Solar energy resource potential in Alaska
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SOLAR ENERGY RESOURCE POTENTIAL IN ALASKA

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Report No. IWR-89

March 1978

ACKNOWLEDGMENTS

This work was made possible by a grant from the Solar Planning Office, West, 3333 Quebec, Denver, Colorado. It was performed as the Alaskan response to a western regional solar energy planning grant from the U. S. Department of Energy.

The authors wish to acknowledge the support and cooperation of the Alaska State Department of Commerce, Division of Energy and Power Development, through whose efforts the grant was made available, especially Clarissa Quinlan, Grant Peterson, and Don Markle.

The authors also acknowledge gratefully the assistance of the following staff members: Mayo Murray, Susan Hoffman, Mary Hayes, Charles Hartman, and Dianna Lascano.

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ABSTRACT

Solar energy applications are receiving attention in Alaska as in much of the rest of the country. Solar energy possibilities for Alaska include domestic water heating, hot-water or hot-air collection for space heating, and the use of passive solar heating in residential or commercial buildings.

As a first analysis, this study concentrated on applying solar energy to domestic hot-water heating needs (not space heating) in Alaska, and an analysis of solar hot-water heating economics was performed using the F-CHART solar energy simulation computer program. Results indicate that solar energy cannot compete economically with oil-heated domestic hot water at any of the five study locations in Alaska, but that it may be economical in comparison with electrically heated hot water if solar collector systems can be purchased and installed for $20 to $25 per square foot.

INTRODUCTION

Contrary to popular belief, the northern latitudes receive more possible hours of sunlight in a year than do the tropics. In fact, at the Arctic Circle there are 230 more hours of sunlight per year than at the equator (Sater et al., 1971). Although interesting, this statistic is of little consolation when one is interested in applying solar energy to heating applications in Alaska and other areas of the far north. Practical use of heat from the sun is a relatively new possibility for the North, and its development is only beginning. The federal government, the state of Alaska, and many interested citizens and professionals within Alaska have been curious for some time as to the possibilities of using solar energy in Alaska. This report assembles the historical data available from five sites in Alaska: Annette Island, Barrow, Bethel, Fairbanks, and Matanuska (see Fig. 1). Using this data, several analyses were performed to evaluate the potential of applications of solar energy to domestic water-heating. The analyses were accomplished with the aid of computer simulations of these solar energy systems using the data available from the five Alaskan sites. The computer programs used will be described in further detail later in this report.

The computer simulations also provide a means of economic evaluation of solar energy as an alternate form of energy. In this way, a fair assessment can be made of the dollar value of solar energy systems when compared to the present utility costs.

Solar energy applications consist of three types: 1) domestic hot-water heating, which refers only to hot-water supply heating, not space heating; 2) active (pumped) solar space heating, which refers to the heating of buildings using collectors; and 3) passive space heating, in which the building itself is designed to function as a collector without pumping or auxiliary energy input.

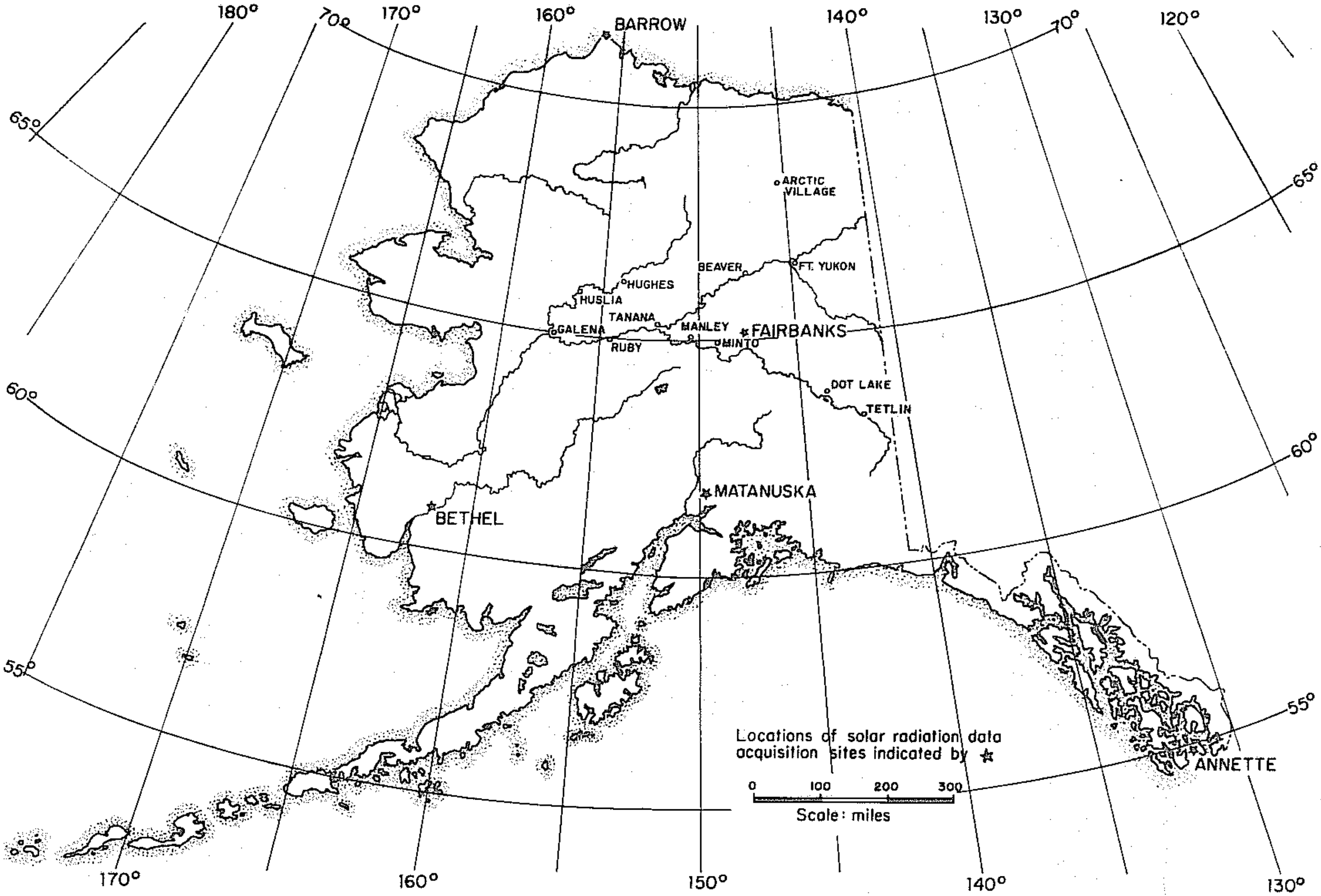


Fig. 1: MAP OF ALASKA SHOWING DATA ACQUISITION SITES.

HISTORICAL BACKGROUND AND INFORMATION

The solar radiation data acquisition sites in Alaska have varied histories. The Annette Island station was established in July, 1949, at approximately the same time data acquisition began at Fairbanks and at Matanuska at the Palmer Agricultural Experiment Station. The station at Barrow was added in April, 1955, and the Bethel station began recording data in October, 1958 (USWS, personal communication). These three stations have since terminated data aquisition, mostly because of outdated faulty equipment and lack of financial support. The Barrow site ceased acquiring data in 1974, and Annette Island and Bethel stations terminated recording solar insolation in 1975. Matanuska still acquires hourly data using a strip chart recorder. Fairbanks is the only site supported by the National Weather Service which is still acquiring data. A new system was recently installed in Fairbanks in which solar radiation data is recorded directly onto cassette tapes. This new system provides for easier copying and dissemination of the data and is also a more accurate system.

Presently, and for the last few years, data acquisition at Barrow has been supported by the Smithsonian Institution, and the data are available through their operations.

PRESENTLY AVAILABLE DATA

Normally, radiation measurements are made using a pyranometer or radiometer mounted on a horizontal surface. The standard radiation measurements are the intensity of the direct and diffuse components of radiation impinging on the surface. The sum of these two main components of solar radiation is called the total global hemispheric radiation, and is often designated as $\bar{H}$. This is the basic measurement which is available from the Alaskan sites. The effect of cloudiness and atmospheric conditions at each site can be indicated by taking the ratio between the theoretically incident solar radiation on a horizontal surface outside the earth's atmosphere, called H_o, and the total global hemispheric radiation $\bar{H}$. This factor $\bar{K}_T$ is defined by that ratio:

$$\bar{K}_T = \frac{\bar{H}}{H_o}$$

The values of $\bar{H}$ and $\bar{K}_T$ are given in Table 1 on a monthly basis for each site, along with the average monthly daytime temperature in degrees Fahrenheit.

A comparison of the average solar radiation on a vertical south-facing surface at the five radiation sites in Alaska is shown in Table 2. Theoretical solar radiation calculated from the American Society of Heating and Air Conditioning Engineers (ASHRAE) equation is given in a tabular format in units of Btu-hr/ft^2 for various collector tilts and for the 21st day of each month in Tables 3 and 4. The insolation rates are given on an hourly basis at 56°N and 64°N latitude and are not adjusted for cloud cover. (Please see Appendix A for further explanation concerning the data formulated for these tables.)

A question often asked about solar collectors concerns their performance in cloudy weather. According to Dr. Gerd Wendler of the Geophysical Institute of the University of Alaska, a conservative estimate is that cloudy day-diffuse radiation intensity is approximately 40% of that expected on a clear day.

The National Bureau of Standards has used real data in a way which simulates the natural daily distribution of solar radiation. The mean monthly solar radiation for each month on a horizontal surface has been used as a basis upon which radiation on the eight primary vertical directional surfaces was calculated (N, NE, E, SE, S, SW, W, NW) according

TABLE 1
Insolation and Temperature Data for Five Alaskan Locations

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Annette Island, Alaska--Latitude: 55°02'N; Elevation: 110 ft.												
$\bar{H}$[1]	236.2	428.4	883.4	1357.2	1634.7	1638.7	1632.1	1269.4	962	454.6	220.3	152
$\bar{K}_t$[2]	0.427	0.415	0.492	0.507	0.484	0.441	0.454	0.427	0.449	0.347	0.304	0.361
t_o[3]	38.5	37.5	39.7	44.4	51.0	56.2	58.6	59.8	54.8	48.2	41.9	37.4
Barrow, Alaska--Latitude: 71°20'N; Elevation: 22 ft.												
$\bar{H}$	13.3	143.2	713.3	1491.5	1883	2055.3	1602.2	953.5	428.4	152.4	22.9	--
$\bar{K}_t$	--	0.776	0.773	0.726	0.553	0.533	0.448	0.377	0.315	0.35	--	--
t_o	- 13.2	- 15.9	- 12.7	2.1	20.5	35.4	41.6	40.0	31.7	18.6	2.6	- 8.6
Bethel, Alaska--Latitude: 60°47'N; Elevation 125 ft.												
$\bar{H}$	142.4	404.8	1052.4	1662.3	1711.8	1698.1	1401.8	938.7	755	430.6	164.9	83
$\bar{K}_t$	0.536	0.557	0.704	0.675	0.519	0.458	0.398	0.336	0.406	0.432	0.399	0.459
t_o	9.2	11.6	14.2	29.4	42.7	55.5	56.9	54.8	47.4	33.7	19.0	9.4
Fairbanks, Alaska--Latitude: 64°49'N; Elevation 436 ft.												
$\bar{H}$	66	283.4	860.5	1481.2	1806.2	1970.8	1702.9	1247.6	699.6	323.6	104.1	20.3
$\bar{K}_t$	0.639	0.556	0.674	0.647	0.546	0.529	0.485	0.463	0.419	0.416	0.47	0.458
t_o	- 7.0	0.3	13.0	32.2	50.5	62.4	63.8	58.3	47.1	29.6	5.5	- 6.6
Matanuska, Alaska--Latitude: 61°30'N; Elevation: 180 ft.												
$\bar{H}$	119.2	34.5	--	1327.6	1628.4	1727.6	1526.9	1169	737.3	373.8	142.8	56.4
$\bar{K}_t$	0.513	0.503	--	0.545	0.494	0.466	0.434	0.419	0.401	0.390	0.372	0.364
t_o	13.9	21.0	27.4	38.6	50.3	57.6	60.1	58.1	50.2	37.7	22.9	13.9

[1] $\bar{H}$ = Monthly average daily total radiation on horizontal surface, Btu-day/ft^2

[2] $\bar{K}_t = \bar{H}/H_o$, where H_o = solar radiation on a horizontal surface outside the earth's atmosphere, Btu-day/ft^2

[3] t_o = average daytime temperature, °F

SOURCE: Liu and Jordan, 1977, in ASHRAE, GRP170, Applications of Solar Energy for Heating and Cooling of Buildings.

TABLE 2
Vertical South-Facing Surface
Average Monthly Radiation Data
$Btu\text{-}day/ft^2$

	Annette	Barrow*	Bethel	Fairbanks	Matanuska
January	719	0	832	864	753
February	837	98	1224	1149	1034
March	1126	467	1892	1808	---
April	1119	995	1689	1679	1307
May	1001	1367	1176	1323	1126
June	901	1479	1021	1271	1052
July	936	1204	886	1158	980
August	915	618	715	1094	945
September	992	331	874	912	859
October	627	79.5	823	723	696
November	397	0	518	513	446
December	470	0	502	263	316

*Calculated from $\bar{H}$

TABLE 3
Solar Position and Insolation Values for 56° North Latitude

DATE	SOLAR TIME		SOLAR POSITION		BTUH/SQ. FT. TOTAL INSOLATION ON SURFACES						
	AM	PM	ALT	AZM	NORMAL	HORIZ.	SOUTH FACING SURFACE ANGLE WITH HORIZ.				
							46	56	66	76	90
JAN 21	9	3	5.0	41.8	78	11	50	55	59	60	60
	10	2	9.9	28.5	170	39	135	146	154	156	153
	11	1	12.9	14.5	207	58	183	197	206	208	201
	12		14.0	0.0	217	65	198	214	222	225	217
	SURFACE DAILY TOTALS				1126	282	934	1010	1058	1074	1044
FEB 21	8	4	7.6	59.4	129	25	65	69	72	72	69
	9	3	14.2	45.9	214	65	151	159	162	161	151
	10	2	19.4	31.5	250	98	215	225	228	224	208
	11	1	22.8	16.1	266	119	254	265	268	263	243
	12		24.0	0.0	270	126	268	279	282	276	255
	SURFACE DAILY TOTALS				1986	740	1640	1716	1742	1716	1598
MAR 21	7	5	8.3	77.5	128	28	40	40	39	37	32
	8	4	16.2	64.4	215	75	119	120	117	111	97
	9	3	23.3	50.3	253	118	192	193	189	180	154
	10	2	29.0	34.9	272	151	249	251	246	234	205
	11	1	32.7	17.9	282	172	285	288	282	268	236
	12		34.0	0.0	284	179	297	300	294	280	246
	SURFACE DAILY TOTALS				2586	1268	2066	2084	2040	1938	1700
APR 21	5	7	1.4	108.8	0	0	0	0	0	0	0
	6	6	9.6	96.5	122	32	14	9	8	7	6
	7	5	18.0	84.1	201	81	74	66	57	46	29
	8	4	26.1	70.9	239	129	143	135	123	108	82
	9	3	33.6	56.3	260	169	208	200	186	167	133
	10	2	39.9	39.7	272	201	259	251	236	214	174
	11	1	44.1	20.7	278	220	292	284	268	245	200
	12		45.6	0.0	280	227	303	295	279	255	209
	SURFACE DAILY TOTALS				3024	1892	2282	2186	2038	1830	1458
MAY 21	4	8	1.2	125.5	0	0	0	0	0	0	0
	5	7	8.5	113.4	93	25	10	9	8	7	6
	6	6	16.5	101.5	175	71	28	17	15	13	11
	7	5	24.8	89.3	219	119	88	74	58	41	16
	8	4	33.1	76.3	244	163	153	138	119	98	63
	9	3	40.9	61.6	259	201	212	197	176	151	109
	10	2	47.6	44.2	268	231	259	244	222	194	146
	11	1	52.3	23.4	273	249	288	274	251	222	170
	12		54.0	0.0	275	255	299	284	261	231	178
	SURFACE DAILY TOTALS				3340	2374	2374	2188	1962	1682	1218
JUN 21	4	8	4.2	127.2	21	4	2	2	2	2	1
	5	7	11.4	115.3	122	40	14	13	11	10	8
	6	6	19.3	103.6	185	86	34	19	17	15	12
	7	5	27.6	91.7	222	132	92	76	57	38	15
	8	4	35.9	78.8	243	175	154	137	116	92	55
	9	3	43.8	64.1	257	212	211	193	170	143	98
	10	2	50.7	46.4	265	240	255	238	214	184	133
	11	1	55.6	24.9	269	258	284	267	242	210	156
	12		57.5	0.0	271	264	294	276	251	219	164
	SURFACE DAILY TOTALS				3438	2562	2388	2166	1910	1606	1120
JUL 21	4	8	1.7	125.8	0	0	0	0	0	0	0
	5	7	9.0	113.7	91	27	11	10	9	8	6
	6	6	17.0	101.9	169	72	30	18	16	14	12
	7	5	25.3	89.7	212	119	88	74	58	41	15
	8	4	33.6	76.7	237	163	151	136	117	96	61
	9	3	41.4	62.0	252	201	208	193	173	147	106
	10	2	48.2	44.6	261	230	254	239	217	189	142
	11	1	52.9	23.7	265	248	283	268	245	216	165
	12		54.6	0.0	267	254	293	278	255	225	173
	SURFACE DAILY TOTALS				3240	2372	2342	2152	1926	1646	1186
AUG 21	5	7	2.0	109.2	1	0	0	0	0	0	0
	6	6	10.2	97.0	112	34	16	11	10	9	7
	7	5	18.5	84.5	187	82	73	65	56	45	28
	8	4	26.7	71.3	225	128	140	131	119	104	78
	9	3	34.3	56.7	246	168	202	193	179	160	126
	10	2	40.5	40.0	258	199	251	242	227	206	166
	11	1	44.8	20.9	264	218	282	274	258	235	191
	12		46.3	0.0	266	225	293	285	269	245	200
	SURFACE DAILY TOTALS				2850	1884	2218	2118	1966	1760	1392
SEP 21	7	5	8.3	77.5	107	25	36	36	34	32	28
	8	4	16.2	64.4	194	72	111	111	108	102	89
	9	3	23.3	50.3	233	114	181	182	178	168	147
	10	2	29.0	34.9	253	146	236	237	232	221	193
	11	1	32.7	17.9	263	166	271	273	267	254	223
	12		34.0	0.0	266	173	283	285	279	265	233
	SURFACE DAILY TOTALS				2368	1220	1950	1962	1918	1820	1594
OCT 21	8	4	7.1	59.1	104	20	53	57	59	59	57
	9	3	13.8	45.7	193	60	138	145	148	147	138
	10	2	19.0	31.3	231	92	201	210	213	210	195
	11	1	22.3	16.0	248	112	240	250	253	248	230
	12		23.5	0.0	253	119	253	263	266	261	241
	SURFACE DAILY TOTALS				1804	688	1516	1586	1612	1588	1480
NOV 21	9	3	5.2	41.9	76	12	49	54	57	59	58
	10	2	10.0	28.5	165	39	132	143	149	152	148
	11	1	13.1	14.5	201	58	179	193	201	203	196
	12		14.2	0.0	211	65	194	209	217	219	211
	SURFACE DAILY TOTALS				1094	284	914	986	1032	1046	1016
DEC 21	9	3	1.9	40.5	5	0	3	4	4	4	4
	10	2	6.6	27.5	113	19	86	95	101	104	103
	11	1	9.5	13.9	166	37	141	154	163	167	164
	12		10.6	0.0	180	43	159	173	182	186	182
	SURFACE DAILY TOTALS				748	156	620	678	716	734	722

NOTE: 1) BASED ON DATA IN TABLE 1, pp 387 in 1972 ASHRAE HANDBOOK OF FUNDAMENTALS; 0% GROUND REFLECTANCE; 1.0 CLEARNESS FACTOR.
2) SEE FIG. 4, pp 394 in 1972 ASHRAE HANDBOOK OF FUNDAMENTALS FOR TYPICAL REGIONAL CLEARNESS FACTORS.
3) GROUND REFLECTION NOT INCLUDED ON NORMAL OR HORIZONTAL SURFACES.

