn drying results measured by Johnson and Otten (1979) in a test beginning 26 Oct. 1978 indicate, as do our predictions, that electricity costs are lower with solar-heated air than with unheated ambient air but that total costs are higher for solar drying. Even though there are differences in many of the variables and our predictions are averages for 10 yr of weather data, their costs are surprisingly close to our predictions for average drying for a 1 Nov. harvest at London (Table V). Johnson and Otten (1979) indicate electric energy costs of \$2.98/t for ambient air drying and \$2.50/t for solar-heated drying while we predict average costs of \$2.80/t and \$2.30/t, respectively. They found the total cost of solar drying (\$11.81/t) to be considerably greater than for ambient drying (\$8.87/t) while we predicted a 10-yr average increase of \$0.30/t from \$9.00/ to \$9.30/t.

Drying Cost for Different Parameter Values

The simulation results presented in this paper can be used to calculate drying costs for other values of the basic parameters. A revised total drying cost can be calculated by:

$$C_r = E_c(E_r/E) + O_c(G_r/G) + B_c(B_r/B)(D/D_r)^2 + S_c(S_r/S)(A_r/A) \quad (1)$$

where:

C_r = revised total drying cost, \$/t,
E_c = electricity cost from Tables I–V, \$/t,
E = electrical energy rate used in analysis, \$0.01/MJ,
E_r = revised electrical energy rate, \$/MJ,
O_c = overdrying cost from Tables I–V, \$/t,
G = grain value used in analysis, \$130/t,
G_r = revised grain value, \$/t,
B_c = drying equipment depreciation from Tables I–V, \$/t,
B = annual cost of drying equipment used in this analysis, \$325/(bin · a),
B_r = revised annual cost of drying equipment, \$/(bin · a),
D = diameter of bin used in analysis, 5.7 m,
D_r = revised diameter of bin, m,
S_c = solar collector depreciation from Tables I–V, \$/t,
S = annual cost of solar collector used in this analysis, \$1.00/(m^2 · a),
Sr = revised annual cost of solar collector, \$/(m^2 · a),
A = 1.0 m^2 of horizontal collector,
A_r = area of revised solar collector that provides the same amount of solar energy as 1 m^2 of horizontal collector having a 50% efficiency, m^2.

If cost of electricity doubles and the cost of other inputs increases 50%, then by using the above equation it can be determined that the predicted cost of drying wheat at Winnipeg, harvested on 15 Sept. at 20% moisture content is \$14.50/t with ambient air and \$14.75 with a solar collector having a coefficient of 5°C. For this same set of conditions, the above equation can be used to determine that the cost of electricity would have to increase to \$0.026/MJ for the predicted cost of solar drying to be equal to the predicted cost of ambient air drying when all other prices rise 50%.

An additional cost that must be included when considering using ambient or solar-heated air for grain drying is the cost of installing an adequate supply of electrical power. For one installation this was \$15 000 (private communication from Professor L. Otten, Guelph, 1980 01 10).

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