TABLE 4
Solar Position and Insolation Values for 64° North Latitude

DATE	SOLAR TIME AM	SOLAR TIME PM	SOLAR POSITION ALT	SOLAR POSITION AZM	BTUH/SQ. FT. TOTAL INSOLATION ON SURFACES NORMAL	HORIZ.	SOUTH FACING SURFACE ANGLE WITH HORIZ. 54	64	74	84	90
JAN 21	10	2	2.8	28.1	22	2	17	19	20	20	20
	11	1	5.2	14.1	81	12	72	77	80	81	81
	12		6.0	0.0	100	16	91	98	102	103	103
	SURFACE DAILY TOTALS				306	45	268	290	302	306	304
FEB 21	8	4	3.4	58.7	35	4	17	19	19	19	19
	9	3	8.6	44.8	147	31	103	108	111	110	107
	10	2	12.6	30.3	199	55	170	178	181	178	173
	11	1	15.1	15.3	222	71	212	220	223	219	213
	12		16.0	0.0	228	77	225	235	237	232	226
	SURFACE DAILY TOTALS				1432	400	1230	1286	1302	1282	1252
MAR 21	7	5	6.5	76.5	95	18	30	29	29	27	25
	8	4	20.7	62.6	185	54	101	102	99	94	89
	9	3	18.1	48.1	227	87	171	172	169	160	153
	10	2	22.3	32.7	249	112	227	229	224	213	203
	11	1	25.1	16.6	260	129	262	265	259	246	235
	12		26.0	0.0	263	134	274	277	271	258	246
	SURFACE DAILY TOTALS				2296	932	1856	1870	1830	1736	1656
APR 21	5	7	4.0	108.5	27	5	2	2	2	1	1
	6	6	10.4	95.1	133	37	15	9	8	7	6
	7	5	17.0	81.6	194	76	70	63	54	43	37
	8	4	23.3	67.5	228	112	136	128	116	102	91
	9	3	29.0	52.3	248	144	197	189	176	158	145
	10	2	33.5	36.0	260	169	246	239	224	203	188
	11	1	36.5	18.4	266	184	278	270	255	233	216
	12		97.6	0.0	268	190	289	281	266	243	225
	SURFACE DAILY TOTALS				2982	1644	2176	2082	1936	1736	1594
MAY 21	4	8	5.8	125.1	51	11	5	4	4	3	3
	5	7	11.6	112.1	132	42	13	11	10	9	8
	6	6	17.9	99.1	185	79	29	16	14	12	11
	7	5	24.5	85.7	218	117	86	72	56	39	28
	8	4	30.9	71.5	239	152	148	133	115	94	80
	9	3	36.8	56.1	252	182	204	190	170	145	128
	10	2	41.6	38.9	261	205	249	235	213	186	167
	11	1	44.9	20.1	265	219	278	264	242	213	193
	12		46.0	0.0	267	224	288	274	251	222	201
	SURFACE DAILY TOTALS				3470	2236	2312	2124	1898	1624	1436
JUN 21	3	9	4.2	139.4	21	4	2	2	2	2	1
	4	8	9.0	126.4	93	27	10	9	8	7	6
	5	7	14.7	113.6	154	60	16	15	13	11	10
	6	6	21.0	100.8	194	96	34	19	17	14	13
	7	5	27.5	87.5	221	132	91	74	55	36	23
	8	4	34.0	73.3	239	166	150	133	112	88	73
	9	3	39.9	57.8	251	195	204	187	164	137	119
	10	2	44.9	40.4	258	217	247	230	206	177	157
	11	1	48.3	20.9	262	231	275	258	233	202	181
	12		49.5	0.0	263	235	284	267	242	211	189
	SURFACE DAILY TOTALS				3650	2488	2342	2118	1862	1558	1356
JUL 21	4	8	6.4	125.3	53	13	6	5	5	4	4
	5	7	12.1	112.4	128	44	14	13	11	10	9
	6	6	18.4	99.4	179	81	30	17	16	13	12
	7	5	25.0	86.0	211	118	86	72	56	38	28
	8	4	31.4	71.8	231	152	146	131	113	91	77
	9	3	37.3	56.3	245	182	201	186	166	141	124
	10	2	42.2	39.2	253	204	245	230	208	181	162
	11	1	45.4	20.2	257	218	273	258	236	207	187
	12		46.6	0.0	259	223	282	267	245	216	195
	SURFACE DAILY TOTALS				3372	2248	2280	2090	1864	1588	1400
AUG 21	5	7	4.6	108.8	29	6	3	3	2	2	2
	6	6	11.0	95.5	123	39	16	11	10	8	7
	7	5	17.6	81.9	181	77	69	61	52	42	35
	8	4	23.9	67.8	214	113	132	123	112	97	87
	9	3	29.6	52.6	234	144	190	182	169	150	138
	10	2	34.2	36.2	246	168	237	229	215	194	179
	11	1	37.2	18.5	252	183	268	260	244	222	205
	12		38.3	0.0	254	188	278	270	255	232	215
	SURFACE DAILY TOTALS				2808	1646	2108	2008	1860	1662	1522
SEP 21	7	5	6.5	76.5	77	16	25	25	24	23	21
	8	4	12.7	72.6	163	51	92	92	90	85	81
	9	3	18.1	48.1	206	83	159	159	156	147	141
	10	2	22.3	32.7	229	108	212	213	209	198	189
	11	1	25.1	16.6	240	124	246	248	243	230	220
	12		26.0	0.0	244	129	258	260	254	241	230
	SURFACE DAILY TOTALS				2074	892	1726	1736	1696	1608	1532
OCT 21	8	4	3.0	58.5	17	2	9	9	10	10	10
	9	3	8.1	44.6	122	26	86	91	93	92	90
	10	2	12.1	30.2	176	50	152	159	161	159	155
	11	1	14.6	15.2	201	65	193	201	203	200	295
	12		15.5	0.0	208	71	207	215	217	213	208
	SURFACE DAILY TOTALS				1238	358	1088	1136	1152	1134	1106
NOV 21	10	2	3.0	28.1	23	3	18	20	21	21	21
	11	1	5.4	14.2	79	12	70	76	79	80	79
	12		6.2	0.0	97	17	89	96	100	101	100
	SURFACE DAILY TOTALS				302	46	266	286	298	302	300
DEC 21	11	1	1.8	13.7	4	0	3	4	4	4	4
	12		2.6	0.0	16	2	14	15	16	17	17
	SURFACE DAILY TOTALS				24	2	20	22	24	24	24

NOTE: 1) BASED ON DATE IN TABLE 1, pp 387 in 1972 ASHRAE HANDBOOK OF FUNDAMENTALS; 0% GROUND REFLECTANCE; 1.0 CLEARNESS FACTOR.
2) SEE FIG. 4, pp 394 in 1972 ASHRAE HANDBOOK OF FUNDAMENTALS FOR TYPICAL REGIONAL CLEARNESS FACTORS.
3) GROUND REFLECTION NOT INCLUDED ON NORMAL OR HORIZONTAL SURFACES.

to the method of Liu and Jordan (1977). The daily sum of this calculated radiation was then distributed over the hours of the day according to the aspect, i.e. in the summer in Alaska the northeast slope has a radiation maximum at 7 a.m., the northwest slope maximum occurs at 5 p.m., etc. This table of radiation data (in Btu-hr/ft^2 on a vertical or horizontal unit surface area) is included in Appendix B of this report.

Averaged weekly data for the radiation site at Barrow, Alaska is available from Baker and Klink (1975). The data is given in langleys per day (.271 Btu-day/ft^2) and is based on the period of record from 1952 to 1975.

Data used for the program for initial studies of passive solar heating, the transient systems simulation program, TRNSYS, was obtained from the NBS Building Science series Publication No. 96 entitled "Hourly Solar Radiation Data for Vertical and Horizontal Surfaces on Average Days in the United States and Canada" (1977). The National Bureau of Standards solar radiation data referred to here was calculated by using theoretical solar radiation equations and average measured solar radiation data to generate the average hourly solar radiation values incident on vertical surfaces oriented in the eight primary directions (S, SW, W, NW, N, NE, E, SE), as well as the horizontal surface. The averaged solar radiation data on a horizontal surface was punched onto data cards and then converted to tapes to simplify data access. (This data is public information and is available for use. Contact the Institute of Water Resources, or the Department of Mechanical Engineering, University of Alaska, Fairbanks, for details.)

The TRNSYS computer program was developed at the University of Wisconsin as an hourly, accurate simulation tool for predicting the performance of solar energy systems of many types. Because it is an hourly simulation it is very expensive to use. Consequently the University of Wisconsin developed charts, called "F" charts to correlate the TRNSYS performance estimates with the estimates given by simulations which used averaged monthly data. This process resulted in the F-CHART solar energy program which is easier and less expensive to use, and it is the major tool used in this assessment.

There is also evidence that within the next year, because of the increasing emphasis on the use of solar energy in buildings, much of the solar radiation data for Alaska will be rehabilitated and additional data will be collected. The National Climatic Center (NCC), National Oceanographic and Atmospheric Administration, Asheville, N. C., has assured the authors of this report that, within one year, solar radiation data from Alaska will be available on tapes in Fortran compatible format from the NCC.

F-CHART COMPUTER SIMULATIONS

Solar Collector Specifications Used in F-Chart Simulations

Flat-plate solar collectors (Figure 2) are usually designed with one or two glazings covering a blackened metal plate which acts as an absorber and to which tubes or pipes are connected with a good, thermally conductive bond. A fluid, either water or an antifreeze solution, is pumped through the collector, and as it passes through, it absorbs heat. The back and sides of the solar flat-plate collector are usually well insulated to reduce heat loss. At least one and, in cold climates, two transparent coverplates cover the surface of the flat-plate collector with a 3/4- to 1-inch separation between them and function in the same way that a glass greenhouse does. Glass is transparent (∿80-90%) to incoming solar beam and diffuse radiation but is nearly opaque to longer wavelength thermal infrared radiation, which, because it is trapped as in a greenhouse, enhances the heating of the collector surface.

There are other types of collectors available, including focusing types and evacuated-tube collectors, but these will not be discussed in detail since they involve more complex applications, such as industrial uses.

The collector specifications used in the F-CHART simulations are conservative values based on the Lennox brand, commercially available solar collector manufactured by Honeywell, Inc. This is a typical solar collector representative of many commercially available models. Its choice in these simulations is an arbitrary one and is not to be construed as an endorsement. The specifications for a Lennox solar collector model LSC18-1 are given below.

Specifications:

Collector Model Number - Double Glass Cover LSC18-1

Nominal Collector Area - 18 sq. ft.

Effective Absorber Area - 15.4 sq. ft.

Ratio of Usable Absorber Area to Total Surface Covered - 86%

Glass Cover(s):

1/8-in. Thick
Tempered, Low Iron, Clear
Transmittance - .96

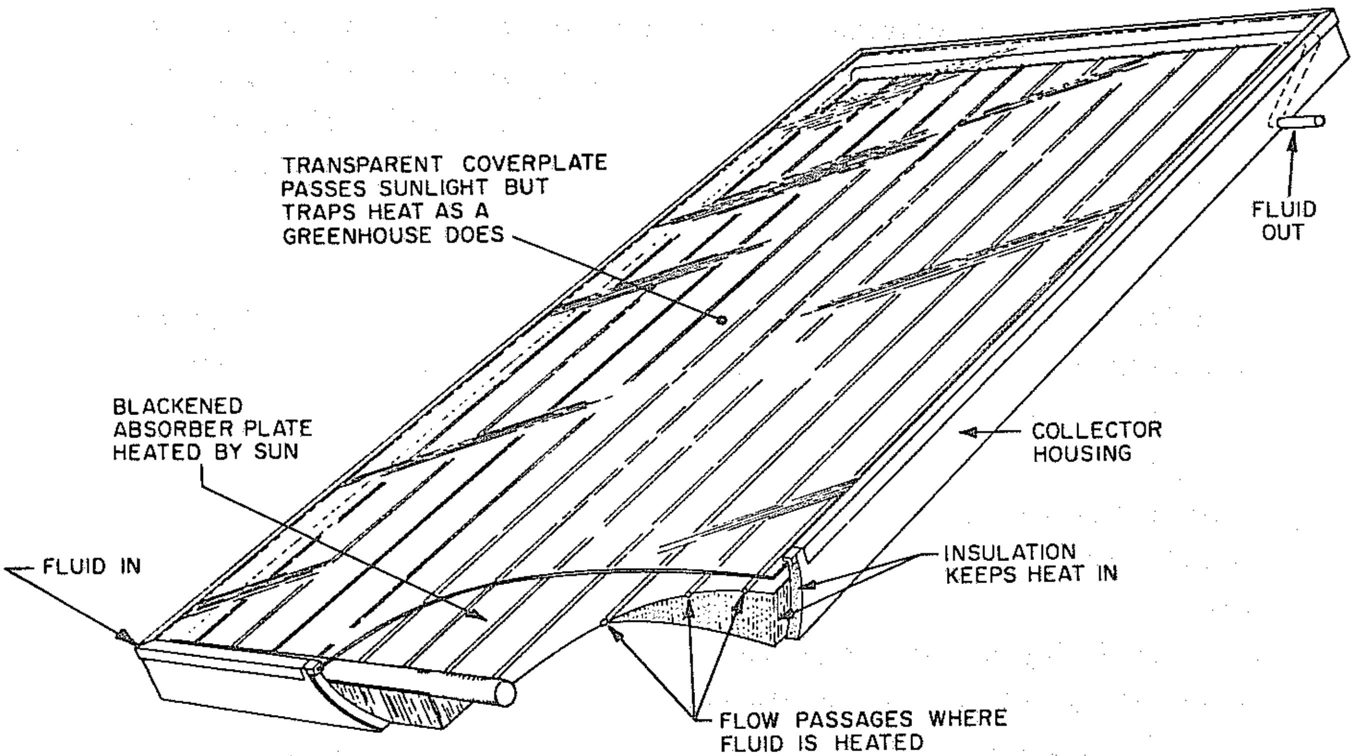


Fig. 2: A SCHEMATIC VIEW OF A TYPICAL FLAT-PLATE SOLAR COLLECTOR.

Absorber Coating - Black Chrome on Bright Nickel:

Absorptivity - .94
Emissivity - .10
Stable to 850°F

Absorber Construction:

Steel Plate
Copper Flow Tubes - (10) 1/4 in o.d. (.194 in. id.)
Tube Spacing - 3 in. on Center
Tube Pattern - "Z" Flow
Manifold - 1-1/8 in. o.d. (1.079 in. i.d.)
Tube Connections to Manifold: ASTM BCuP-3 Brazing Material
Bond Between Tubes & Steel Plate - 95-5 Solder
Piping Connections (inlet-outlet) - 3/8-18 fpt (federal pipe thread)
Manifolds & Tubes Pressure Tested: To 150 psig (pounds per square inch gauge) Working Pressure

Recommended Flow Rate through Collector - .3 to .7 gpm

Collector Fluid Capacity - .3 gal.

Collector Fluid (50-50 Dowtherm SR-1 or Equivalent): SR-1 Data:

Density - 1.045 g/ml (at 160°F)
Viscosity - 1.4 centipoise (at 160°F)
Thermal Conductivity - 0.23 Btu/lb-°F (at 160°F)
Specific Heat - 0.85 Btu/lb-°F (at 160°F)
Boiling Point - 232°F
Freezing Point - -34°F

Insulation - Semirigid Fiberglass Board:

Density - 3.0 lb/ft^3
Thermal Conductivity - 0.28 Btu in./$hr\text{-}ft^2$ (at 200°F) (R=12.5)
Specific Heat - 16 Btu/lb °F
Maximum Temperature - 550°F (without outgassing)

Collector Shipping Weight (lbs.) - (1 Package)

LSC18-1 - 170

Collector Net Weight (lbs.)

LSC18-1 - 150

The physical parameters listed here determine the performance of the collector such that the efficiency is dependent on several factors including incident solar radiation, ambient temperature, and collector fluid inlet temperature. The efficiency is commonly in the range of 40-70%.

Results of F-Chart Computer Simulations

There are essentially two ways to assess the feasibility of solar energy systems. The first and most direct way is simply to purchase solar collectors, monitor their long-term performance corresponding to the incident solar radiation, and report upon the results. A second, more expedient method is to use computer simulation programs to model the thermal and economic performance of solar energy applications. Since this study provided neither the time nor the resources for a test of collector-system performance, the computer simulation technique was chosen to assess the solar energy resource potential in Alaska.

F-CHART, a computer solar simulation design program developed at the University of Wisconsin Solar Energy Laboratory, was purchased by the Institute of Water Resources and Department of Mechanical Engineering for this project. It has been designed to simulate the long-term performance of solar domestic or commercial water-heating systems using average monthly solar radiation data and the system specifications supplied by the program user. In addition to providing an estimate of the average percentage of the hot water or space-heating load provided by a solar energy system, F-CHART is capable of supplying an economic optimization of a hybrid solar/conventional hot water or heating system. By comparing the cost per square foot of the collector and storage tank against interest rate, mortgage term, and the cost of the conventional fuel (among other economic factors), the program will suggest an optimum economic size for a solar collector at each location of interest. The program is not difficult to use and is easy to run from a remote computer terminal. It is public information and available on the University of Alaska's computer system for the cost of computer time.

In this study, the optimization of solar energy systems for heating domestic water was the area of concentration. The rationale for this attention to water heating is that hot water is needed year around in contrast to space heating, and if an economic analysis indicates that this application is viable at a site in Alaska, other uses for solar energy might also be worth pursuing. Water heating was also felt to be the most likely "first application" of solar energy in a residential or commercial building because of the system's availability and relatively low first cost.

To perform an up-to-date economic analysis for each of the areas of Alaska at which solar radiation is measured, it was necessary to survey public utilities in Alaska to get their current electric rates, and oil and natural gas prices. Most electricity rates in Alaska are declining block rates, which means that electricity gets cheaper as more is used. To equalize the cost of electricity for a comparison with solar collector-supplied heat in a simulation, the cost of 1000 kwh of electricity was determined and then divided by 1000 kwh to yield a fair "average" cost per kilowatt hour. Each of the utility rates is given in terms of the cost of one million Btus of heat since this is the unit of comparison in the F-CHART simulation. (One million Btus equals 292.9 kwh.) The following chart (Table 5) lists the parameters used in the F-CHART evaluation of solar hot-water heating in Fairbanks, Alaska. All the parameters used are an accurate reflection or a best estimate of the factors which presently prevail in Fairbanks and are conservative. The evaluation is based on monthly average solar radiation data, a cost of solar collectors at $\$15.50/ft^2$, calculated on a 20-year mortgage base, for a demand of 100 gallons per day delivered at 140°F.

In addition to these basic factors, the physical performance of the collector can be modeled (items 1-7, Table 5), the heating and hot water load can be varied, as well as the inlet supply temperature and the temperature of delivered hot water (items 8-14). The simulation can allow for performance degradation due to corrosion (item 19). Solar energy system fixed costs, such as installation, pumps, and plumbing, as well as the collector area-associated costs can be adjusted by the user (items 21-22). The cost of present fuels used for the various types of heating is the basis upon which the F-CHART program optimizes the contribution and cost of a solar energy alternative. Most of the other factors are economic and can also be adjusted by the user (Table 5). The F-CHART program includes its own instructions and is used through a series of question and answer interchanges between the user and the program. All of the simulations which follow use the same data as in Table 5 except of course for location (item 15), groundwater temperature (item

TABLE 5
F-CHART Solar Simulation Parameters for Fairbanks, Alaska

Code	Variable Description	Value	Units
1	AIR SYSTEM = 1, LIQUID SYSTEM = 2	2.00	
2	COLLECTOR AREA	162.00	FT2
3	FRPRIME-TAU-ALPHA PRODUCT (NORMAL INCIDENCE)	0.70	
4	FRPRIME-UL PRODUCT	0.83	BTU/H-F-F2
5	NUMBER OF TRANSPARENT COVERS	2.00	
6	COLLECTOR SLOPE	64.00	DEGREES
7	AZIMUTH ANGLE (E.G. SOUTH = 0, WEST = 90)	0.00	DEGREES
8	STORAGE CAPACITY	15.00	BTU/F-FT2
9	EFFECTIVE BUILDING UA	0.	BTU/HR-F
10	CONSTANT DAILY BLDG HEAT GENERATION	0.	BTU/DAY
11	(EPSILON) (CMIN)/(EFFECTIVE BUILDING UA)	2.00	
12	HOT WATER USAGE	100.00	GAL/DAY
13	WATER SET TEMPERATURE	140.00	F
14	WATER MAIN TEMPERATURE	37.00	F
15	CITY CALL NUMBER	49.00	
16	THERMAL PRINT OUT BY MONTH = 1, BY YEAR = 2	1.00	
17	ECONOMIC ANALYSIS ? YES = 1, NO = 2	1.00	
18	USE OPTMZD. COLLECTOR AREA = 1, SPECFD. AREA = 2	1.00	
19	SOLAR SYSTEM THERMAL PERFORMANCE DEGRADATION	0.	%/YR
20	PERIOD OF THE ECONOMIC ANALYSIS	20.00	YEARS
21	COLLECTOR AREA DEPENDENT SYSTEM COSTS	15.50	$/FT2 COLL
22	CONSTANT SOLAR COSTS	1000.00	$
23	DOWN PAYMENT (% OF ORIGINAL INVESTMENT)	10.00	%
24	ANNUAL INTEREST RATE ON MORTGAGE	8.00	%
25	TERM OF MORTGAGE	20.00	YEARS
26	ANNUAL NOMINAL (MARKET) DISCOUNT RATE	8.00	%
27	EXTRA INSUR., MAINT. IN YEAR 1(% OF ORIGN. INV.)	1.00	%
28	ANNUAL % INCREASE IN ABOVE EXPENSES	6.00	%
29	PRESENT COST OF SOLAR BACKUP FUEL (BF)	14.60	$/MILLION BTU
30	BF RISE: %/YEAR = 1, SEQUENCE OF VALUES = 2	1.00	
31	IF 1, WHAT IS THE ANNUAL RATE OF BF RISE	10.00	%
32	PRESENT COST OF CONVENTIONAL FUEL (CF)	14.60	$/MILLION BTU
33	CF RISE: %/YR = 1, SEQUENCE OF VALUES = 2	1.00	
34	IF 1, WHAT IS THE ANNUAL RATE OF CF ROSE	10.00	
35	ECONOMIC PRINT OUT BY YEAR = 1, CUMULATIVE = 2	2.00	
35	EFFECTIVE FEDERAL-STATE INCOME TAX RATE	35.00	%
37	TRUE PROP. TAX RATE PER $ OF ORIGINAL INVEST.	2.00	%
38	ANNUAL % INCREASE IN PROPERTY TAX RATE	6.00	%
39	CALC. RT. OF RETURN ON SOLAR INVTMT? YES = 1, NO = 2	2.00	
40	SALVAGE VALUE (% OF ORIGINAL INVESTMENT)	0.	%
41	INCOME PRODUCING BUILDING? YES = 1, NO = 2	2.00	

14), and the cost of the back-up electrical energy (items 29 and 32), which varies widely within Alaska. The F-CHART program utilizes standard economic evaluation techniques, and based on a 20-year mortgage at 8% annual interest, the program calculates the following economic factors as an evaluation of the solar option:

1. Optimized collector area: F-CHART optimizes the size of the solar flat-plate collectors as a function of the domestic hot water demand and the cost of heating that water with an electric hot-water heater as a back-up system.
2. Initial cost of the solar system: This is the total initial capital cost of buying and installing a solar hot-water system, based on reasonable estimates. It includes $1,000 fixed costs for plumbing, connectors, and labor, plus the area-associated collector costs ($\$15.50/ft^2$).
3. Annual mortgage payment for 20 years: This figure is the amount by which an annual mortgage payment would be increased to pay for the solar hot-water system.
4. Discounted rate of return on the solar investment: This is the "interest rate" at which the solar hot-water system investment pays for itself in savings, without considering the loss due to the inflation of the value of the investment.
5. Discounted pay-back period: The time period in which the solar hot-water system will pay for itself, without considering inflation or financing costs.
6. Years until cumulative savings equals the mortgage plus principle: This is somewhat self-explanatory. It is the amount of time required for the solar hot-water system's saving to equal the cost of financing it for twenty years.
7. Present worth of yearly total costs with solar: The cumulative 20-year cost of purchasing and maintaining a solar hot-water system.
8. Present worth of yearly system costs without solar: The integrated 20-year cumulative costs of purchasing, operating, and maintaining a standard electric hot-water heating system.

9. Present worth of solar savings: The cumulative savings over 20 years of using solar energy versus an electric hot-water heating system.

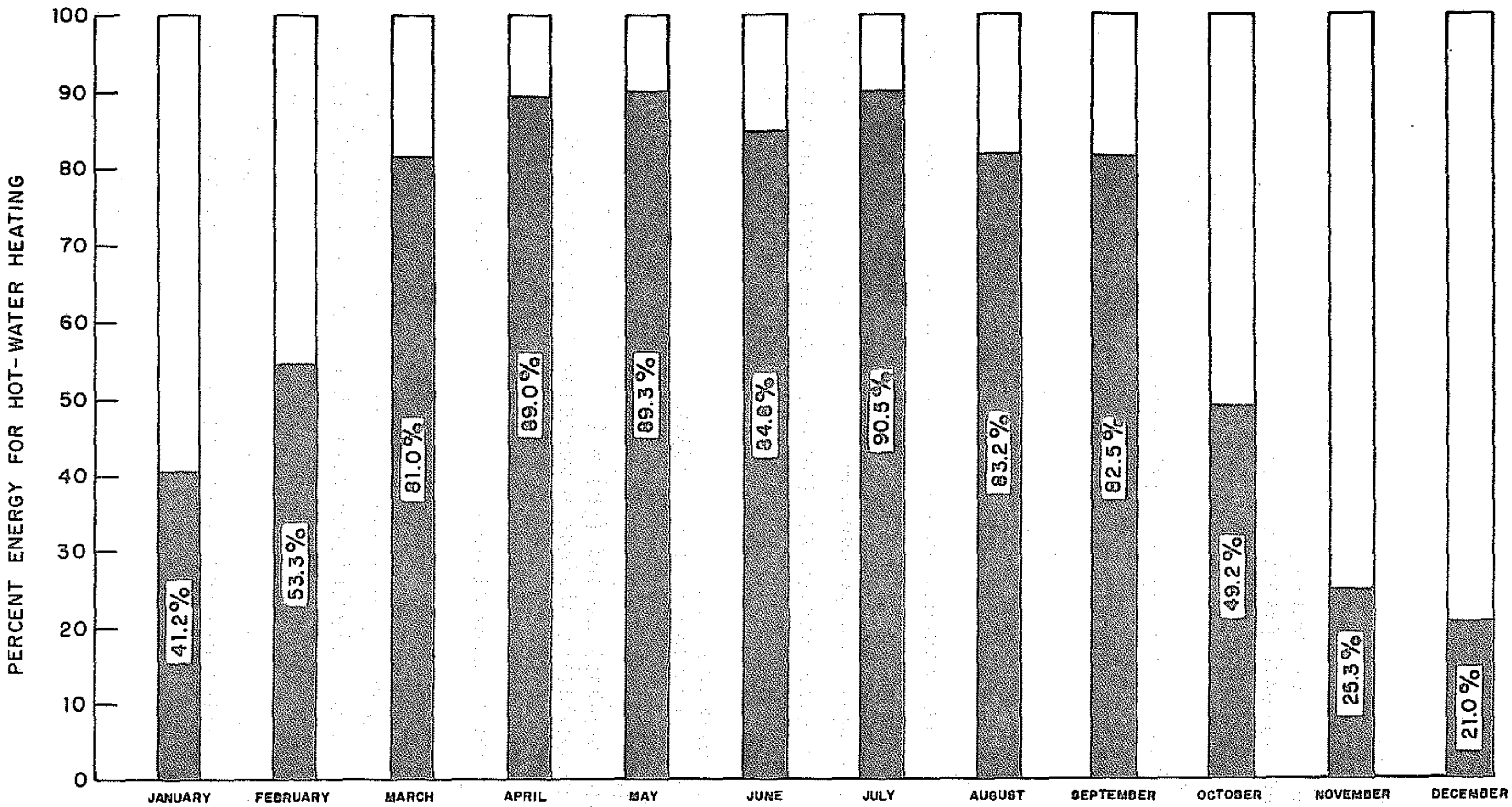
These factors are listed as an evaluation of solar domestic hot-water heating in the F-CHART simulation section for each of the Alaskan locations in the following section.

Results of F-Chart Simulations by Location

Annette Island, Alaska. Annette Island is one of the southernmost islands of the Alexander Archipelago in Southeast Alaska (see Figure 1). It's climate is very wet and cloud cover is frequent. A large percentage of the incident solar radiation is diffuse. For a comparison of solar energy costs, two prices for electricity as a back-up fuel were used. The price in Metlakatla, the major village on Annette Island, is $9.78 per million Btus; the Ketchikan Public Utilities price, is $11.19 for a million Btus equivalent of electricity. Solar energy is not competitive with oil-fired hot water systems in Southeast Alaska where oil costs are in the range of 43 to 52 cents per gallon.

A plot of the contribution solar energy can economically provide in an average year in Ketchikan is shown in Figure 3. Ketchikan is shown first since it is the major population center near Annette Island. The F-CHART system uses real average monthly radiation data for each site, so the effect of cloud cover is an integral part of the simulation. This is very likely the reason for the lower solar contribution in June for Annette Island as compared to May and July. Using the solar radiation data from Annette Island, the economic pay-back period and present worth of a solar hot-water heater in Ketchikan was calculated and is shown below.

Optimized collector area = 162 ft^2
Initial cost of solar system = $3511
Annual mortgage payment for 20 years = $322
Discounted rate of return on the solar investment = 17.2%
Discounted pay-back period (yr) = 13
Yrs until cumulative savings = mortgage + principal = 15
Present worth of yearly total costs with solar = $6811
Present worth of yearly total costs w/o solar = $7916
Present worth of cumulative solar savings = $1105



ENERGY % SUPPLIED BY ELECTRICITY

ENERGY % SUPPLIED BY SOLAR COLL.
(ANNUAL SOLAR PERCENTAGE: 65.9%)

OPTIMUM COLLECTOR AREA: 162 FT.^{2} (LENNOX COMMERCIAL COLLECTOR SPECIFICATIONS)

F-CHART COMPUTER SIMULATION USING AVERAGE MONTHLY SOLAR RAD. DATA

100 GAL/DAY HOT WATER USE. 140°F. HOT WATER DELIVERY TEMP.

55° COLLECTOR TILT

Fig. 3: ANNETTE, ALASKA (55° 02'N.) (KETCHIKAN ELECTRIC RATE = $11.71 MMBTU)

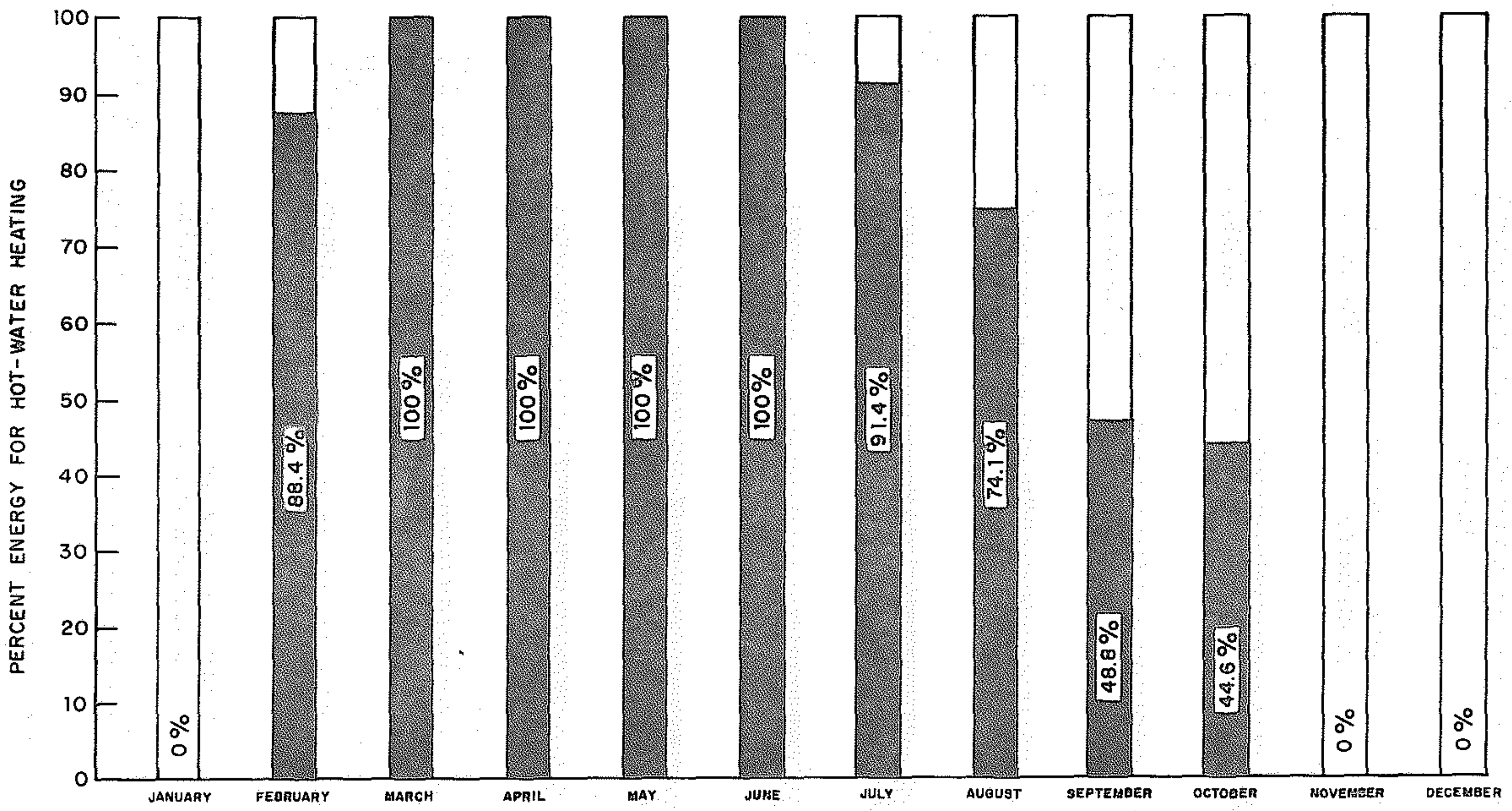
A comparison of the economic pay-back period and present worth value for Metlakatla are shown below.

Optimized collector area = 126 ft^2
Initial cost of solar system = $2953
Annual mortgage payment for 20 years = $271
Discounted rate of return on the solar investment = 11.0%
Discounted pay-back period (yr) = 18
Yrs until cumulative savings = mortgage + principle = 19
Present worth of yearly total costs with solar = $6317
Present worth of yearly total costs w/o solar = $6611
Present worth of cumulative solar savings = $294

<u>Barrow, Alaska</u>. Barrow, Alaska is an anomaly in energy economics. Electricity costs in Barrow are the highest encountered in this study--11.8¢ kwh or $34.56 per million Btus. However, very inexpensive natural gas is also available (20¢/$10^3 ft^3$ or 28.5¢ per million Btus). The North Slope Borough has an interest in an economic hot-water supply, since many new structures will be connected with utilidors requiring service hot water. Figure 4 shows the percentage of heat supplied by an economically optimum solar hot water system for Barrow. The economic analysis for this system, which uses an electric back-up unit, is shown below.

Optimized collector area = 216 ft^2
Initial cost of solar system = $4348
Annual mortgage payment for 20 years = $399
Discounted rate of return on the solar investment = 69.1%
Discounted pay-back period (yr) = 2
Yrs until cumulative savings = mortgage + principle = 6
Present worth of yearly total costs with solar = $14,666
Present worth of yearly total costs w/o solar = $25,230
Present worth of cumulative solar savings = $10,564

<u>Bethel, Alaska</u>. Bethel, Alaska, on the Kuskokwim River in Southwest Alaska, is in the transitional climatic area between arctic and continental climates. Electricity costs here are very high (10¢ per kwh or $29.29 per million Btus). Oil is relatively inexpensive, and at 53 to 56¢ per gallon, is less costly than at Fairbanks. Solar is not competitive with oil-fired hot-water systems in Bethel, but if electricity is used to heat hot water, solar hot water in Bethel has a discounted pay-back period of 3 years. The contributed solar heat to the hot water load is shown in Figure 5, and the economic data is shown below.



ENERGY % SUPPLIED BY ELECTRICITY

ENERGY % SUPPLIED BY SOLAR COLL.
(ANNUAL SOLAR PERCENTAGE: 62.1 %)

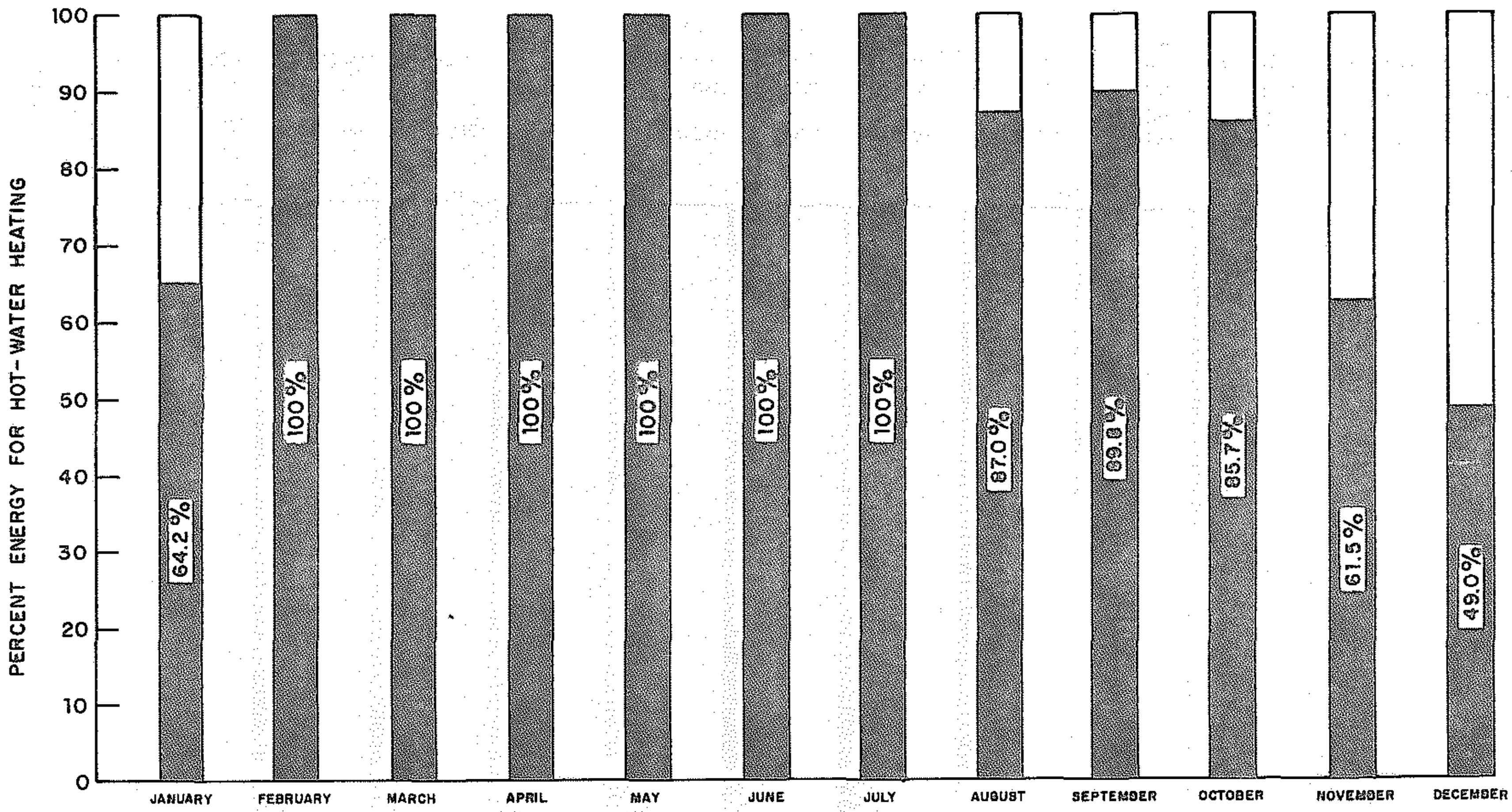
OPTIMUM COLLECTOR AREA: 216 FT.^{2} (LENNOX COMMERCIAL COLLECTOR SPECIFICATIONS)

F-CHART COMPUTER SIMULATION USING AVERAGE MONTHLY SOLAR RAD. DATA

100 GAL/DAY HOT WATER USE. 140°F. HOT WATER DELIVERY TEMP.

71° COLLECTOR TILT

Fig. 4: BARROW, ALASKA (71° 20'N.)(UTILITY RATE = $34.56 / MMBTU)



ENERGY % SUPPLIED BY ELECTRICITY

ENERGY % SUPPLIED BY SOLAR COLL.
(ANNUAL SOLAR PERCENTAGE: 86.3%)

OPTIMUM COLLECTOR AREA: 324 FT.^{2} (LENNOX COMMERCIAL COLLECTOR SPECIFICATIONS)

F-CHART COMPUTER SIMULATION USING AVERAGE MONTHLY SOLAR RAD. DATA

100 GAL/DAY HOT WATER USE. 140°F. HOT WATER DELIVERY TEMP.

60° COLLECTOR TILT

Fig. 5: BETHEL, ALASKA (60° 47'N.)(UTILITY RATE = $29.29/MMBTU)

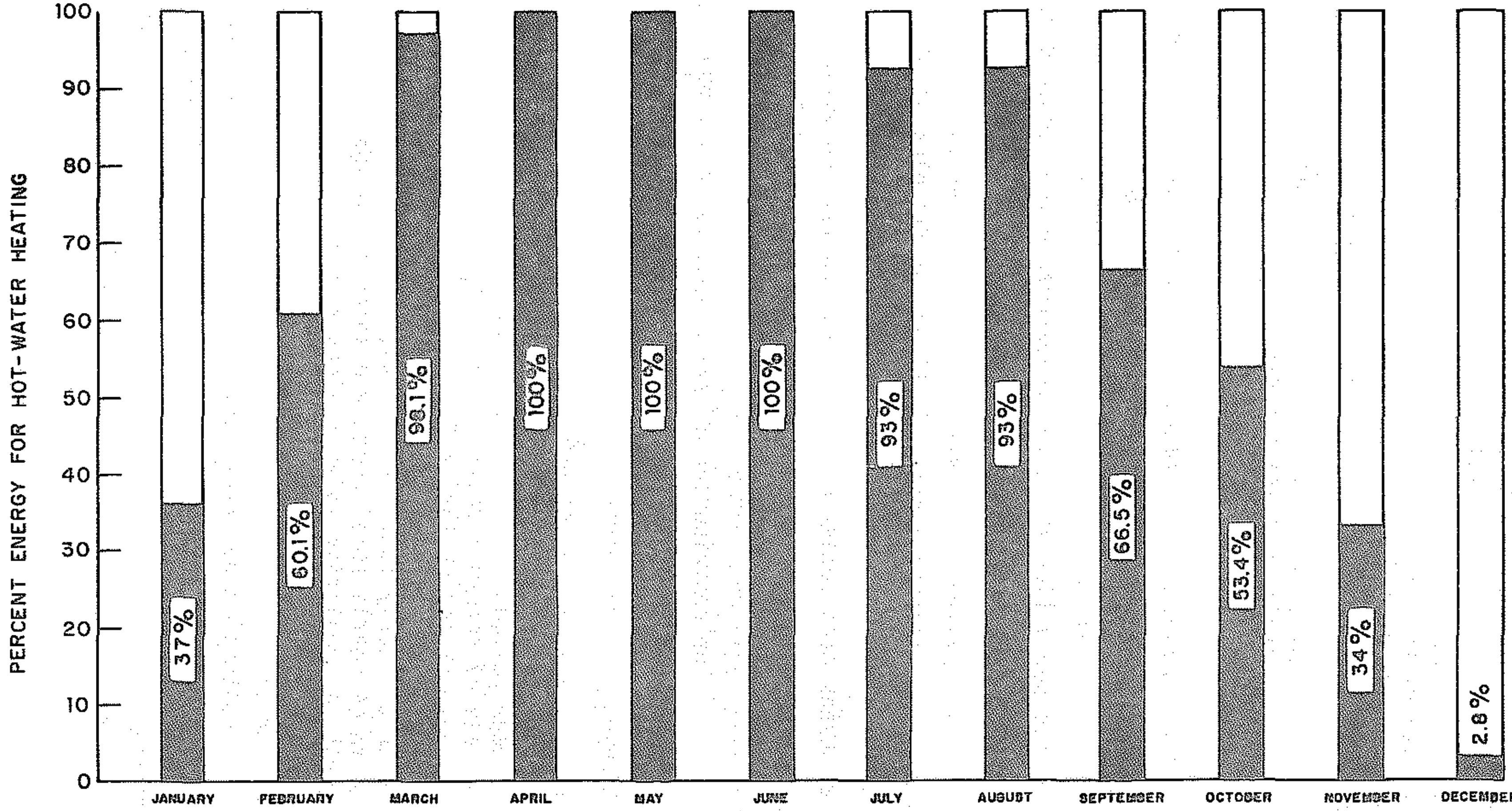
Optimized collector area = 324 ft^2
Initial cost of solar system = $6022
Annual mortgage payment for 20 years = $552
Discounted rate of return on the solar investment = 63.6%
Discounted pay-back period (yr) = 3
Yrs until cumulative savings = mortgage + principle = 8
Present worth of yearly total costs with solar = $9846
Present worth of yearly total costs w/o solar = $20,393
Present worth of cumulative solar savings = $10,547

Fairbanks, Alaska. Fairbanks is the major city of interior Alaska, a region of subarctic continental climate, with short, relatively warm, summers and long, cold winters. Electricity is expensive in Fairbanks, averaging nearly 5¢ per kwh or $14.60 per million Btus. Oil, at an average price of 57¢ per gallon is at the break-even price compared to solar hot-water systems, since the pay-back period for solar systems compared to oil-fired systems is 19 years of a 20-year mortgage. This is at a collector area-associated cost of $15.50 per ft^2 plus $1,000 in initial fixed costs.

Many Fairbanksans heat domestic water electrically, and solar energy is competitive with electrically heated hot water in Fairbanks, given the associated costs per square foot of collector ($20-25/$ft^2$ total system costs). The contribution of solar heat to an optimum size (for Fairbanks) system is shown in Figure 6. The economic analysis for this optimum system is shown below.

Optimized collector area = 162 ft^2
Initial cost of solar system = $3511
Annual mortgage payment for 20 years = $322
Discounted rate of return = 34.2%
Discounted pay-back period (yr) = 7
Yrs until cumulative savings = mortgage + principle = 11
Present worth of yearly total costs with solar = $7177
Present worth of yearly total costs w/o solar = $10,165
Present worth of cumulative solar savings = $2989

Matanuska, Alaska. The Matanuska solar radiation data is acquired at the Palmer Agricultural Experiment Station. This is the only source of data available for the state's major population area. For this reason two analyses were done--one using the Matanuska Electric Association (MEA) electrical rates and the other using Anchorage Municipal Light and Power rates for electricity. The MEA rates average 3.72¢ per



ENERGY % SUPPLIED BY ELECTRICITY

ENERGY % SUPPLIED BY SOLAR COLL.
(ANNUAL SOLAR PERCENTAGE: 69.9%)

OPTIMUM COLLECTOR AREA: 162 FT.^{2} (LENNOX COMMERCIAL COLLECTOR SPECIFICATIONS)

F-CHART COMPUTER SIMULATION USING AVERAGE MONTHLY SOLAR RAD. DATA

100 GAL/DAY HOT WATER USE. 140°F HOT WATER DELIVERY TEMP.

64° COLLECTOR TILT

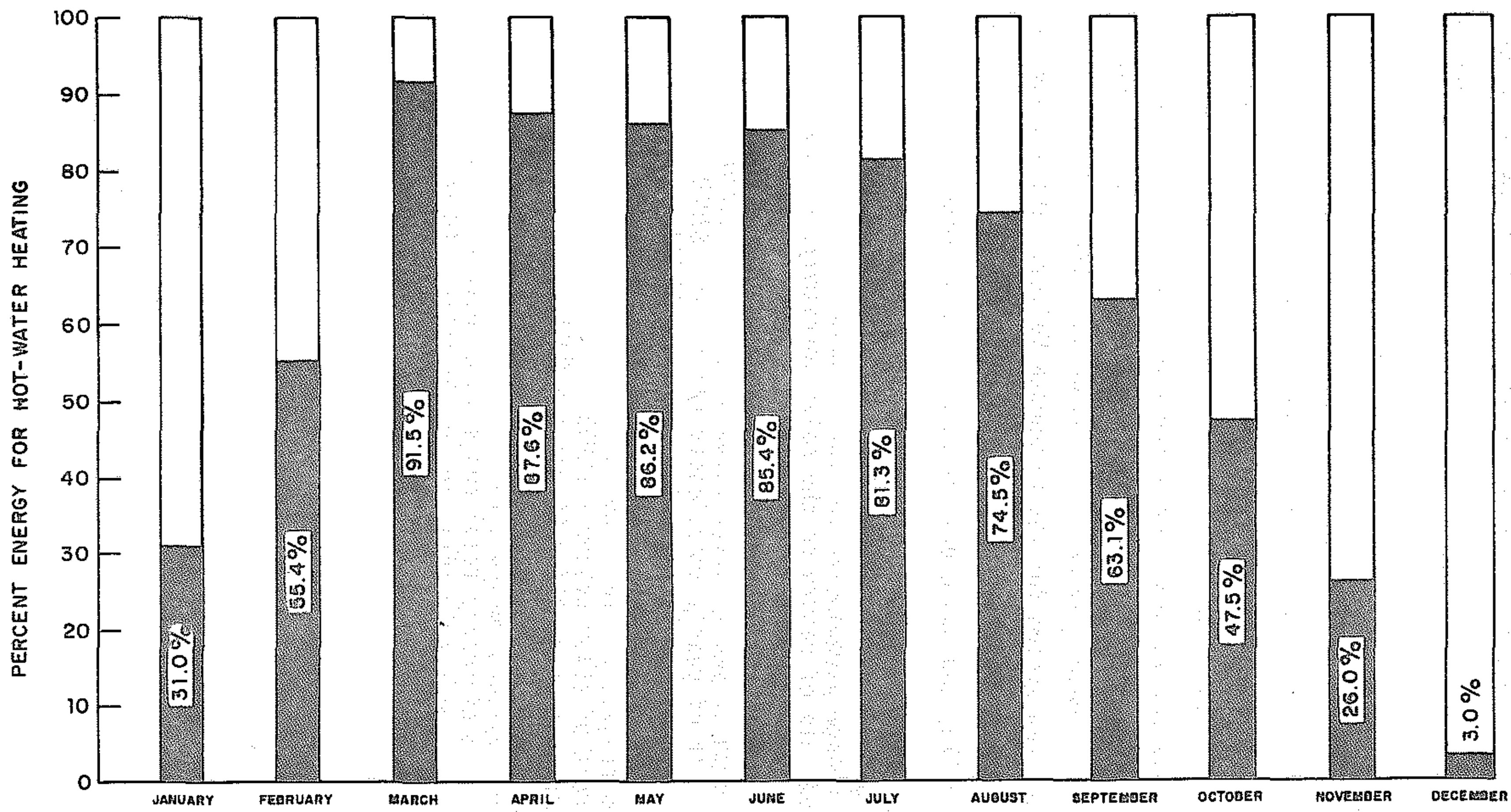
Fig. 6: FAIRBANKS, ALASKA (64°49'N.)(UTILITY RATE = $14.60/MMBTU)

kwh or $10.89 per million Btus. In Anchorage, based as always on 1000 kwh use per month, the cost averages 3.12¢ per kwh or $9.13 per million Btus.

The pay back and present worth of a solar energy system in economic competition with electrically heated hot water depends mostly on the cost of electricity. In the Matanuska Valley, solar energy for hot-water heating is economical with a pay back of 12 years. In Anchorage, the economic situation is not yet favorable to solar energy systems, as the electric rates are at about the break-even point, and a solar hot-water heating system would pay back in 19 years of a 20-year mortgage. Figure 7 shows the monthly solar contribution to hot-water heating of an economically optimum system for the Matanuska Valley. Shown below is the economic analysis of solar hot-water heating for the cases of the MEA-Matanuska Valley and municipal Anchorage respectively.

Optimized collector area = 144 ft^2
Initial cost of solar system = $3232
Annual mortgage payment for 20 years = $296
Discounted rate of return on the solar investment = 19.0%
Discounted pay-back period (yr) = 12
Yrs until cumulative savings = mortgage + principle = 15
Present worth of yearly total costs with solar = $6770
Present worth of yearly total costs w/o solar = $8000
Present worth of cumulative solar savings = $1230.

Optimized collector area = 126 ft^2
Initial cost of solar system = $2953
Annual mortgage payment for 20 years = $271
Discounted rate of return on the solar investment = 9.2%
Discounted pay-back period (yr) = 19
Present worth of yearly total costs with solar = $6236
Present worth of yearly total costs w/o solar = $6350
Present worth of cumulative solar savings = $114



ENERGY % SUPPLIED BY ELECTRICITY

ENERGY % SUPPLIED BY SOLAR COLL.
(ANNUAL SOLAR PERCENTAGE: 56.3%)

OPTIMUM COLLECTOR AREA: 144 FT.^{2} (LENNOX COMMERCIAL COLLECTOR SPECIFICATIONS)

F-CHART COMPUTER SIMULATION USING AVERAGE MONTHLY SOLAR RAD. DATA

100 GAL/DAY HOT WATER USE. 140°F. HOT WATER DELIVERY TEMP.

60° COLLECTOR TILT

Fig. 7: MATANUSKA, ALASKA (61° 34'N.)(UTILITY RATE = $10.89/MMBTU)

GENERAL ECONOMIC ANALYSES

In order to indicate the interrelationships between the unit-area collector costs, cost of electricity, and the discounted pay-back period as economic factors in the use of solar energy, two plots of these relationships were made for solar hot-water systems using F-CHART. The first (Figure 8) is a plot of the curves for optimized collector area at various unit-area collector costs in Fairbanks. The second (Figure 9) is a plot of the relationships using a fixed collector size instead of the optimum size and is relevant for all the sites in Alaska. Fairbanks is used as the example in the economic analysis for two reasons: (1) Fairbanks has a more favorable economic picture for the use of solar energy, and (2) except for the cost of power in other areas of the state, economic determinants are similar. It is important to point out that in all five areas of the state where comparisons were made, solar energy does not compete economically with oil unless collector costs are less than \$15 per ft^2.

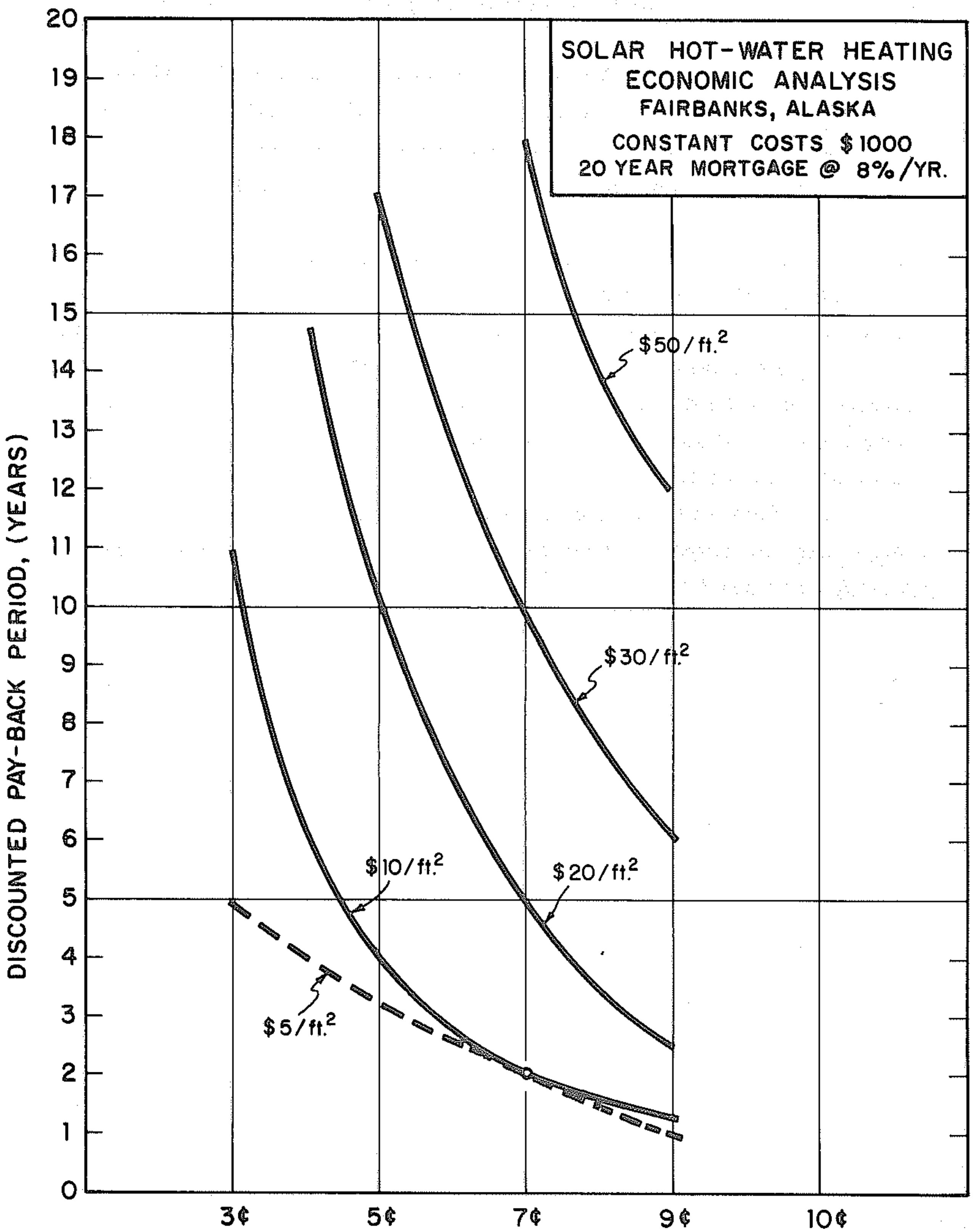


Fig. 8: COST OF ELECTRICITY, KILOWATT-HOUR
(OPTIMIZED COLLECTOR AREA)

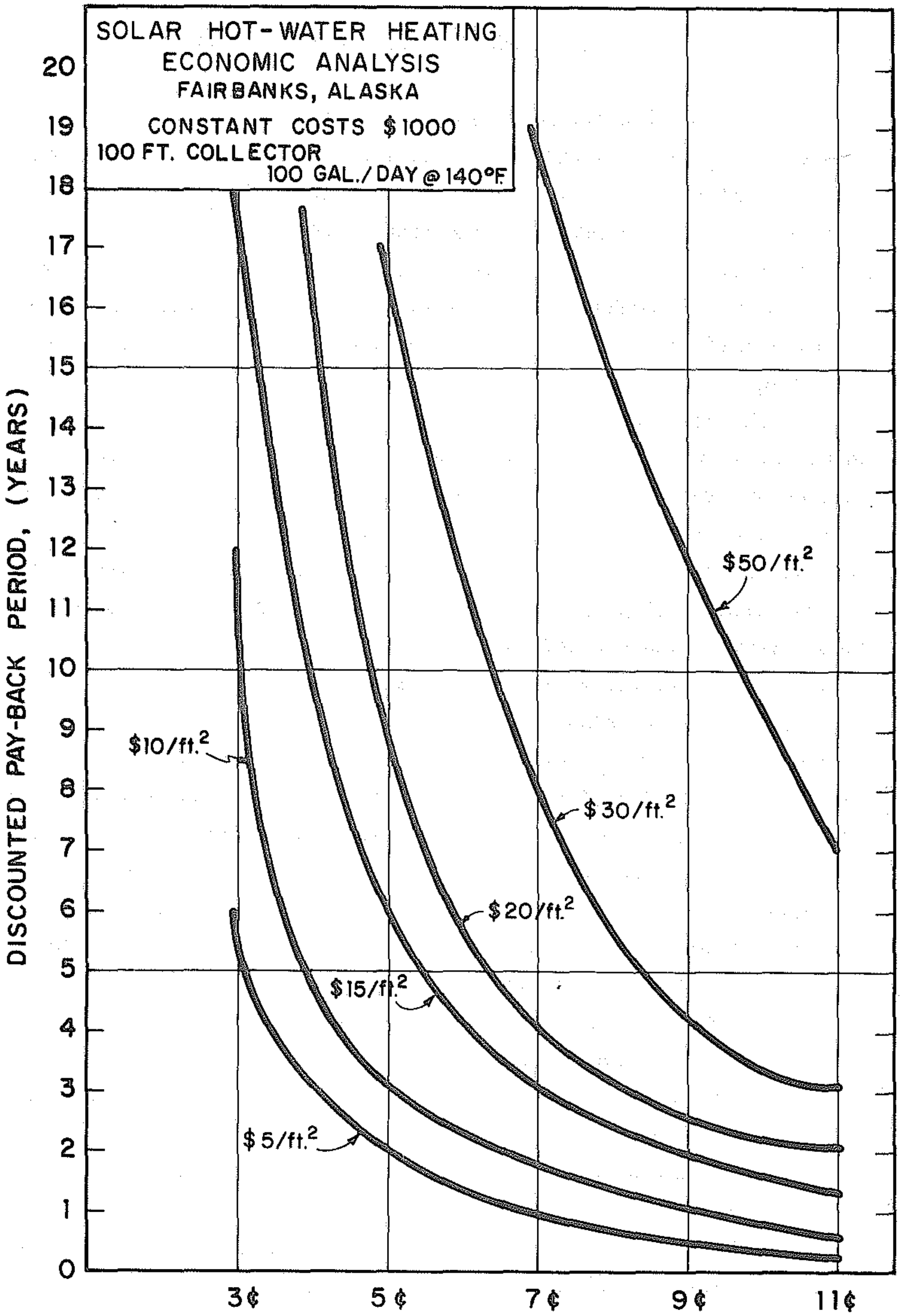


Fig. 9: COST OF ELECTRICITY, KILOWATT-HOUR
(FIXED COLLECTOR AREA)

THE LEVEL OF SOLAR DEVELOPMENT IN ALASKA

Because of climatic constraints, Alaska is often assumed to have little potential for solar-heating applications. However, individual Alaskans are very interested in building energy-efficient homes, energy conservation, and in simply saving money. Consequently a few citizens in Alaska have built solar collectors, or are designing or building solar homes or greenhouses. However, solar energy development in Alaska is not significant enough to make any impact on energy use or public energy policy to date.

Alaska has, however, an interesting and unique economic situation which may serve to enhance the appeal of solar energy hot water or space heating systems. This is due simply to the costs of conventional fuels, both in the cities and in the bush. Solar energy systems at $20 to $25 per square foot, total initial cost, are competitive with electricity for hot-water heating in nearly all areas of Alaska, even though they cannot provide 100 per cent of the heating needs. For this reason, solar energy deserves wider public exposure and experience.

As to further incentives for solar energy use, the U. S. Department of Housing and Urban Development has recently published a listing of possible federal financial incentives to expand the residential market for solar energy systems. In a six-month study (RVPI, Inc., report to HUD, July, 1977) that emphasized applications to single homes, the following list of major findings and recommendations were submitted:

1. Federal incentives can work to increase the rate of growth of the residential solar market substantially, if provided at subsidy levels above the thresholds required to elicit significant consumer response. Estimated response to major incentive options at varying subsidy levels are compared in the body of the report.
2. Front-end subsidies (tax credit or rebate/grant type programs) appear more desirable than loan programs. Front-end incentives should have a significantly greater market impact than loans on the market for solar domestic hot water systems, the solar application with the most immediate potential for residential use. Government loan programs, particularly at the

small dollar amounts required for hot water systems, have transaction costs and administrative complexities that make a loan approach likely to be unworkable in practice.

3. A grant approach which provides "rebates" upon application by solar purchasers appears preferable to a tax credit in light of its potentially greater market impact and the degree of administrative control desirable given the solar state-of-the-art today.
4. Broad-based financial incentives might best be limited at the outset of solar water-heating systems, which are at a more advanced stage of commercialization, easier to certify, and involve substantially less cost and risk for homeowners than solar space-heating systems. Support for solar heating (and cooling) could be continued through demonstration programs, assuring greater geographic distribution.
5. The design of system certification procedures to assure adequate standards for solar components, and possibly for installation, may prove as critical to the success of an incentive program as the specific type of financial support made available.
6. Skewing benefits toward lower income households appears inappropriate at this time, given the risk still inherent in the use of solar technologies and the availability of more proven means to help relieve the hardship imposed on the poor by rising energy costs. Conversely, concern with extending subsidies to more affluent households may be out of place in the context of a program encouraging homeowners to "pioneer" a new technology.
7. Steps might be taken to ensure that purchasers of new solar homes are not penalized by credit standards that exclude consideration of energy costs and savings, and that they are able to finance a normal portion of their solar investment as part of their mortgage loan.
8. An incentive capable of inducing any significant degree of solar use in multifamily rental housing would require an unprecedented and, most likely, politically unacceptable level of subsidy.

The Congress has yet to agree on the final form of energy legislation which would involve any financial incentives for homeowners who install solar energy systems (as of January, 1978). Hopefully when something is finally accepted at the federal level, the public information necessary to take advantage of the incentives will be forthcoming.

For a larger overview of the perspectives and problems of solar access and the law, the reader is referred to the most recent treatise on the subject entitled "Barriers to Solar Heating and Cooling of Buildings" (Environmental Law Institute, 1977).

LEGAL ASPECTS OF SOLAR ENERGY IN ALASKA

At present, the only law on the books concerned with solar energy is a tax credit law presently in litigation. The credit allows 10 per cent of a capital expenditure (or $200 maximum) of the cost of installing any nonfossil fuel source of power in a domestic building. Retrofitting a home with insulation is also included in this tax credit. The uncertain status of the law makes this an empty incentive at present. At best it is not substantial enough to give much incentive to solar hot- water installations. Since, in our calculations, an optimum solar hot water-heating system would cost in the range of $3500 to $4000 in Fairbanks, $200 is only 5 per cent of the cost--probably not enough to change anyone's mind about trying a new technology.

Another problem commonly discussed with reference to solar energy systems is that of easement, sun rights, and protection from foliage shadowing. Commonly referred to as "sun rights", this concept is analogous to right-of-way easements in real estate. The state of Alaska has no sun rights laws, as the question has not yet arisen. However, anyone making a $3500 to $4000 investment would do well to ensure that a 10-story highrise apartment is not planned for the block just south of him. These questions and legal problems are not trivial and are magnified by the lower sun angles in the high latitudes. It is much easier to block a February sun which is only 18° above the horizon in Fairbanks than the same sun 48° above the horizon on the same day in Los Angeles. Certain concessions have to be made to the natural constraints of the northern solar geometry.

CONCLUSIONS FROM THIS STUDY

1. The re-establishment of solar energy data acquisition at Annette, Barrow, and Bethel should be accomplished, as these stations have 20 or more years of historical data. As attention to solar energy becomes more widespread this data base will become more valuable with time. Lost data is lost forever. It is ironic that these stations were shut down just as interest in solar energy began to increase. The National Weather Service or the Department of Energy should fund these stations.

Recently the Department of Energy awarded the University of Alaska's Geophysical Institute a grant to develop and maintain a precision solar radiation monitoring station. Unfortunately only one such installation will be made and it will be made in Fairbanks.

Optimally small solar radiation measurement stations should be placed at many locations in Alaska in order to establish a data grid.

2. The time and resources provided in this study were not adequate to do a thorough assessment of solar passive space heating applied to Alaskan architecture. This use of solar energy may be the most esthetically acceptable and reliable application, and it deserves further detailed study.

3. Solar energy for heating hot water compares favorably in cost with electrically heated hot water in most areas of the state. In Metlakatla, which has the least expensive electrical power in the state of the areas studied, solar energy has a present worth of $294, and a payback period of 18 years of a 20-year mortgage. The economic appeal of solar energy becomes more apparent the farther north in the state of Alaska one travels. This is primarily, but not entirely, due to the fuel transportation costs in the northern, more remote, areas of the state. In Barrow, a solar-heated hot-water system, when compared with an electric one, looks quite appealing. The pay-back period is two years and the present worth is $10,564. Note that the optimum collector area in Barrow is less than that at Bethel (216 ft^2 vs. 324 ft^2), even though Barrow's electricity costs more. This is because of the period in Barrow when the sun is below the horizon, so that the collection of solar energy is not optimized for the winter period.

Since many Fairbanksans heat their hot water electrically, solar energy is to their economic benefit now, <u>if</u> the collector cost can be kept to $20 to $25 per square foot. Commercial list prices at the present in Fairbanks are higher than this range. Solar-heated hot water does not compete economically with that heated with oil anywhere in Alaska.

4. General economic analyses (Figures 8 and 9) show that as electrical costs approach 9¢ per kwh, solar energy for heating hot water has a reasonable pay-back period even if solar energy systems were to cost $50 per square foot.

5. Public responses to this study have been numerous and demonstrate a strong interest in solar energy from the general public and from the businesses and people who were polled in the survey (see Appendix C). Fifteen of 23 commercial companies surveyed said they wanted to be involved in marketing solar equipment but were cautious because they felt they needed more economic information.

6. The main deterrents to solar energy were surveyed as well in the above study. The major deterrents to solar energy development in Alaska were described by those surveyed as follows: the high cost of solar equipment, the lack of solar energy, the lack of relevant and detailed information, and the lack of experience with solar energy applications in Alaska.

7. This preliminary study did not attempt to validate or justify the use of solar energy on any but economic grounds. Social and environmental justifications for substituting solar resources for fossil fuels have not been discussed, but do deserve more attention. The choice of solar energy technologies for the home can be as much a philosophical and personal choice as an economic one. Often those individuals who have already chosen to use solar energy have built their own systems and have not given cost a high priority in their decision. Social values such as patriotism, self-reliance, a desire for independence, frugality, and concern for the environmental effects of fossil fuel use may be very significant in the development of solar and other alternative technologies. These issues are discussed further in a text entitled "Energy and Reality: Three Perceptions," by James W. Benson, available from the Institute for Ecological Policies, 9208 Christopher Street, Fairfax, Virginia 22030.

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APPENDIX A

The following appendix is the introduction to the Kusuda and Ishii (1977) National Bureau of Standards solar radiation data tabulations for eighty cities in the United States. It outlines in detail the calculations used to derive the tables in that text. Data from that text is quoted in Table 2 of this report also. The user of this data is cautioned as to the calculated values at the low sun periods of the year. Calculated values using the method of Kusuda and Ishii (1977) contrast markedly with those of Liu and Jordan (Tables 3 and 4) for vertical south-facing surfaces during November, December, and January; and real measurements on a vertical surface are not available for comparison. All measurements presently available are made on horizontal surfaces and extrapolations are made from this horizontally indented radiation data.

Hourly Solar Radiation Data for Vertical and Horizontal Surfaces on Average Days in the United States and Canada

by

Tamami Kusuda and Katsumi Ishii

1. Introduction

There are basically two ways that solar radiation data can be used for design purposes in the building profession. One way is to use past hourly data for the locality or similar locality in question, estimate through mathematical simulation what the performance factors of the building and for its components would have been under those conditions, and base future predictions for performance on that analysis. The second way is to use data that have been derived for specific types of days, either completely clear, "average", or statistically analyzed data for a particular solar process, to calculate the performance of the building and for its components for those types of days.

The first technique has the advantage of easily accounting for the detailed transient nature of the interaction between the solar radiation and the building, and the building and its heating and air conditioning system. This is particularly important when the heating and air conditioning system has been specifically designed to collect the solar energy and utilize it inside the building for heating and/or cooling. ASHRAE has been very active in the recent past in outlining recommended procedures to conduct such hourly calculations for computing heating and cooling loads on buildings [1]*. In the ASHRAE-recommended procedures [1], completely clear day data are predicted using theoretical equations and these data are in turn modified with actual hourly recorded cloud-cover data. Computer programs that have been written for predicting the performance of solar heating and/or cooling systems on an hourly basis use actual recorded hourly solar radiation data [2, 3].

The primary disadvantages of using this first technique are the cost and complexity associated with the use of the computer programs and the lack of good hourly data, particularly for the solar radiation itself.

The major source of solar radiation data in the United States is the National Weather Service and its network of stations. The data collection began in 1902 with the first measurements of the direct component of the solar radiation at normal incidence being made in Asheville, North Carolina. At the present time, there are 86 stations covering the U.S. and the West Indies. Reference 4 gives a complete history of the network. The majority of the present 86 stations record only the total radiation on a horizontal surface. At five of the stations, the direct component is also measured. Of the 86 stations, 67 have their data processed for daily total only, while hourly data are processed at the other 19. Reference 5 describes how the data can be made available either on tape or punched cards.

In addition to the relatively small amount of hourly solar radiation data generally available as described above, the quality of the data has been questioned. Jessup has reported [4] that estimated data errors range from $\pm$ 5 percent to $\pm$ 30 percent. This has been mainly due to insufficient resources in all but the recent past to properly maintain the network. A complete analysis of some of the specific problems with the network instrumentation is included in references 6 and 7.

There is evidence, with the increasing emphasis on the use of solar energy in buildings, that much of the past solar radiation data will be rehabilitated and additional data will be collected in the future; however, it is unlikely that the hourly data to be taken will be extended to cover surfaces other than the horizontal for the majority of the stations. For this and other reasons given above, emphasis will be placed in the foreseeable future on using solar radiation data for specific types of days and orientations for design purposes.

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* See references at end of text.

The 1977 ASHRAE Handbook of Fundamentals [8] will include tables of solar heat gain factors for all combinations of six different northern latitudes, sixteen primary compass orientations plus the horizontal, for the 21st day of each month of the year and for each hour of that day. This enables one to calculate the amount of solar energy passing through a unit area of reference glazing (single sheet of 0.3 cm (1/8 in.) thick double-strength window glass) on a completely clear day, and is based on a calculation procedure developed by Stephenson [9]. Recently Morrison and Farber [10] have extended this type of calculation and have produced tables of incident solar radiation for all combinations of six different northern latitudes, five different south-facing surfaces tilted up at angles ranging from latitude minus 10 degrees to the vertical plus the horizontal, for the 21st day of each month of the year and for each hour of that day. Both of these above sets of data can be used for design purposes to determine the maximum effect that the solar radiation is likely to have for a given condition or in a given situation. However, it is felt desirable to also have similar tables of data for "average" conditions so that estimates can be made for the long-term effect that incident solar radiation has on a building and for its heating and air conditioning system.

References 11 and 12 contain a series of 12 monthly maps showing isoclines of daily total radiation on a horizontal surface for the United States and the world, respectively. The data were gathered from a large number of sources and can be used to indicate general trends and to predict areas of potential solar energy applications.

Liu and Jordan [13, 14, 15] conducted extensive analyses during the early 1960's on the available solar radiation data and developed several empirical correlations that can be used to estimate the available solar radiation on "average" days for each month of the year and for a large number of locations in the United States and Canada. Using the correlations, it is possible to take the monthly average daily total radiation on a horizontal surface, divide the daily total into direct and diffuse components, convert each component into hourly values, and then compute the hourly value of either component on a surface of any orientation desired.

This report outlines the technique that was used to compute and tabulate the monthly "average" incident radiation on an hourly basis during the day for each month of the year, and each of eight different vertical orientations. The data was tabulated for 80 different locations in the United States and Canada. A minor modification was made to the basic technique recommended in the Liu, Jordan procedure [14, 15] in order to eliminate what was believed to be erroneous results near the sunrise and sunset hours. An additional parameter called "sol-air temperature for glass" was also computed and tabulated for each of the locations. An explanation of the meaning of this parameter is included in Section 7 of the report.

2. Calculation Procedure of Liu and Jordan

The pertinent correlations developed by Liu and Jordan [13, 14, 15] were for:

a. the monthly average daily diffuse radiation on a horizontal surface as a function of the monthly average daily total radiation on a horizontal surface,

b. the ratio of the hourly diffuse radiation to the daily diffuse radiation (both on a horizontal surface) as a function of the number of daylight hours, and

c. the ratio of the hourly total radiation to the daily total radiation (both on a horizontal surface) as a function of the number of daylight hours.

The correlations were based on available solar radiation data from Blue Hill, Massachusetts; Nice, France; Helsingfors, Finland; and Kew Observatory, London, England.

Liu and Jordan [15, 16] also compiled for each of twelve months at 80 different locations in the United States and Canada, the "average" daily total radiation on a horizontal surface ($\overline{H}$) and the ratio $\overline{K}_T = \overline{H}/H_o$, where H_o is the daily total extraterrestrial radiation on a horizontal surface calculated for the 15th or 16th of each month. The ratio $\overline{K}_T$ represents the fraction of extraterrestrial radiation that is transmitted through the atmosphere and thus provides a useful index for the solar climate of a particular location.

The correlations described in a, b, and c above are included herein as Table 2, Figure 1, and Figure 2, respectively. $\overline{K}_d$ in Table 2 is defined as $\overline{D}/H_o$, where $\overline{D}$ is the "average" daily diffuse radiation on a horizontal surface. The step-by-step technique for using the correlations to compute the "average" incident solar radiation on a horizontal or vertical surface is as follows:

a. Daily total extraterrestrial radiation on a horizontal surface for a given latitude and declination angle is calculated as follows:

$$H_o = \frac{24}{\pi} r I_{sc} (\cos L \cos S \sin W_s + W_s \sin L \sin S) \quad (1)$$

where

r = ratio of solar radiation intensity at normal incidence outside the earth's atmosphere to the solar constant (monthly average values are given in Table 1)

I_{sc} = solar constant, 1,393 W/m^2 (442 Btu/(h · ft^2)*

L = latitude, radians

S = solar declination angle, radians, monthly values are given in Table 1

W_s = sunrise hour angle, radians, obtained from:

$$\cos W_s = - \tan L \tan S \quad (2)$$

b. Obtain the monthly average daily total radiation on a horizontal surface, $\overline{H}$, from references 15 and 16 or other available sources.

c. Calculate $\overline{K}_T$ by:

$$\overline{K}_T = \frac{\overline{H}}{H_o} \quad (3)$$

or obtain the value from references 15 and 16 for any of 80 locations.

d. Determine the value of $\overline{K}_d$ from Table 2.

e. Calculate the monthly average daily diffuse radiation on a horizontal surface, $\overline{D}$, by:

$$\overline{D} = \overline{K}_d \cdot H_o \quad (4)$$

f. Calculate the value of a factor, r_d, from the following equation or determine from Figure 1:

$$r_d = \frac{\pi}{24} \frac{\cos W - \cos W_s}{\sin W_s - W_s \cos W_s} \quad (5)$$

where

W = hour angle corresponding to a given hour of the day (solar time), radians

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* This was the value used by Liu and Jordan. A value of 1,353 W/m^2 (428 Btu/(h · ft^2)) is the value currently recommended by a number of governmental agencies and technical societies in the U.S. [17].

g. Calculate the average hourly diffuse radiation on a horizontal surface ($\overline{I}_{dh}$) by:

$$\overline{I}_{dh} = r_d \, \overline{D} \tag{6}$$

h. Determine the value of a factor, r_T, from Figure 2.

i. Calculate the average hourly total radiation on a horizontal surface ($\overline{I}_{Th}$) by:

$$\overline{I}_{Th} = r_T \, \overline{H} \tag{7}$$

j. Calculate the average hourly direct radiation on a horizontal surface ($\overline{I}_{Dh}$) by:

$$\overline{I}_{Dh} = \overline{I}_{Th} - \overline{I}_{dh} \tag{8}$$

k. Calculate the angle of incidence between the sun's direct beam and a horizontal (θ_H) or vertical surface (θ_v) by:

$$\cos \theta_H = \cos L \cos S \cos W + \sin L \sin S \tag{9}$$

or

$$\cos \theta_v = \cos ALT \cos SAZM \tag{10}$$

where

ALT = solar altitude angle, the angle between the sun's direct beam and the horizontal, radians

SAZM = the difference between the solar azimuth angle (AZM) and the wall azimuth angle (WAZ), radians

Figure 3 shows the relationship between the various angles.

l. Calculate the average hourly direct radiation on a given vertical surface ($\overline{I}_{Dv}$) by:

$$\overline{I}_{Dv} = \frac{\overline{I}_{Dh}}{\cos \theta_H} \cdot \cos \theta_v \; , \tag{11}$$

m. Approximate the average hourly diffuse radiation on a given vertical surface ($\overline{I}_{dv}$) by:

$$\overline{I}_{dv} = \frac{\overline{I}_{dh}}{2} \tag{12}$$

n. Approximate the average hourly reflected radiation from the ground on a given vertical surface ($\overline{I}_{gv}$) by:

$$\overline{I}_{gv} = \frac{\rho_g \, I_{Th}}{2} \tag{13}$$

where

ρ_g = ground reflectance

o. Calculate the average hourly total radiation incident on a given vertical surface by:

$$\overline{I}_{Tv} = \overline{I}_{Dv} + \overline{I}_{dv} + \overline{I}_{gv} \quad (14)$$

3. Anomalous Calculated Values Using the Liu and Jordan Calculation Procedure

The procedure described in the previous section was used to generate the hourly solar radiation values incident on vertical surfaces oriented in the eight primary directions (S, SW, W, NW, N, NE, E, and SE) as well as the horizontal surface. Upon analyzing the data, exceptionally large values of incident solar radiation were observed near the sunrise and sunset hours. A close examination of the calculation procedure revealed that the large peak resulted from the use of equation (11) where cos θ_H is very close to zero at the sunrise and sunset hours. This phenomenon is illustrated in Figure 3 where the value of the direct component of the solar radiation ($\overline{I}_{DN}$) is computed for a vertical surface oriented directly facing the sun (equation (11) with cos $\theta_v = 1$) on February 22 in Miami, Florida:

$$\overline{I}_{DN} = \overline{I}_{Dh}/\cos\theta_H \quad (15)$$

The inconsistency appeared to arise as a result of the sensitive empirical relationship between $\overline{K}_T$, r_T, $\overline{K}_d$, and r_d. Upon discussions with one of the authors of [15, 16]*, it is felt that the inconsistency is mainly due to the inaccuracy of the empirical relationship for r_T (Figure 2).

4. ASHRAE Methodology for the Computation of the Direct Component of the Solar Radiation

In order to circumvent the anomaly described in the previous section, it was decided to replace equation (15) with an equation similar to one used in reference 18:

$$\overline{I}_{DN} = \overline{A}\, e^{-\left[\frac{B}{\cos\theta_H}\right]} \quad (16)$$

The original equation was developed by Stephenson [9] for completely clear sky conditions. It has been assumed in this work that the same basic form of the equation is valid for "average" day solar radiation. A modified multiplying coefficient has been adapted, denoted in equation (16) as $\overline{A}$ (as opposed to A in reference 9).

The monthly values of B for equation (16) are given in Table 1. In order to develop appropriate values of $\overline{A}$, it was necessary to calculate the average daily direct radiation over a horizontal surface, $\overline{H}_{Dh}$ by:

$$\overline{H}_{Dh} = \int_{\text{sunrise}}^{\text{sunset}} \overline{I}_{DN} \cos\theta_H \, dt \quad (17)$$

where t denotes time. Combining equations (16) and (17):

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* Private communication with Dr. Liu.

$$\bar{H}_{Dh} = \frac{24}{\pi} \bar{A} \int_0^{W_s} e^{-\left[\frac{B}{\cos \theta_H}\right]} \cos \theta_H \, dW \tag{18}$$

By denoting the integral of the above equations by G, and by using $\bar{K}_T$ and $\bar{K}_d$ of the Liu and Jordan procedure, equation (18) can be written:

$$\bar{H}_{Dh} = \frac{24}{\pi} \bar{A} \cdot G = (\bar{K}_T - \bar{K}_d)\, H_o \tag{19}$$

By substituting equation (1) into equation (19), the value of $\bar{A}$ can be calculated as follows:

$$\bar{A} = (\bar{K}_T - \bar{K}_d)\, f \tag{20}$$

where

$$f = \frac{r\, I_{sc}}{G} (\cos L \cos S \sin W_s + W_s \sin L \sin S) \tag{21}$$

Table 3 lists the values of f which were computed using the above equations. The values are tabulated for latitudes of 0 through 50 degrees in one-degree increments and for each of the 12 months. The monthly values are plotted in Figure 5.

The concept of f is convenient since its value is independent of the specific local climate. As an example, both Hatteras, North Carolina and Albuquerque, New Mexico are at a latitude of 35° N. Table 3 indicates the value of f in January to be 644.5 at this latitude. The Liu and Jordan tabulated data [15, 16] show the following values of $\bar{K}_T$ and $\bar{K}_d$ for these two cities.

	Hatteras	Albuquerque
$\bar{K}_T$	0.634	0.704
$\bar{K}_d$	0.166	0.147

Using these data, $\bar{A}$ for Hatteras and Albuquerque were determined as 302 and 359 respectively, whereas the cloudless sky value of A developed by Stephenson [9] was 390.

5. Modification of the Liu and Jordan Procedure to Eliminate the Anomalous Calculated Solar Radiation Values

With the relationship between equation (16), the constant $\bar{A}$, and the constants $\bar{K}_T$ and $\bar{K}_d$ established, a modified hourly calculation procedure was developed as follows:

a. Same as before.

b. Same as before.

c. Same as before.

d. Same as before.

e. Same as before.

f. Same as before.

g. Same as before.

h. Determine the value of f from Table 3 for a given month and latitude.

i. Calculate $\overline{A}$ using equation (20).

j. Calculate the hourly value of $\overline{I}_{DN}$ using equation (16).

k. Same as before.

l. Calculate the average hourly direct radiation on a horizontal surface by:

$$\overline{I}_{Dh} = \overline{I}_{DN} \cos \theta_H \tag{22}$$

m. Calculate the average hourly total radiation on a horizontal surface by:

$$\overline{I}_{Th} = \overline{I}_{Dh} + \overline{I}_{dh} \tag{23}$$

n. Calculate the average hourly direct radiation on a vertical surface by:

$$\overline{I}_{Dv} = \overline{I}_{DN} \cos \theta_v \tag{24}$$

o. Same as m. in Section 2.

p. Same as n. in Section 2.

q. Same as o. in Section 2.

6. Computation and Tabulation of Data for Eighty Locations

A computer program was written for carrying out the calculation procedure described in the previous section. A listing of the program is given at the end of this report. Complete tables of total solar radiation values are also included at the end of the report in Table 4 for 80 different locations in the United States and Canada [15, 16]. The tabulated solar radiation data are all in units of either Btu/(h · ft^2) (= 3.152 W/m^2) or Btu/ft^2 (= 11,348.9 J/m^2).

Sample results are shown in Figures 6 through 12 for the horizontal and different vertical orientations in February in Miami, Florida. Shown in these figures are the hourly radiation values calculated by Liu and Jordan, the authors' modification of the Liu and Jordan procedure, and the data for completely clear skies [10].

7. Calculation of "Sol-Air Temperature for Glass"

In general, energy is transferred through glazing both by transmitted solar radiation and by conduction and convection as a result of a temperature difference between the outside and the inside air. The governing equation for the net heat transfer, q (W), across the glazing into a building space is:

$$q = A\left[\overline{\tau} I + U (t_o - t_i)\right] \tag{25}$$

where

A = cross-sectional area of the glazing, m^2

$\bar{\tau}$ = effective transmittance of the glazing to short-wave radiation

I = incident total solar radiation on the glazing, W/m^2

U = overall heat transfer coefficient for the glazing, $(W/(m^2 \cdot °C))$

t_o = outside air temperature, °C

t_i = inside air temperature, °C

If the first term in equation (25) is multiplied and divided by U, the equation can be rearranged to:

$$Q = U\ A \left[\frac{\bar{\tau}\ I}{U} + t_o - t_i\right] \tag{26}$$

or

$$q = U\ A \left[SATG - t_i\right] \tag{27}$$

where

$$SATG = \frac{\bar{\tau}\ I + t_o}{U} = \text{sol-air temperature for glass, °C}$$

Values of SATG are useful in assessing the net heat transfer through glazing into the building. In other words, for those periods of time when SATG > t_i, there is a net heat gain into the building and when SATG < t_i, there is a net heat loss.

Equation (26) is written on an instantaneous basis and can be used for computing hourly values. The equation can also be written to be valid for a period covering a number of hours N:

$$Q = U\ A \left[\frac{\bar{\tau} \sum_{i=1}^{N} I}{U} + N\ (\bar{t}_o - t_i)\right] \tag{28}$$

where

Q = net heat transfer over the time period N, W

N = number of hours

$\bar{t}_o$ = average outdoor air temperature over the time period N, °C

The indoor air temperature, t_i, has been assumed to be constant for the t'me period N. Equation (28) can be rearranged as was done with equation (25):

$$Q = U\ A\ N \left[\frac{\bar{\tau} \sum_{i=1}^{N} I}{UN} + \bar{t}_o - t_i\right] \tag{29}$$

$$Q = U\ A\ N \left[SAG - t_i\right] \tag{30}$$

where

$$SAG = \frac{\bar{\tau} \sum_{i=1}^{N} I}{UN} + \bar{t}_o, \ ^\circ C \qquad (31)$$

The values of SAG were computed for each month of the year, for each of the eight primary vertical orientations and the horizontal, and for each of the 80 locations in the United States and Canada. The values are tabulated in Table 4 in units of °F along with the average hourly radiation values discussed previously.

Four different values of SAG were computed. Two values were for a 24-hour period (N = 24), one for single glazing (SATGS) and a second for double glazing (SATGD). The other two computations were also for single and double glazing, but the time period N was shortened to include only the daylight hours. In all cases, the radiation values $\sum_{i=1}^{N} I$ were the total incident radiation under "average" conditions discussed previously. The values of $\bar{\tau}$ used in the computations were 0.87 for single glazing and 0.78 for double glazing. The overall heat transfer coefficients were 6.4 W/(m^2 · °C) (1.13 Btu/(h · ft^2 · °F)) and 6.0 W/(m^2 · °C) (1.06 Btu/(h · ft^2 · °F) for single glazing and for winter and summer, respectively. The values used for double glazing were 3.1 W/(m^2 · °C) (0.55 Btu/(h · ft^2 · °F)) and 3.1 W/(m^2 · °C) (0.54 Btu/(h · ft^2 · °F), respectively. The value of $\bar{t}_o$ was either the average over the 24-hour period or daylight hours only, depending on the time period N.

The intent in calculating and compiling the data was to permit computation, for a given glazing size and orientation, of the net heat transfer into the space of a building for "average" solar conditions and for any period of months desired. By repeating the calculation for all the glazing in a given building, the total net effect for the entire building could be determined.

8. Summary

The Liu and Jordan method for calculating the incident hourly solar radiation on a surface of any tilt and orientation under "average" conditions was modified and used to compute the average hourly incident total radiation on the eight primary vertical orientations and the horizontal for each month of year and for each of 80 locations in the United States and Canada. In addition, a new parameter was introduced and computed for the 80 locations called "sol-air temperature for glass". The tabulated values enable one to easily compute the net heat transfer through single or double glazing under "average" solar conditions for any of the eight primary vertical orientations or on a horizontal surface.

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APPENDIX B

Solar Radiation Data for Alaska

Table 6 was extracted from the U. S. Department of Commerce (1977) and Table 7 from Farber and Morrison who are quoted in Liu and Jordan (1977).

Table 6 is a tabulation of the average daily solar radiation on a surface oriented in each of the eight directions of the compass (N, NE, E, SE, S, SW, W, NW) and a horizontal surface for each of the five sites in Alaska.

Table 7 is a listing of the incidence angles of solar insolation on surfaces tilted with respect to the horizontal given for latitudes 56°N and 64°N only.

LOCATION ANNETTE IS., ALASKA LATITUDE 55 DEGREES 1 MINUTES

MONTH 1 HO 611. TOD 36. TOT 35. KT .427 KD .184

ORIENTATION	HOURLY SOLAR RADIATION 4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	DAILY TOTAL RADIATION	SAG/DAYTIME SATGS	SAG/DAYTIME SATGD	SAG/ALL DAY SATGS	SAG/ALL DAY SATGD
SOUTH	0.	0.	0.	0.	0.	48.	104.	135.	145.	135.	104.	48.	0.	0.	0.	0.	0.	719.	106.	164.	5[illegible]	77.
SOUTHWEST	0.	0.	0.	0.	0.	9.	41.	78.	107.	122.	113.	63.	0.	0.	0.	0.	0.	533.	88.	131.	52.	66.
WEST	0.	0.	0.	0.	0.	6.	12.	15.	17.	46.	62.	44.	0.	0.	0.	0.	0.	202.	56.	72.	41.	46.
NORTHWEST	0.	0.	0.	0.	0.	6.	12.	15.	17.	15.	12.	6.	0.	0.	0.	0.	0.	82.	44.	50.	37.	39.
NORTH	0.	0.	0.	0.	0.	6.	12.	15.	17.	15.	12.	6.	0.	0.	0.	0.	0.	82.	44.	50.	37.	39.
NORTHEAST	0.	0.	0.	0.	0.	6.	12.	15.	17.	15.	12.	6.	0.	0.	0.	0.	0.	82.	44.	50.	37.	39.
EAST	0.	0.	0.	0.	0.	44.	62.	46.	17.	15.	12.	6.	0.	0.	0.	0.	0.	202.	56.	72.	41.	46.
SOUTHEAST	0.	0.	0.	0.	0.	63.	113.	122.	107.	78.	41.	9.	0.	0.	0.	0.	0.	533.	88.	131.	52.	66.
HORIZ.	0.	0.	0.	0.	0.	15.	36.	51.	56.	51.	36.	15.	0.	0.	0.	0.	0.	260.	61.	82.	43.	50.

MONTH 2 HO 1205. TOD 38. TOT 36. KT .415 KD .184

ORIENTATION	HOURLY SOLAR RADIATION 4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	DAILY TOTAL RADIATION	SAG/DAYTIME SATGS	SAG/DAYTIME SATGD	SAG/ALL DAY SATGS	SAG/ALL DAY SATGD
SOUTH	0.	0.	0.	0.	36.	79.	109.	128.	134.	128.	109.	79.	36.	0.	0.	0.	0.	837.	102.	155.	63.	85.
SOUTHWEST	0.	0.	0.	0.	7.	15.	45.	76.	102.	118.	121.	106.	62.	0.	0.	0.	0.	654.	88.	129.	57.	74.
WEST	0.	0.	0.	0.	7.	15.	21.	24.	26.	54.	75.	81.	56.	0.	0.	0.	0.	358.	65.	88.	48.	57.
NORTHWEST	0.	0.	0.	0.	7.	15.	21.	24.	26.	24.	21.	16.	21.	0.	0.	0.	0.	175.	51.	62.	42.	46.
NORTH	0.	0.	0.	0.	7.	15.	21.	24.	26.	24.	21.	15.	7.	0.	0.	0.	0.	160.	50.	60.	41.	45.
NORTHEAST	0.	0.	0.	0.	21.	16.	21.	24.	26.	24.	21.	15.	7.	0.	0.	0.	0.	175.	51.	62.	42.	46.
EAST	0.	0.	0.	0.	56.	81.	75.	54.	26.	24.	21.	15.	7.	0.	0.	0.	0.	358.	65.	88.	48.	57.
SOUTHEAST	0.	0.	0.	0.	62.	106.	121.	118.	102.	76.	45.	15.	7.	0.	0.	0.	0.	654.	88.	129.	5[illegible]	74.
HORIZ.	0.	0.	0.	0.	19.	44.	66.	79.	84.	79.	66.	44.	19.	0.	0.	0.	0.	499.	76.	108.	52.	65.

MONTH 3 HO 1972. TOD 40. TOT 38. KT .492 KD .188

ORIENTATION	HOURLY SOLAR RADIATION 4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	DAILY TOTAL RADIATION	SAG/DAYTIME SATGS	SAG/DAYTIME SATGD	SAG/ALL DAY SATGS	SAG/ALL DAY SATGD
SOUTH	0.	0.	0.	24.	65.	104.	135.	154.	161.	154.	135.	104.	65.	24.	0.	0.	0.	1126.	112.	170.	74.	104.
SOUTHWEST	0.	0.	0.	9.	18.	26.	54.	92.	125.	147.	156.	149.	122.	68.	0.	0.	0.	967.	101.	152.	69.	94.
WEST	0.	0.	0.	9.	18.	26.	32.	36.	38.	75.	105.	122.	118.	78.	0.	0.	0.	658.	82.	116.	59.	76.
NORTHWEST	0.	0.	0.	9.	18.	26.	32.	36.	38.	36.	32.	39.	56.	47.	0.	0.	0.	370.	63.	83.	50.	60.
NORTH	0.	0.	0.	9.	18.	26.	32.	36.	38.	36.	32.	26.	18.	9.	0.	0.	0.	281.	58.	72.	47.	54.
NORTHEAST	0.	0.	0.	47.	56.	39.	32.	36.	38.	36.	32.	26.	18.	9.	0.	0.	0.	370.	63.	83.	50.	60.
EAST	0.	0.	0.	78.	118.	122.	105.	75.	38.	36.	32.	26.	18.	9.	0.	0.	0.	658.	82.	116.	59.	76.
SOUTHEAST	0.	0.	0.	68.	122.	149.	156.	147.	125.	92.	54.	26.	18.	9.	0.	0.	0.	967.	101.	152.	69.	94.
HORIZ.	0.	0.	0.	24.	58.	90.	115.	130.	136.	130.	115.	90.	58.	24.	0.	0.	0.	969.	102.	152.	69.	95.

LOCATION ANNETTE IS., ALASKA LATITUDE 55 DEGREES 1 MINUTES

MONTH 4 HO 2844. TOD 44. TOT 43. KT .507 KD .187

ORIENTATION	HOURLY SOLAR RADIATION																	DAILY TOTAL	SAG/DAYTIME		SAG/ALL DAY	
	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	RADIATION	SATGS	SATGD	SATGS	SATGD
SOUTH	0.	1.	9.	29.	66.	101.	129.	147.	154.	147.	129.	101.	66.	29.	9.	1.	0.	1119.	104.	153.	78.	108.
SOUTHWEST	0.	1.	9.	19.	28.	36.	51.	90.	122.	145.	156.	153.	135.	101.	51.	1.	0.	1100.	103.	152.	78.	107.
WEST	0.	1.	9.	19.	28.	36.	42.	46.	47.	85.	116.	136.	141.	125.	77.	1.	0.	910.	93.	133.	72.	96.
NORTHWEST	0.	1.	9.	19.	28.	36.	42.	46.	47.	46.	42.	61.	81.	87.	63.	1.	0.	610.	77.	104.	62.	78.
NORTH	0.	1.	18.	19.	28.	36.	42.	46.	47.	46.	42.	36.	28.	19.	18.	1.	0.	426.	67.	86.	56.	67.
NORTHEAST	0.	1.	63.	87.	81.	61.	42.	46.	47.	46.	42.	36.	28.	19.	9.	1.	0.	610.	77.	104.	62.	78.
EAST	0.	1.	77.	125.	141.	136.	116.	85.	47.	46.	42.	36.	28.	19.	9.	1.	0.	910.	93.	133.	72.	96.
SOUTHEAST	0.	1.	51.	101.	135.	153.	156.	145.	122.	90.	51.	36.	28.	19.	9.	1.	0.	1100.	103.	152.	78.	107.
HORIZ.	0.	2.	26.	61.	97.	128.	153.	168.	173.	168.	153.	128.	97.	61.	26.	2.	0.	1442.	122.	185.	89.	127.

MONTH 5 HO 3481. TOD 51. TOT 49. KT .484 KD .187

ORIENTATION	HOURLY SOLAR RADIATION																	DAILY TOTAL	SAG/DAYTIME		SAG/ALL DAY	
	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	RADIATION	SATGS	SATGD	SATGS	SATGD
SOUTH	1.	8.	16.	25.	57.	88.	112.	127.	133.	127.	112.	88.	57.	25.	16.	8.	1.	1001.	102.	140.	83.	109.
SOUTHWEST	1.	8.	16.	25.	34.	41.	47.	80.	109.	129.	139.	137.	123.	98.	64.	24.	1.	1076.	105.	147.	86.	114.
WEST	1.	8.	16.	25.	34.	41.	47.	50.	51.	85.	112.	130.	137.	128.	101.	50.	1.	1017.	102.	142.	84.	110.
NORTHWEST	1.	8.	16.	25.	34.	41.	47.	50.	51.	50.	47.	71.	90.	98.	89.	51.	1.	769.	90.	120.	75.	95.
NORTH	1.	26.	34.	25.	34.	41.	47.	50.	51.	50.	47.	41.	34.	25.	34.	26.	1.	567.	80.	102.	68.	83.
NORTHEAST	1.	51.	89.	98.	90.	71.	47.	50.	51.	50.	47.	41.	34.	25.	16.	8.	1.	769.	90.	120.	75.	95.
EAST	1.	50.	101.	128.	137.	130.	112.	85.	51.	50.	47.	41.	34.	25.	16.	8.	1.	1017.	102.	142.	84.	110.
SOUTHEAST	1.	24.	64.	98.	123.	137.	139.	129.	109.	80.	47.	41.	34.	25.	16.	8.	1.	1076.	105.	147.	86.	114.
HORIZ.	1.	18.	49.	82.	115.	143.	165.	178.	183.	178.	165.	143.	115.	82.	49.	18.	1.	1684.	136.	201.	10–.	151.

MONTH 6 HO 3733. TOD 56. TOT 54. KT .441 KD .185

ORIENTATION	HOURLY SOLAR RADIATION																	DAILY TOTAL	SAG/DAYTIME		SAG/ALL DAY	
	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	RADIATION	SATGS	SATGD	SATGS	SATGD
SOUTH	3.	10.	18.	27.	51.	77.	97.	111.	115.	111.	97.	77.	51.	27.	18.	10.	3.	901.	99.	133.	85.	109.
SOUTHWEST	3.	10.	18.	27.	34.	41.	46.	72.	96.	113.	121.	120.	108.	87.	59.	27.	4.	987.	104.	140.	88.	114.
WEST	3.	10.	18.	27.	34.	41.	46.	50.	51.	79.	102.	117.	122.	115.	95.	57.	8.	974.	103.	139.	88.	113.
NORTHWEST	3.	10.	18.	27.	34.	41.	46.	50.	51.	50.	49.	70.	85.	92.	86.	59.	9.	780.	94.	122.	81.	101.
NORTH	7.	32.	37.	30.	34.	41.	46.	50.	51.	50.	46.	41.	34.	30.	37.	32.	7.	607.	85.	108.	75.	91.
NORTHEAST	9.	59.	86.	92.	85.	70.	49.	50.	51.	50.	46.	41.	34.	27.	18.	10.	3.	780.	94.	122.	81.	101.
EAST	8.	57.	95.	115.	122.	117.	102.	79.	51.	50.	46.	41.	34.	27.	18.	10.	3.	974.	103.	139.	88.	113.
SOUTHEAST	4.	27.	59.	87.	108.	120.	121.	113.	96.	72.	46.	41.	34.	27.	18.	10.	3.	987.	104.	140.	88.	114.
HORIZ.	5.	25.	53.	83.	111.	136.	156.	168.	172.	168.	156.	136.	111.	83.	53.	25.	5.	1647.	135.	196.	111.	154.

LOCATION ANNETTE IS., ALASKA LATITUDE 55 DEGREES 1 MINUTES

MONTH 7 HO 3485. TOD 59. TOT 57. KT .454 KD .186

ORIENTATION	HOURLY SOLAR RADIATION																	DAILY TOTAL RADIATION	SAG/DAYTIME		SAG/ALL DAY	
	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20		SATGS	SATGD	SATGS	SATGD
SOUTH	1.	8.	16.	25.	54.	82.	104.	118.	123.	118.	104.	82.	54.	25.	16.	8.	1.	936.	106.	142.	89.	113.
SOUTHWEST	1.	8.	16.	25.	33.	40.	45.	76.	102.	120.	128.	126.	113.	90.	58.	22.	1.	1003.	109.	148.	91.	117.
WEST	1.	8.	16	25.	33.	40.	45.	49.	50.	80.	104.	120.	126.	117.	91.	44.	1.	949.	106.	143.	89.	114.
NORTHWEST	1.	8.	16.	25.	33.	40.	45.	49.	50.	49.	46.	67.	84.	90.	81.	45.	1.	728.	95.	123.	82.	101.
NORTH	1.	24.	32.	25.	33.	40.	45.	49.	50.	49.	45.	40.	33.	25.	32.	24.	1.	546.	86.	107.	75.	90.
NORTHEAST	1.	45.	81.	90.	84.	67.	46.	49.	50.	49.	45.	40.	33.	25.	16.	8.	1.	728.	95.	123.	82.	101.
EAST	1.	44.	91.	117.	126.	120.	104.	80.	50.	49.	45.	40.	33.	25.	16.	8.	1.	949.	106.	143.	89.	114.
SOUTHEAST	1.	22.	58.	90.	113.	126.	128.	120.	102.	76.	45.	40.	33.	25.	16.	8.	1.	1003.	109.	148.	91.	117.
HORIZ.	1.	18.	46.	77.	107.	134.	154.	167.	172.	167.	154.	134.	107.	77.	46.	18.	1.	1582.	138.	199.	111.	152.

MONTH 8 HO 2827. TOD 60. TOT 58. KT .427 KD .184

ORIENTATION	HOURLY SOLAR RADIATION																	DAILY TOTAL RADIATION	SAG/DAYTIME		SAG/ALL DAY	
	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20		SATGS	SATGD	SATGS	SATGD
SOUTH	0.	1.	9.	25.	54.	82.	105.	119.	124.	119.	105.	82.	54.	25.	9.	1.	0.	915.	112.	152.	89.	113.
SOUTHWEST	0.	1.	9.	18.	26.	33.	46.	76.	101.	118.	125.	121.	106.	78.	38.	1.	0.	896.	111.	150.	89.	112.
WEST	0.	1.	9.	18.	26.	33.	39.	42.	44.	72.	95.	109.	110.	96.	56.	1.	0.	752.	103.	136.	84.	103.
NORTHWEST	0.	1.	9.	18.	26.	33.	39.	42.	44.	42.	39.	52.	66.	68.	46.	1.	0.	527.	90.	113.	76.	90.
NORTH	0.	1.	15.	18.	26.	33.	39.	42.	44.	42.	39.	33.	26.	18.	15.	1.	0.	393.	82.	99.	71.	82.
NORTHEAST	0.	1.	46.	68.	66.	52.	39.	42.	44.	42.	39.	33.	26.	18.	9.	1.	0.	527.	90.	113.	76.	90.
EAST	0.	1.	56.	96.	110.	109.	95.	72.	44.	42.	39.	33.	26.	18.	9.	1.	0.	752.	103.	136.	84.	103.
SOUTHEAST	0.	1.	38.	78.	106.	121.	125.	118.	101.	76.	46.	33.	26.	18.	9.	1.	0.	896.	111.	150.	89.	112.
HORIZ.	0.	2.	22.	51.	81.	107.	128.	140.	145.	140.	128.	107.	81.	51.	22.	2.	0.	1207.	129.	182.	99.	131.

MONTH 9 HO 1972. TOD 55. TOT 53. KT .449 KD .185

ORIENTATION	HOURLY SOLAR RADIATION																	DAILY TOTAL RADIATION	SAG/DAYTIME		SAG/ALL DAY	
	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20		SATGS	SATGD	SATGS	SATGD
SOUTH	0.	0.	0.	20.	57.	91.	119.	137.	143.	137.	119.	91.	57.	20.	0.	0.	0.	992.	122.	174.	87.	113.
SOUTHWEST	0.	0.	0.	9.	17.	25.	49.	83.	111.	131.	138.	130.	105.	56.	0.	0.	0.	855.	113.	157.	82.	105.
WEST	0.	0.	0.	9.	17.	25.	31.	35.	36.	68.	94.	107.	102.	64.	0.	0.	0.	589.	95.	125.	73.	89.
NORTHWEST	0.	0.	0.	9.	17.	25.	31.	35.	36.	35.	31.	36.	49.	40.	0.	0.	0.	344.	78.	96.	65.	74.
NORTH	0.	0.	0.	9.	17.	25.	31.	35.	36.	35.	31.	25.	17.	9.	0.	0.	0.	271.	73.	87.	62.	69.
NORTHEAST	0.	0.	0.	40.	49.	36.	31.	35.	36.	35.	31.	25.	17.	9.	0.	0.	0.	344.	78.	96.	65.	74.
EAST	0.	0.	0.	64.	102.	107.	94.	68.	36.	35.	31.	25.	17.	9.	0.	0.	0.	589.	95.	125.	73.	89.
SOUTHEAST	0.	0.	0.	56.	105.	130.	138.	131.	111.	83.	49.	25.	17.	9.	0.	0.	0.	855.	113.	157.	82.	105.
HORIZ.	0.	0.	1.	22.	53.	82.	104.	119.	124.	119.	104.	82.	53.	22.	1.	0.	0.	884.	115.	161.	83.	107.

LOCATION ANNETTE IS., ALASKA LATITUDE 55 DEGREES 1 MINUTES

MONTH 10 HO 1174. TOD 48. TOT 47. KT .347 KD .181

ORIENTATION	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	DAILY TOTAL RADIATION	SAG/DAYTIME SATGS	SAG/DAYTIME SATGD	SAG/ALL DAY SATGS	SAG/ALL DAY SATGD
SOUTH	0.	0.	0.	0.	25.	58.	82.	97.	102.	97.	82.	58.	25.	0.	0.	0.	0.	627.	97.	137.	67.	83.
SOUTHWEST	0.	0.	0.	0.	7.	14.	36.	60.	79.	90.	91.	78.	42.	0.	0.	0.	0.	496.	87.	118.	63.	76.
WEST	0.	0.	0.	0.	7.	14.	19.	22.	23.	44.	58.	59.	38.	0.	0.	0.	0.	283.	70.	88.	56.	63.
NORTHWEST	0.	0.	0.	0.	7.	14.	19.	22.	23.	22.	19.	14.	15.	0.	0.	0.	0.	156.	60.	70.	52.	56.
NORTH	0.	0.	0.	0.	7.	14.	19.	22.	23.	22.	19.	14.	7.	0.	0.	0.	0.	146.	60.	69.	52.	55.
NORTHEAST	0.	0.	0.	0.	15.	14.	19.	22.	23.	22.	19.	14.	7.	0.	0.	0.	0.	156.	60.	70.	52.	56.
EAST	0.	0.	0.	0.	38.	59.	58.	44.	23.	22.	19.	14.	7.	0.	0.	0.	0.	283.	70.	88.	56.	63.
SOUTHEAST	0.	0.	0.	0.	42.	78.	91.	90.	79.	60.	36.	14.	7.	0.	0.	0.	0.	496.	87.	118.	63.	76.
HORIZ.	0.	0.	0.	0.	15.	36.	53.	65.	68.	65.	53.	36.	15.	0.	0.	0.	0.	407.	80.	106.	60.	71.

MONTH 11 HO 602. TOD 42. TOT 41. KT .304 KD .179

ORIENTATION	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	DAILY TOTAL RADIATION	SAG/DAYTIME SATGS	SAG/DAYTIME SATGD	SAG/ALL DAY SATGS	SAG/ALL DAY SATGD
SOUTH	0.	0.	0.	0.	0.	26.	57.	75.	81.	75.	57.	26.	0.	0.	0.	0.	0.	397.	81.	113.	53.	64.
SOUTHWEST	0.	0.	0.	0.	0.	7.	25.	46.	61.	68.	62.	33.	0.	0.	0.	0.	0.	302.	72.	96.	50.	58.
WEST	0.	0.	0.	0.	0.	5.	10.	13.	14.	29.	36.	24.	0.	0.	0.	0.	0.	132.	55.	65.	45.	48.
NORTHWEST	0.	0.	0.	0.	0.	5.	10.	13.	14.	13.	10.	5.	0.	0.	0.	0.	0.	72.	49.	55.	43.	45.
NORTH	0.	0.	0.	0.	0.	5.	10.	13.	14.	13.	10.	5.	0.	0.	0.	0.	0.	72.	49.	55.	43.	45.
NORTHEAST	0.	0.	0.	0.	0.	5.	10.	13.	14.	13.	10.	5.	0.	0.	0.	0.	0.	72.	49.	55.	43.	45.
EAST	0.	0.	0.	0.	0.	24.	36.	29.	14.	13.	10.	5.	0.	0.	0.	0.	0.	132.	55.	65.	45.	48.
SOUTHEAST	0.	0.	0.	0.	0.	33.	62.	68.	61.	46.	25.	7.	0.	0.	0.	0.	0.	302.	72.	96.	50.	58.
HORIZ.	0.	0.	0.	0.	0.	11.	25.	35.	39.	35.	25.	11.	0.	0.	0.	0.	0.	182.	60.	74.	47.	51.

MONTH 12 HO 413. TOD 37. TOT 36. KT .361 KD .181

ORIENTATION	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	DAILY TOTAL RADIATION	SAG/DAYTIME SATGS	SAG/DAYTIME SATGD	SAG/ALL DAY SATGS	SAG/ALL DAY SATGD
SOUTH	0.	0.	0.	0.	0.	9.	68.	102.	112.	102.	68.	9.	0.	0.	0.	0.	0.	470.	90.	133.	51.	64.
SOUTHWEST	0.	0.	0.	0.	0.	3.	28.	59.	83.	91.	73.	12.	0.	0.	0.	0.	0.	348.	76.	108.	47.	56.
WEST	0.	0.	0.	0.	0.	2.	7.	11.	12.	33.	39.	8.	0.	0.	0.	0.	0.	113.	50.	60.	40.	43.
NORTHWEST	0.	0.	0.	0.	0.	2.	7.	11.	12.	11.	7.	2.	0.	0.	0.	0.	0.	53.	43.	48.	38.	39.
NORTH	0.	0.	0.	0.	0.	2.	7.	11.	12.	11.	7.	2.	0.	0.	0.	0.	0.	53.	43.	48.	38.	39.
NORTHEAST	0.	0.	0.	0.	0.	2.	7.	11.	12.	11.	7.	2.	0.	0.	0.	0.	0.	53.	43.	48.	38.	39.
EAST	0.	0.	0.	0.	0.	8.	39.	33.	12.	11.	7.	2.	0.	0.	0.	0.	0.	113.	50.	60.	40.	43.
SOUTHEAST	0.	0.	0.	0.	0.	12.	73.	91.	83.	59.	28.	3.	0.	0.	0.	0.	0.	348.	76.	108.	47.	56.
HORIZ.	0.	0.	0.	0.	0.	4.	20.	32.	37.	32.	20.	4.	0.	0.	0.	0.	0.	149.	54.	68.	41.	45.

LOCATION BETHEL, ALASKA LATITUDE 60 DEGREES 46 MINUTES

MONTH 1 HO 324. TOD 9. TOT 7. KT .536 KD .183

ORIENTATION	Hourly solar radiation: 4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	DAILY TOTAL RADIATION	SAG/DAYTIME SATGS	SAG/DAYTIME SATGD	SAG/ALL DAY SATGS	SAG/ALL DAY SATGD
SOUTH	0.	0.	0.	0.	0.	4.	113.	191.	216.	191.	113.	4.	0.	0.	0.	0.	0.	832.	106.	184.	34.	55.
SOUTHWEST	0.	0.	0.	0.	0.	2.	41.	106.	156.	171.	122.	5.	0.	0.	0.	0.	0.	602.	79.	136.	26.	42.
WEST	0.	0.	0.	0.	0.	1.	6.	10.	12.	56.	64.	4.	0.	0.	0.	0.	0.	153.	27.	41.	12.	16.
NORTHWEST	0.	0.	0.	0.	0.	1.	6.	10.	12.	10.	6.	1.	0.	0.	0.	0.	0.	47.	15.	19.	8.	10.
NORTH	0.	0.	0.	0.	0.	1.	6.	10.	12.	10.	6.	1.	0.	0.	0.	0.	0.	47.	15.	19.	8.	10.
NORTHEAST	0.	0.	0.	0.	0.	1.	6.	10.	12.	10.	6.	1.	0.	0.	0.	0.	0.	47.	15.	19.	8.	10.
EAST	0.	0.	0.	0.	0.	4.	64.	56.	12.	10.	6.	1.	0.	0.	0.	0.	0.	153.	27.	41.	12.	16.
SOUTHEAST	0.	0.	0.	0.	0.	5.	122.	171.	156.	106.	41.	2.	0.	0.	0.	0.	0.	602.	79.	136.	26.	42.
HORIZ.	0.	0.	0.	0.	0.	2.	21.	40.	47.	40.	21.	2.	0.	0.	0.	0.	0.	174.	29.	46.	12.	17.

MONTH 2 HO 887. TOD 12. TOT 9. KT .557 KD .180

ORIENTATION	Hourly solar radiation: 4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	DAILY TOTAL RADIATION	SAG/DAYTIME SATGS	SAG/DAYTIME SATGD	SAG/ALL DAY SATGS	SAG/ALL DAY SATGD
SOUTH	0.	0.	0.	0.	32.	109.	166.	200.	211.	200.	166.	109.	32.	0.	0.	0.	0.	1224.	112.	193.	48.	80.
SOUTHWEST	0.	0.	0.	0.	4.	11.	60.	112.	156.	182.	184.	150.	56.	0.	0.	0.	0.	916.	86.	147.	38.	62.
WEST	0.	0.	0.	0.	4.	11.	17.	21.	22.	70.	105.	109.	50.	0.	0.	0.	0.	410.	45.	72.	22.	33.
NORTHWEST	0.	0.	0.	0.	4.	11.	17.	21.	22.	21.	17.	11.	17.	0.	0.	0.	0.	142.	23.	33.	14.	17.
NORTH	0.	0.	0.	0.	4.	11.	17.	21.	22.	21.	17.	11.	4.	0.	0.	0.	0.	129.	22.	31.	13.	17.
NORTHEAST	0.	0.	0.	0.	17.	11.	17.	21.	22.	21.	17.	11.	4.	0.	0.	0.	0.	142.	23.	33.	14.	17.
EAST	0.	0.	0.	0.	50.	109.	105.	70.	22.	21.	17.	11.	4.	0.	0.	0.	0.	410.	45.	72.	22.	33.
SOUTHEAST	0.	0.	0.	0.	56.	150.	184.	182.	156.	112.	60.	11.	4.	0.	0.	0.	0.	916.	86.	147.	38.	62.
HORIZ.	0.	0.	0.	0.	11.	40.	67.	84.	90.	84.	67.	40.	11.	0.	0.	0.	0.	495.	52.	85.	25.	38.

MONTH 3 HO 1685. TOD 14. TOT 11. KT .704 KD .147

ORIENTATION	Hourly solar radiation: 4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	DAILY TOTAL RADIATION	SAG/DAYTIME SATGS	SAG/DAYTIME SATGD	SAG/ALL DAY SATGS	SAG/ALL DAY SATGD
SOUTH	0.	0.	0.	33.	104.	174.	230.	266.	278.	266.	230.	174.	104.	33.	0.	0.	0.	1892.	135.	233.	72.	122.
SOUTHWEST	0.	0.	0.	7.	15.	22.	76.	146.	206.	248.	266.	253.	204.	106.	0.	0.	0.	1550.	113.	194.	61.	102.
WEST	0.	0.	0.	7.	15.	22.	28.	32.	33.	104.	162.	197.	193.	120.	0.	0.	0.	915.	73.	120.	41.	65.
NORTHWEST	0.	0.	0.	7.	15.	22.	28.	32.	33.	32.	28.	39.	78.	69.	0.	0.	0.	383.	39.	59.	24.	34.
NORTH	0.	0.	0.	7.	15.	22.	28.	32.	33.	32.	28.	22.	15.	7.	0.	0.	0.	242.	30.	42.	19.	26.
NORTHEAST	0.	0.	0.	69.	78.	39.	28.	32.	33.	32.	28.	22.	15.	7.	0.	0.	0.	383.	39.	59.	24.	34.
EAST	0.	0.	0.	120.	193.	197.	162.	104.	33.	32.	28.	22.	15.	7.	0.	0.	0.	915.	73.	120.	41.	65.
SOUTHEAST	0.	0.	0.	106.	204.	253.	266.	248.	206.	146.	76.	22.	15.	7.	0.	0.	0.	1550.	113.	194.	61.	102.
HORIZ.	0.	0.	0.	24.	68.	109.	143.	164.	171.	164.	143.	109.	68.	24.	0.	0.	0.	1186.	90.	152.	50.	81.

LOCATION BETHEL, ALASKA LATITUDE 60 DEGREES 46 MINUTES

MONTH 4 HO 2653. TOD 29. TOT 27. KT .675 KD .155

ORIENTATION	HOURLY SOLAR RADIATION																	DAILY TOTAL	SAG/DAYTIME		SAG/ALL DAY	
	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	RADIATION	SATGS	SATGD	SATGS	SATGD
SOUTH	0.	2.	10.	40.	98.	153.	197.	226.	236.	226.	197.	153.	98.	40.	10.	2.	0.	1689.	116.	187.	81.	125.
SOUTHWEST	0.	2.	10.	18.	26.	33.	65.	127.	180.	218.	237.	234.	208.	158.	87.	9.	0.	1611.	112.	180.	78.	121.
WEST	0.	2.	10.	18.	26.	33.	39.	42.	44.	107.	160.	198.	212.	194.	131.	16.	0.	1231.	93.	144.	66.	99.
NORTHWEST	0.	2.	10.	18.	26.	33.	39.	42.	44.	42.	39.	65.	107.	127.	104.	15.	0.	714.	66.	96.	50.	68.
NORTH	0.	7.	22.	18.	26.	33.	39.	42.	44.	42.	39.	33.	26.	18.	22.	7.	0.	420.	51.	69.	40.	51.
NORTHEAST	0.	15.	104.	127.	107.	65.	39.	42.	44.	42.	39.	33.	26.	18.	10.	2.	0.	714.	66.	96.	50.	68.
EAST	0.	16.	131.	194.	212.	198.	160.	107.	44.	42.	39.	33.	26.	18.	10.	2.	0.	1231.	93.	144.	66.	99.
SOUTHEAST	0.	9.	87.	158.	208.	234.	237.	218.	180.	127.	65.	33.	26.	18.	10.	2.	0.	1611.	112.	180.	78.	121.
HORIZ.	0.	5.	35.	77.	120.	158.	188.	206.	213.	206.	188.	158.	120.	77.	35.	5.	0.	1791.	122.	197.	84.	131.

MONTH 5 HO 3403. TOD 43. TOT 40. KT .519 KD .185

ORIENTATION	HOURLY SOLAR RADIATION																	DAILY TOTAL	SAG/DAYTIME		SAG/ALL DAY	
	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	RADIATION	SATGS	SATGD	SATGS	SATGD
SOUTH	4.	10.	18.	31.	68.	102.	130.	148.	154.	148.	130.	102.	68.	31.	18.	10.	4.	1176.	98.	140.	80.	111.
SOUTHWEST	4.	10.	18.	26.	33.	40.	52.	91.	123.	146.	158.	156.	141.	114.	77.	37.	6.	1231.	100.	145.	82.	114.
WEST	4.	10.	18.	26.	33.	40.	44.	48.	49.	87.	119.	141.	151.	145.	121.	75.	15.	1124.	95.	136.	78.	108.
NORTHWEST	4.	10.	18.	26.	33.	40.	44.	48.	49.	48.	44.	67.	92.	106.	103.	76.	18.	824.	81.	111.	68.	90.
NORTH	12.	37.	36.	26.	33.	40.	44.	48.	49.	48.	44.	40.	33.	26.	36.	37.	12.	600.	71.	92.	61.	76.
NORTHEAST	18.	76.	103.	106.	92.	67.	44.	48.	49.	48.	44.	40.	33.	26.	18.	10.	4.	824.	81.	111.	68.	90.
EAST	15.	75.	121.	145.	151.	141.	119.	87.	49.	48.	44.	40.	33.	26.	18.	10.	4.	1124.	95.	136.	78.	108.
SOUTHEAST	6.	37.	77.	114.	141.	156.	158.	146.	123.	91.	52.	40.	33.	26.	18.	10.	4.	1231.	100.	145.	82.	114.
HORIZ.	7.	28.	57.	89.	119.	146.	166.	179.	184.	179.	166.	146.	119.	89.	57.	28.	7.	1766.	126.	189.	100.	147.

MONTH 6 HO 3712. TOD 55. TOT 53. KT .458 KD .186

ORIENTATION	HOURLY SOLAR RADIATION																	DAILY TOTAL	SAG/DAYTIME		SAG/ALL DAY	
	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	RADIATION	SATGS	SATGD	SATGS	SATGD
SOUTH	6.	13.	20.	29.	59.	87.	109.	123.	128.	123.	109.	87.	59.	29.	20.	13.	6.	1021.	100.	134.	88.	114.
SOUTHWEST	6.	13.	20.	27.	34.	40.	48.	79.	105.	123.	132.	130.	118.	97.	68.	37.	11.	1092.	103.	140.	90.	119.
WEST	6.	13.	20.	27.	34.	40.	45.	47.	48.	79.	104.	121.	129.	124.	107.	75.	32.	1054.	102.	137.	89.	116.
NORTHWEST	6.	13.	20.	27.	34.	40.	45.	47.	48.	47.	45.	65.	84.	95.	94.	77.	38.	828.	92.	119.	81.	103.
NORTH	26.	41.	38.	27.	34.	40.	45.	47.	48.	47.	45.	40.	34.	27.	38.	41.	26.	647.	84.	105.	75.	92.
NORTHEAST	38.	77.	94.	95.	84.	65.	45.	47.	48.	47.	45.	40.	34.	27.	20.	13.	6.	828.	92.	119.	81.	103.
EAST	32.	75.	107.	124.	129.	121.	104.	79.	48.	47.	45.	40.	34.	27.	20.	13.	6.	1054.	102.	137.	89.	116.
SOUTHEAST	11.	37.	68.	97.	118.	130.	132.	123.	105.	79.	48.	40.	34.	27.	20.	13.	6.	1092.	103.	140.	90.	119.
HORIZ.	14.	35.	60.	88.	114.	136.	153.	164.	168.	164.	153.	136.	114.	88.	60.	35.	14.	1701.	130.	187.	111.	155.

LOCATION BETHEL, ALASKA LATITUDE 60 DEGREES 46 MINUTES

MONTH 7 HO 3411. TOD 57. TOT 54. KT .398 KD .183

ORIENTATION	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	DAILY TOTAL RADIATION	SAG/DAYTIME SATGS	SAG/DAYTIME SATGD	SAG/ALL DAY SATGS	SAG/ALL DAY SATGD
SOUTH	4.	10.	16.	27.	52.	76.	95.	107.	112.	107.	95.	76.	52.	27.	16.	10.	4.	886.	98.	130.	85.	108.
SOUTHWEST	4.	10.	16.	23.	30.	36.	45.	71.	92.	106.	113.	110.	99.	80.	54.	26.	5.	921.	100.	133.	86.	110.
WEST	4.	10.	16.	23.	30.	36.	40.	43.	44.	68.	88.	101.	106.	100.	82.	51.	11.	851.	97.	127.	84.	106.
NORTHWEST	4.	10.	16.	23.	30.	36.	40.	43.	44.	43.	40.	54.	68.	75.	71.	51.	13.	659.	88.	111.	77.	94.
NORTH	9.	27.	28.	23.	30.	36.	40.	43.	44.	43.	40.	36.	30.	23.	28.	27.	9.	516.	81.	100.	72.	86.
NORTHEAST	13.	51.	71.	75.	68.	54.	40.	43.	44.	43.	40.	36.	30.	23.	16.	10.	4.	659.	88.	111.	77.	94.
EAST	11.	51.	82.	100.	106.	101.	88.	68.	44.	43.	40.	36.	30.	23.	16.	10.	4.	851.	97.	127.	84.	106.
SOUTHEAST	5.	26.	54.	80.	99.	110.	113.	106.	92.	71.	45.	36.	30.	23.	16.	10.	4.	921.	100.	133.	86.	110.
HORIZ.	7.	23.	45.	69.	91.	111.	127.	136.	139.	136.	127.	111.	91.	69.	45.	23.	7.	1357.	120.	169.	101.	137.

MONTH 8 HO 2640. TOD 55. TOT 53. KT .336 KD .180

ORIENTATION	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	DAILY TOTAL RADIATION	SAG/DAYTIME SATGS	SAG/DAYTIME SATGD	SAG/ALL DAY SATGS	SAG/ALL DAY SATGD
SOUTH	0.	3.	9.	22.	43.	63.	80.	90.	94.	90.	80.	63.	43.	22.	9.	3.	0.	715.	94.	124.	77.	96.
SOUTHWEST	0.	3.	9.	16.	22.	28.	40.	60.	77.	88.	91.	88.	76.	56.	31.	4.	0.	689.	93.	121.	76.	94.
WEST	0.	3.	9.	16.	22.	28.	32.	35.	36.	54.	69.	77.	77.	67.	43.	6.	0.	574.	86.	110.	72.	87.
NORTHWEST	0.	3.	9.	16.	22.	28.	32.	35.	36.	35.	32.	37.	46.	47.	36.	6.	0.	421.	78.	96.	67.	78.
NORTH	0.	4.	13.	16.	22.	28.	32.	35.	36.	35.	32.	28.	22.	16.	13.	4.	0.	337.	73.	87.	64.	73.
NORTHEAST	0.	6.	36.	47.	46.	37.	32.	35.	36.	35.	32.	28.	22.	16.	9.	3.	0.	421.	78.	96.	67.	78.
EAST	0.	6.	43.	67.	77.	77.	69.	54.	36.	35.	32.	28.	22.	16.	9.	3.	0.	574.	86.	110.	72.	87.
SOUTHEAST	0.	4.	31.	56.	76.	88.	91.	88.	77.	60.	40.	28.	22.	16.	9.	3.	0.	689.	93.	121.	76.	94.
HORIZ.	0.	5.	21.	40.	60.	77.	91.	99.	102.	99.	91.	77.	60.	40.	21.	5.	0.	888.	103.	141.	83.	106.

MONTH 9 HO 1689. TOD 47. TOT 45. KT .406 KD .183

ORIENTATION	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	DAILY TOTAL RADIATION	SAG/DAYTIME SATGS	SAG/DAYTIME SATGD	SAG/ALL DAY SATGS	SAG/ALL DAY SATGD
SOUTH	0.	0.	0.	17.	49.	80.	106.	122.	127.	122.	106.	80.	49.	17.	0.	0.	0.	874.	106.	152.	75.	98.
SOUTHWEST	0.	0.	0.	7.	14.	21.	44.	74.	99.	115.	120.	112.	88.	44.	0.	0.	0.	738.	97.	135.	71.	90.
WEST	0.	0.	0.	7.	14.	21.	26.	29.	30.	57.	79.	90.	83.	49.	0.	0.	0.	485.	80.	105.	62.	75.
NORTHWEST	0.	0.	0.	7.	14.	21.	26.	29.	30.	29.	26.	27.	39.	30.	0.	0.	0.	277.	66.	80.	55.	62.
NORTH	0.	0.	0.	7.	14.	21.	26.	29.	30.	29.	26.	21.	14.	7.	0.	0.	0.	223.	62.	74.	53.	59.
NORTHEAST	0.	0.	0.	30.	39.	27.	26.	29.	30.	29.	26.	21.	14.	7.	0.	0.	0.	277.	66.	80.	55.	62.
EAST	0.	0.	0.	49.	83.	90.	79.	57.	30.	29.	26.	21.	14.	7.	0.	0.	0.	485.	80.	105.	62.	75.
SOUTHEAST	0.	0.	0.	44.	88.	112.	120.	115.	99.	74.	44.	21.	14.	7.	0.	0.	0.	738.	97.	135.	71.	90.
HORIZ.	0.	0.	1.	17.	41.	63.	81.	92.	96.	92.	81.	63.	41.	17.	1.	0.	0.	685.	94.	129.	69.	87.

LOCATION BETHEL, ALASKA LATITUDE 60 DEGREES 46 MINUTES

MONTH 10 HO 859. TOD 34. TOT 32. KT .432 KD .195

ORIENTATION	HOURLY SOLAR RADIATION 4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	DAILY TOTAL RADIATION	SAG/DAYTIME SATGS	SATGD	SAG/ALL DAY SATGS	SATGD
SOUTH	0.	0.	0.	0.	18.	72.	112.	137.	145.	137.	112.	72.	18.	0.	0.	0.	0.	823.	101.	157.	58.	80.
SOUTHWEST	0.	0.	0.	0.	4.	10.	44.	79.	108.	125.	124.	97.	30.	0.	0.	0.	0.	622.	85.	127.	52.	68.
WEST	0.	0.	0.	0.	4.	10.	15.	19.	20.	51.	72.	71.	27.	0.	0.	0.	0.	291.	58.	77.	41.	49.
NORTHWEST	0.	0.	0.	0.	4.	10.	15.	19.	20.	19.	15.	10.	10.	0.	0.	0.	0.	123.	44.	52.	36.	39.
NORTH	0.	0.	0.	0.	4.	10.	15.	19.	20.	19.	15.	10.	4.	0.	0.	0.	0.	117.	43.	51.	36.	39.
NORTHEAST	0.	0.	0.	0.	10.	10.	15.	19.	20.	19.	15.	10.	4.	0.	0.	0.	0.	123.	44.	52.	36.	39.
EAST	0.	0.	0.	0.	27.	71.	72.	51.	20.	19.	15.	10.	4.	0.	0.	0.	0.	291.	58.	77.	41.	49.
SOUTHEAST	0.	0.	0.	0.	30.	97.	124.	125.	108.	79.	44.	10.	4.	0.	0.	0.	0.	622.	85.	127.	52.	68.
HORIZ.	0.	0.	0.	0.	8.	30.	50.	63.	68.	63.	50.	30.	8.	0.	0.	0.	0.	372.	64.	89.	44.	53.

MONTH 11 HO 317. TOD 19. TOT 17. KT .399 KD .183

ORIENTATION	HOURLY SOLAR RADIATION 4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	DAILY TOTAL RADIATION	SAG/DAYTIME SATGS	SATGD	SAG/ALL DAY SATGS	SATGD
SOUTH	0.	0.	0.	0.	0.	2.	69.	120.	136.	120.	69.	2.	0.	0.	0.	0.	0.	518.	79.	129.	34.	47.
SOUTHWEST	0.	0.	0.	0.	0.	1.	26.	67.	99.	107.	74.	2.	0.	0.	0.	0.	0.	378.	63.	99.	29.	39.
WEST	0.	0.	0.	0.	0.	1.	6.	9.	10.	37.	39.	2.	0.	0.	0.	0.	0.	105.	31.	41.	20.	23.
NORTHWEST	0.	0.	0.	0.	0.	1.	6.	9.	10.	9.	6.	1.	0.	0.	0.	0.	0.	42.	24.	28.	18.	19.
NORTH	0.	0.	0.	0.	0.	1.	6.	9.	10.	9.	6.	1.	0.	0.	0.	0.	0.	42.	24.	28.	18.	19.
NORTHEAST	0.	0.	0.	0.	0.	1.	6.	9.	10.	9.	6.	1.	0.	0.	0.	0.	0.	42.	24.	28.	18.	19.
EAST	0.	0.	0.	0.	0.	2.	39.	37.	10.	9.	6.	1.	0.	0.	0.	0.	0.	105.	31.	41.	20.	23.
SOUTHEAST	0.	0.	0.	0.	0.	2.	74.	107.	99.	67.	26.	1.	0.	0.	0.	0.	0.	378.	63.	99.	29.	39.
HORIZ.	0.	0.	0.	0.	0.	2.	15.	29.	34.	29.	15.	2.	0.	0.	0.	0.	0.	127.	34.	46.	21.	24.

MONTH 12 HO 158. TOD 9. TOT 7. KT .459 KD .186

ORIENTATION	HOURLY SOLAR RADIATION 4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	DAILY TOTAL RADIATION	SAG/DAYTIME SATGS	SATGD	SAG/ALL DAY SATGS	SATGD
SOUTH	0.	0.	0.	0.	0.	0.	21.	138.	183.	138.	21.	0.	0.	0.	0.	0.	0.	502.	83.	144.	23.	36.
SOUTHWEST	0.	0.	0.	0.	0.	0.	9.	76.	131.	122.	23.	0.	0.	0.	0.	0.	0.	361.	63.	106.	19.	28.
WEST	0.	0.	0.	0.	0.	0.	2.	6.	7.	38.	12.	0.	0.	0.	0.	0.	0.	65.	19.	27.	9.	11.
NORTHWEST	0.	0.	0.	0.	0.	0.	2.	6.	7.	6.	2.	0.	0.	0.	0.	0.	0.	22.	13.	15.	8.	8.
NORTH	0.	0.	0.	0.	0.	0.	2.	6.	7.	6.	2.	0.	0.	0.	0.	0.	0.	22.	13.	15.	8.	8.
NORTHEAST	0.	0.	0.	0.	0.	0.	2.	6.	7.	6.	2.	0.	0.	0.	0.	0.	0.	22.	13.	15.	8.	8.
EAST	0.	0.	0.	0.	0.	0.	12.	38.	7.	6.	2.	0.	0.	0.	0.	0.	0.	65.	19.	27.	9.	11.
SOUTHEAST	0.	0.	0.	0.	0.	0.	23.	122.	131.	76.	9.	0.	0.	0.	0.	0.	0.	361.	63.	106.	19.	28.
HORIZ.	0.	0.	0.	0.	0.	0.	4.	19.	26.	19.	4.	0.	0.	0.	0.	0.	0.	73.	20.	29.	10.	11.

LOCATION FAIRBANKS, ALASKA LATITUDE 64 DEGREES 48 MINUTES

MONTH 1 HO 149. TOD -7. TOT -10. KT .639 KD .164

ORIENTATION	HOURLY SOLAR RADIATION 4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	DAILY TOTAL RADIATION	SAG/DAYTIME SATGS	SAG/DAYTIME SATGD	SAG/ALL DAY SATGS	SAG/ALL DAY SATGD
SOUTH	0.	0.	0.	0.	0.	0.	36.	237.	317.	237.	36.	0.	0.	0.	0.	0.	0.	864.	118.	220.	18.	41.
SOUTHWEST	0.	0.	0.	0.	0.	0.	13.	128.	227.	211.	39.	0.	0.	0.	0.	0.	0.	617.	82.	155.	10.	26.
WEST	0.	0.	0.	0.	0.	0.	2.	5.	7.	64.	20.	0.	0.	0.	0.	0.	0.	98.	7.	19.	-7.	-4.
NORTHWEST	0.	0.	0.	0.	0.	0.	2.	5.	7.	5.	2.	0.	0.	0.	0.	0.	0.	22.	-4.	-1.	-9.	-9.
NORTH	0.	0.	0.	0.	0.	0.	2.	5.	7.	5.	2.	0.	0.	0.	0.	0.	0.	22.	-4.	-1.	-9.	-9.
NORTHEAST	0.	0.	0.	0.	0.	0.	2.	5.	7.	5.	2.	0.	0.	0.	0.	0.	0.	22.	-4.	-1.	-9.	-9.
EAST	0.	0.	0.	0.	0.	0.	20.	64.	7.	5.	2.	0.	0.	0.	0.	0.	0.	98.	7.	19.	-7.	-4.
SOUTHEAST	0.	0.	0.	0.	0.	0.	39.	211.	227.	128.	13.	0.	0.	0.	0.	0.	0.	617.	92.	155.	10.	26.
HORIZ.	0.	0.	0.	0.	0.	0.	4.	25.	36.	25.	4.	0.	0.	0.	0.	0.	0.	95.	7.	18.	-7.	-4.

MONTH 2 HO 665. TOD 0. TOT -3. KT .556 KD .180

ORIENTATION	HOURLY SOLAR RADIATION 4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	DAILY TOTAL RADIATION	SAG/DAYTIME SATGS	SAG/DAYTIME SATGD	SAG/ALL DAY SATGS	SAG/ALL DAY SATGD
SOUTH	0.	0.	0.	0.	10.	93.	161.	202.	216.	202.	161.	93.	10.	0.	0.	0.	0.	1149.	100.	181.	34.	64.
SOUTHWEST	0.	0.	0.	0.	2.	9.	57.	112.	159.	183.	179.	128.	16.	0.	0.	0.	0.	845.	73.	133.	24.	46.
WEST	0.	0.	0.	0.	2.	8.	13.	16.	18.	67.	99.	92.	15.	0.	0.	0.	0.	330.	29.	52.	7.	16.
NORTHWEST	0.	0.	0.	0.	2.	8.	13.	16.	18.	16.	13.	8.	6.	0.	0.	0.	0.	101.	9.	16.	0.	3.
NORTH	0.	0.	0.	0.	2.	8.	13.	16.	18.	16.	13.	8.	2.	0.	0.	0.	0.	97.	9.	16.	0.	3.
NORTHEAST	0.	0.	0.	0.	6.	6.	13.	16.	18.	16.	13.	8.	2.	0.	0.	0.	0.	101.	9.	16.	0.	3.
EAST	0.	0.	0.	0.	15.	92.	99.	67.	18.	16.	13.	8.	2.	0.	0.	0.	0.	330.	29.	52.	7.	16.
SOUTHEAST	0.	0.	0.	0.	16.	128.	179.	183.	158.	112.	57.	9.	2.	0.	0.	0.	0.	845.	73.	133.	24.	46.
HORIZ.	0.	0.	0.	0.	4.	27.	51.	67.	73.	67.	51.	27.	4.	0.	0.	0.	0.	370.	32.	58.	9.	18.

MONTH 3 HO 1474. TOD 13. TOT 9. KT .674 KD .156

ORIENTATION	HOURLY SOLAR RADIATION 4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	DAILY TOTAL RADIATION	SAG/DAYTIME SATGS	SAG/DAYTIME SATGD	SAG/ALL DAY SATGS	SAG/ALL DAY SATGD
SOUTH	0.	0.	0.	29.	97.	166.	221.	257.	269.	257.	221.	166.	97.	29.	0.	0.	0.	1808.	128.	222.	67.	114.
SOUTHWEST	0.	0.	0.	6.	13.	20.	75.	142.	199.	238.	252.	238.	187.	89.	0.	0.	0.	1458.	106.	182.	56.	94.
WEST	0.	0.	0.	6.	13.	20.	25.	28.	29.	96.	150.	182.	175.	101.	0.	0.	0.	826.	66.	108.	35.	57.
NORTHWEST	0.	0.	0.	6.	13.	20.	25.	28.	29.	28.	25.	31.	68.	57.	0.	0.	0.	331.	34.	51.	20.	28.
NORTH	0.	0.	0.	6.	13.	20.	25.	28.	29.	28.	25.	20.	13.	6.	0.	0.	0.	213.	27.	38.	16.	21.
NORTHEAST	0.	0.	0.	57.	68.	31.	25.	28.	29.	28.	25.	20.	13.	6.	0.	0.	0.	331.	34.	51.	20.	28.
EAST	0.	0.	0.	101.	175.	182.	150.	96.	29.	28.	25.	20.	13.	6.	0.	0.	0.	826.	66.	108.	35.	57.
SOUTHEAST	0.	0.	0.	89.	197.	238.	252.	238.	199.	142.	75.	20.	13.	6.	0.	0.	0.	1458.	106.	182.	56.	94.
HORIZ.	0.	0.	0.	19.	56.	91.	120.	138.	144.	138.	120.	91.	56.	19.	0.	0.	0.	993.	76.	128.	41.	67.

LOCATION FAIRBANKS, ALASKA LATITUDE 64 DEGREES 48 MINUTES

MONTH 4 HO 2512. TOD 32. TOT 29. KT .647 KD .162

HOURLY SOLAR RADIATION

ORIENTATION	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	DAILY TOTAL RADIATION	SAG/DAYTIME SATGS	SAG/DAYTIME SATGD	SAG/ALL DAY SATGS	SAG/ALL DAY SATGD
SOUTH	0.	4.	10.	43.	98.	151.	195.	223.	232.	223.	195.	151.	98.	43.	10.	4.	0.	1679.	115.	183.	83.	127.
SOUTHWEST	0.	4.	10.	18.	25.	31.	57.	126.	176.	212.	229.	226.	200.	153.	88.	19.	0.	1584.	111.	175.	80.	121.
WEST	0.	4.	10.	18.	25.	31.	36.	39.	40.	100.	150.	186.	199.	184.	132.	35.	0.	1190.	91.	139.	67.	98.
NORTHWEST	0.	4.	10.	18.	25.	31.	36.	39.	40.	39.	36.	56.	97.	118.	104.	34.	0.	686.	66.	94.	51.	69.
NORTH	0.	14.	21.	18.	25.	31.	36.	39.	40.	39.	36.	31.	25.	18.	21.	14.	0.	409.	52.	69.	42.	53.
NORTHEAST	0.	34.	104.	118.	97.	56.	36.	39.	40.	39.	36.	31.	25.	18.	10.	4.	0.	686.	66.	94.	51.	69.
EAST	0.	35.	132.	184.	199.	186.	150.	100.	40.	39.	36.	31.	25.	18.	10.	4.	0.	1190.	91.	139.	67.	98.
SOUTHEAST	0.	19.	88.	153.	200.	226.	229.	212.	176.	126.	67.	31.	25.	18.	10.	4.	0.	1584.	111.	175.	80.	121.
HORIZ.	0.	8.	36.	73.	109.	142.	167.	183.	188.	183.	167.	142.	109.	73.	36.	8.	0.	1625.	113.	178.	81.	124.

MONTH 5 HO 3356. TOD 50. TOT 47. KT .546 KD .182

HOURLY SOLAR RADIATION

ORIENTATION	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	DAILY TOTAL RADIATION	SAG/DAYTIME SATGS	SAG/DAYTIME SATGD	SAG/ALL DAY SATGS	SAG/ALL DAY SATGD
SOUTH	6.	12.	19.	36.	77.	115.	145.	165.	172.	165.	145.	115.	77.	36.	19.	12.	6.	1323.	108.	152.	93.	127.
SOUTHWEST	6.	12.	19.	26.	32.	38.	57.	99.	135.	160.	173.	172.	156.	127.	89.	47.	13.	1364.	110.	155.	94.	130.
WEST	6.	12.	19.	26.	32.	38.	42.	45.	46.	88.	124.	150.	163.	159.	137.	96.	40.	1226.	104.	145.	89.	121.
NORTHWEST	6.	12.	19.	26.	32.	38.	42.	45.	46.	45.	42.	63.	93.	112.	115.	95.	47.	882.	89.	118.	78.	101.
NORTH	30.	46.	37.	26.	32.	38.	42.	45.	46.	45.	42.	38.	32.	26.	37.	46.	30.	641.	78.	100.	69.	86.
NORTHEAST	47.	95.	115.	112.	93.	63.	42.	45.	46.	45.	42.	38.	32.	26.	19.	12.	6.	882.	89.	118.	78.	101.
EAST	40.	96.	137.	159.	163.	150.	124.	88.	46.	45.	42.	38.	32.	26.	19.	12.	6.	1226.	104.	145.	89.	121.
SOUTHEAST	13.	47.	89.	127.	156.	172.	173.	160.	135.	99.	57.	38.	32.	26.	19.	12.	6.	1364.	110.	155.	94.	130.
HORIZ.	14.	36.	64.	94.	122.	147.	167.	179.	183.	179.	167.	147.	122.	94.	64.	36.	14.	1833.	130.	191.	110.	158.

MONTH 6 HO 3721. TOD 62. TOT 59. KT .529 KD .184

HOURLY SOLAR RADIATION

ORIENTATION	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	DAILY TOTAL RADIATION	SAG/DAYTIME SATGS	SAG/DAYTIME SATGD	SAG/ALL DAY SATGS	SAG/ALL DAY SATGD
SOUTH	9.	15.	22.	35.	73.	108.	136.	154.	160.	154.	136.	108.	73.	35.	22.	15.	9.	1271.	112.	150.	103.	136.
SOUTHWEST	9.	15.	22.	28.	35.	40.	55.	94.	127.	151.	163.	162.	148.	122.	88.	51.	18.	1340.	115.	155.	105.	140.
WEST	9.	15.	22.	28.	35.	40.	45.	47.	48.	87.	121.	145.	157.	155.	137.	104.	60.	1278.	112.	151.	103.	137.
NORTHWEST	9.	15.	22.	28.	35.	40.	45.	47.	48.	47.	45.	67.	95.	113.	118.	106.	72.	981.	101.	130.	93.	119.
NORTH	46.	54.	43.	28.	35.	40.	45.	47.	48.	47.	45.	40.	35.	28.	43.	54.	46.	764.	92.	115.	85.	105.
NORTHEAST	72.	106.	118.	113.	95.	67.	45.	47.	48.	47.	45.	40.	35.	28.	22.	15.	9.	981.	101.	130.	93.	119.
EAST	60.	104.	137.	155.	157.	145.	121.	87.	48.	47.	45.	40.	35.	28.	22.	15.	9.	1278.	112.	151.	103.	137.
SOUTHEAST	18.	51.	88.	122.	148.	162.	163.	151.	127.	94.	55.	40.	35.	28.	22.	15.	9.	1340.	115.	155.	105.	140.
HORIZ.	24.	47.	74.	102.	129.	153.	171.	182.	186.	182.	171.	153.	129.	102.	74.	47.	24.	1969.	139.	199.	127.	178.

LOCATION FAIRBANKS, ALASKA LATITUDE 64 DEGREES 48 MINUTES

MONTH 7 HO 3367. TOD 64. TOT 61. KT .485 KD .187

ORIENTATION	HOURLY SOLAR RADIATION 4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	DAILY TOTAL RADIATION	SAG/DAYTIME SATGS	SAG/DAYTIME SATGD	SAG/ALL DAY SATGS	SAG/ALL DAY SATGD
SOUTH	6.	12.	18.	34.	68.	100.	125.	142.	147.	142.	125.	100.	68.	34.	18.	12.	6.	1158.	114.	152.	101.	131.
SOUTHWEST	6.	12.	18.	25.	32.	37.	53.	89.	117.	138.	148.	146.	132.	108.	75.	40.	12.	1191.	115.	155.	102.	133.
WEST	6.	12.	18.	25.	32.	37.	41.	44.	45.	79.	108.	129.	138.	133.	114.	79.	33.	1077.	110.	146.	98.	126.
NORTHWEST	6.	12.	18.	25.	32.	37.	41.	44.	45.	44.	41.	58.	81.	96.	96.	78.	38.	797.	98.	125.	88.	109.
NORTH	25.	39.	34.	25.	32.	37.	41.	44.	45.	44.	41.	37.	32.	25.	34.	39.	25.	602.	90.	110.	81.	97.
NORTHEAST	38.	78.	96.	96.	81.	58.	41.	44.	45.	44.	41.	37.	32.	25.	18.	12.	6.	797.	98.	125.	88.	109.
EAST	33.	79.	114.	133.	138.	129.	108.	79.	45.	44.	41.	37.	32.	25.	18.	12.	6.	1077.	110.	146.	98.	126.
SOUTHEAST	12.	40.	75.	108.	132.	146.	148.	138.	117.	88.	53.	37.	32.	25.	18.	12.	6.	1191.	115.	155.	102.	133.
HORIZ.	13.	33.	57.	84.	109.	131.	148.	158.	162.	158.	148.	131.	109.	84.	57.	33.	13.	1633.	134.	189.	117.	160.

MONTH 8 HO 2500. TOD 58. TOT 56. KT .463 KD .186

ORIENTATION	HOURLY SOLAR RADIATION 4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	DAILY TOTAL RADIATION	SAG/DAYTIME SATGS	SAG/DAYTIME SATGD	SAG/ALL DAY SATGS	SAG/ALL DAY SATGD
SOUTH	0.	4.	10.	31.	65.	98.	124.	141.	147.	141.	124.	98.	65.	31.	10.	4.	0.	1094.	116.	160.	93.	122.
SOUTHWEST	0.	4.	10.	17.	24.	29.	52.	86.	115.	135.	144.	140.	122.	92.	52.	11.	0.	1035.	113.	154.	91.	118.
WEST	0.	4.	10.	17.	24.	29.	34.	37.	38.	71.	99.	117.	122.	109.	75.	19.	0.	807.	101.	133.	83.	104.
NORTHWEST	0.	4.	10.	17.	24.	29.	34.	37.	38.	37.	34.	43.	64.	73.	60.	19.	0.	523.	86.	107.	73.	87.
NORTH	0.	9.	16.	17.	24.	29.	34.	37.	38.	37.	34.	29.	24.	17.	16.	9.	0.	371.	78.	93.	68.	78.
NORTHEAST	0.	19.	60.	73.	64.	43.	34.	37.	38.	37.	34.	29.	24.	17.	10.	4.	0.	523.	86.	107.	73.	87.
EAST	0.	19.	75.	109.	122.	117.	99.	71.	38.	37.	34.	29.	24.	17.	10.	4.	0.	807.	101.	133.	83.	104.
SOUTHEAST	0.	11.	52.	92.	122.	140.	144.	135.	115.	86.	52.	29.	24.	17.	10.	4.	0.	1035.	113.	154.	91.	118.
HORIZ.	0.	8.	28.	53.	78.	100.	118.	128.	132.	128.	118.	100.	78.	53.	28.	8.	0.	1157.	119.	166.	95.	126.

MONTH 9 HO 1481. TOD 47. TOT 45. KT .419 KD .184

ORIENTATION	HOURLY SOLAR RADIATION 4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	DAILY TOTAL RADIATION	SAG/DAYTIME SATGS	SAG/DAYTIME SATGD	SAG/ALL DAY SATGS	SAG/ALL DAY SATGD
SOUTH	0.	0.	0.	16.	49.	83.	111.	129.	135.	129.	111.	83.	49.	16.	0.	0.	0.	912.	109.	156.	76.	100.
SOUTHWEST	0.	0.	0.	6.	13.	18.	45.	77.	103.	120.	125.	116.	89.	41.	0.	0.	0.	754.	98.	137.	70.	90.
WEST	0.	0.	0.	6.	13.	18.	23.	25.	26.	56.	79.	91.	83.	46.	0.	0.	0.	469.	79.	103.	61.	73.
NORTHWEST	0.	0.	0.	6.	13.	18.	23.	25.	26.	25.	23.	23.	37.	28.	0.	0.	0.	249.	64.	77.	53.	60.
NORTH	0.	0.	0.	6.	13.	18.	23.	25.	26.	25.	23.	18.	13.	6.	0.	0.	0.	198.	60.	71.	51.	57.
NORTHEAST	0.	0.	0.	28.	37.	23.	23.	25.	26.	25.	23.	18.	13.	6.	0.	0.	0.	249.	64.	77.	53.	60.
EAST	0.	0.	0.	46.	83.	91.	79.	56.	26.	25.	23.	18.	13.	6.	0.	0.	0.	469.	79.	103.	61.	73.
SOUTHEAST	0.	0.	0.	41.	89.	116.	125.	120.	103.	77.	45.	18.	13.	6.	0.	0.	0.	754.	98.	137.	70.	90.
HORIZ.	0.	0.	1.	15.	36.	57.	74.	84.	88.	84.	74.	57.	36.	15.	1.	0.	0.	620.	89.	121.	66.	82.

LOCATION FAIRBANKS, ALASKA LATITUDE 64 DEGREES 48 MINUTES

MONTH 10 HO 639. TOD 30. TOT 27. KT .416 KD .184

ORIENTATION	HOURLY SOLAR RADIATION																	DAILY TOTAL RADIATION	SAG/DAYTIME		SAG/ALL DAY	
	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20		SATGS	SATGD	SATGS	SATGD
SOUTH	0.	0.	0.	0.	4.	56.	102.	130.	140.	130.	102.	56.	4.	0.	0.	0.	0.	723.	93.	144.	51.	70.
SOUTHWEST	0.	0.	0.	0.	2.	8.	38.	74.	103.	118.	112.	75.	6.	0.	0.	0.	0.	538.	77.	115.	45.	59.
WEST	0.	0.	0.	0.	2.	7.	12.	14.	15.	46.	64.	55.	6.	0.	0.	0.	0.	221.	49.	65.	35.	40.
NORTHWEST	0.	0.	0.	0.	2.	7.	12.	14.	15.	14.	12.	7.	3.	0.	0.	0.	0.	87.	37.	43.	30.	33.
NORTH	0.	0.	0.	0.	2.	7.	12.	14.	15.	14.	12.	7.	2.	0.	0.	0.	0.	86.	37.	43.	30.	32.
NORTHEAST	0.	0.	0.	0.	3.	7.	12.	14.	15.	14.	12.	7.	2.	0.	0.	0.	0.	87.	37.	43.	30.	33.
EAST	0.	0.	0.	0.	6.	55.	64.	46.	15.	14.	12.	7.	2.	0.	0.	0.	0.	221.	49.	65.	35.	40.
SOUTHEAST	0.	0.	0.	0.	6.	75.	112.	118.	103.	74.	38.	8.	2.	0.	0.	0.	0.	538.	77.	115.	45.	59.
HORIZ.	0.	0.	0.	0.	3.	19.	36.	48.	52.	48.	36.	19.	3.	0.	0.	0.	0.	266.	53.	72.	36.	43.

MONTH 11 HO 143. TOD 5. TOT 3. KT .470 KD .186

ORIENTATION	HOURLY SOLAR RADIATION																	DAILY TOTAL RADIATION	SAG/DAYTIME		SAG/ALL DAY	
	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20		SATGS	SATGD	SATGS	SATGD
SOUTH	0.	0.	0.	0.	0.	0.	18.	142.	194.	142.	18.	0.	0.	0.	0.	0.	0.	513.	81.	142.	20.	33.
SOUTHWEST	0.	0.	0.	0.	0.	0.	7.	77.	139.	126.	19.	0.	0.	0.	0.	0.	0.	369.	60.	104.	15.	25.
WEST	0.	0.	0.	0.	0.	0.	2.	5.	6.	39.	10.	0.	0.	0.	0.	0.	0.	63.	15.	22.	5.	7.
NORTHWEST	0.	0.	0.	0.	0.	0.	2.	5.	6.	5.	2.	0.	0.	0.	0.	0.	0.	20.	8.	11.	4.	4.
NORTH	0.	0.	0.	0.	0.	0.	2.	5.	6.	5.	2.	0.	0.	0.	0.	0.	0.	20.	8.	11.	4.	4.
NORTHEAST	0.	0.	0.	0.	0.	0.	2.	5.	6.	5.	2.	0.	0.	0.	0.	0.	0.	20.	8.	11.	4.	4.
EAST	0.	0.	0.	0.	0.	0.	10.	39.	6.	5.	2.	0.	0.	0.	0.	0.	0.	63.	15.	22.	5.	7.
SOUTHEAST	0.	0.	0.	0.	0.	0.	19.	126.	139.	77.	7.	0.	0.	0.	0.	0.	0.	369.	60.	104.	15.	25.
HORIZ.	0.	0.	0.	0.	0.	0.	4.	17.	25.	17.	4.	0.	0.	0.	0.	0.	0.	67.	15.	23.	5.	7.

MONTH 12 HO 28. TOD -7. TOT -9. KT .458 KD .186

ORIENTATION	HOURLY SOLAR RADIATION																	DAILY TOTAL RADIATION	SAG/DAYTIME		SAG/ALL DAY	
	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20		SATGS	SATGD	SATGS	SATGD
SOUTH	0.	0.	0.	0.	0.	0.	0.	7.	250.	7.	0.	0.	0.	0.	0.	0.	0.	263.	60.	115.	-1.	6.
SOUTHWEST	0.	0.	0.	0.	0.	0.	0.	4.	177.	6.	0.	0.	0.	0.	0.	0.	0.	187.	41.	80.	-3.	2.
WEST	0.	0.	0.	0.	0.	0.	0.	1.	2.	2.	0.	0.	0.	0.	0.	0.	0.	6.	-5.	-4.	-9.	-9.
NORTHWEST	0.	0.	0.	0.	0.	0.	0.	1.	2.	1.	0.	0.	0.	0.	0.	0.	0.	4.	-6.	-5.	-9.	-9.
NORTH	0.	0.	0.	0.	0.	0.	0.	1.	2.	1.	0.	0.	0.	0.	0.	0.	0.	4.	-6.	-5.	-9.	-9.
NORTHEAST	0.	0.	0.	0.	0.	0.	0.	1.	2.	1.	0.	0.	0.	0.	0.	0.	0.	4.	-6.	-5.	-9.	-9.
EAST	0.	0.	0.	0.	0.	0.	0.	2.	2.	1.	0.	0.	0.	0.	0.	0.	0.	6.	-5.	-4.	-9.	-9.
SOUTHEAST	0.	0.	0.	0.	0.	0.	0.	6.	177.	4.	0.	0.	0.	0.	0.	0.	0.	187.	41.	80.	-3.	2.
HORIZ.	0.	0.	0.	0.	0.	0.	0.	2.	10.	2.	0.	0.	0.	0.	0.	0.	0.	13.	-3.	-1.	-9.	-8.

LOCATION MATANUSKA, ALASKA LATITUDE 61 DEGREES 30 MINUTES

MONTH 1 HO 291. TOD 14. TOT 13. KT .513 KD .186

ORIENTATION	HOURLY SOLAR RADIATION 4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	DAILY TOTAL RADIATION	SAG/DAYTIME SATGS	SAG/DAYTIME SATGD	SAG/ALL DAY SATGS	SAG/ALL DAY SATGD
SOUTH	0.	0.	0.	0.	0.	1.	97.	177.	203.	177.	97.	1.	0.	0.	0.	0.	0.	753.	104.	177.	37.	57.
SOUTHWEST	0.	0.	0.	0.	0.	1.	35.	98.	147.	158.	104.	1.	0.	0.	0.	0.	0.	544.	79.	132.	30.	45.
WEST	0.	0.	0.	0.	0.	1.	6.	9.	11.	52.	54.	1.	0.	0.	0.	0.	0.	134.	30.	43.	17.	21.
NORTHWEST	0.	0.	0.	0.	0.	1.	6.	9.	11.	9.	6.	1.	0.	0.	0.	0.	0.	42.	19.	23.	14.	15.
NORTH	0.	0.	0.	0.	0.	1.	6.	9.	11.	9.	6.	1.	0.	0.	0.	0.	0.	42.	19.	23.	14.	15.
NORTHEAST	0.	0.	0.	0.	0.	1.	6.	9.	11.	9.	6.	1.	0.	0.	0.	0.	0.	42.	19.	23.	14.	15.
EAST	0.	0.	0.	0.	0.	1.	54.	52.	11.	9.	6.	1.	0.	0.	0.	0.	0.	134.	30.	43.	17.	21.
SOUTHEAST	0.	0.	0.	0.	0.	1.	104.	158.	147.	98.	35.	1.	0.	0.	0.	0.	0.	544.	79.	132.	30.	45.
HORIZ.	0.	0.	0.	0.	0.	2.	17.	35.	42.	35.	17.	2.	0.	0.	0.	0.	0.	149.	32.	46.	18.	22.

MONTH 2 HO 848. TOD 21. TOT 19. KT .503 KD .188

ORIENTATION	HOURLY SOLAR RADIATION 4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	DAILY TOTAL RADIATION	SAG/DAYTIME SATGS	SAG/DAYTIME SATGD	SAG/ALL DAY SATGS	SAG/ALL DAY SATGD
SOUTH	0.	0.	0.	0.	24.	91.	141.	170.	180.	170.	141.	91.	24.	0.	0.	0.	0.	1034.	106.	176.	52.	79.
SOUTHWEST	0.	0.	0.	0.	4.	11.	52.	97.	134.	156.	156.	125.	42.	0.	0.	0.	0.	776.	85.	137.	44.	64.
WEST	0.	0.	0.	0.	4.	11.	16.	20.	21.	61.	89.	91.	37.	0.	0.	0.	0.	351.	50.	74.	30.	39.
NORTHWEST	0.	0.	0.	0.	4.	11.	16.	20.	21.	20.	16.	11.	13.	0.	0.	0.	0.	132.	32.	41.	23.	26.
NORTH	0.	0.	0.	0.	4.	11.	16.	20.	21.	20.	16.	11.	4.	0.	0.	0.	0.	122.	31.	39.	23.	26.
NORTHEAST	0.	0.	0.	0.	13.	11.	16.	20.	21.	20.	16.	11.	4.	0.	0.	0.	0.	132.	32.	41.	23.	26.
EAST	0.	0.	0.	0.	37.	91.	89.	61.	21.	20.	16.	11.	4.	0.	0.	0.	0.	351.	50.	74.	30.	39.
SOUTHEAST	0.	0.	0.	0.	42.	125.	156.	156.	134.	97.	52.	11.	4.	0.	0.	0.	0.	776.	85.	137.	44.	64.
HORIZ.	0.	0.	0.	0.	9.	34.	58.	73.	78.	73.	58.	34.	9.	0.	0.	0.	0.	427.	56.	85.	32.	43.

MONTH 3 HO 1648. TOD 27. TOT 25. KT .000 KD .179

ORIENTATION	HOURLY SOLAR RADIATION 4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	DAILY TOTAL RADIATION	SAG/DAYTIME SATGS	SAG/DAYTIME SATGD	SAG/ALL DAY SATGS	SAG/ALL DAY SATGD
SOUTH	0.	0.	0.	6.	12.	16.	20.	22.	23.	22.	20.	16.	12.	6.	0.	0.	0.	176.	39.	48.	30.	35.
SOUTHWEST	0.	0.	0.	6.	12.	16.	20.	22.	23.	22.	20.	16.	12.	6.	0.	0.	0.	176.	39.	48.	30.	35.
WEST	0.	0.	0.	6.	12.	16.	20.	22.	23.	22.	20.	16.	12.	6.	0.	0.	0.	176.	39.	48.	30.	35.
NORTHWEST	0.	0.	0.	6.	12.	16.	20.	22.	23.	22.	20.	16.	12.	6.	0.	0.	0.	176.	39.	48.	30.	35.
NORTH	0.	0.	0.	6.	12.	16.	20.	22.	23.	22.	20.	16.	12.	6.	0.	0.	0.	176.	39.	48.	30.	35.
NORTHEAST	0.	0.	0.	6.	12.	16.	20.	22.	23.	22.	20.	16.	12.	6.	0.	0.	0.	176.	39.	48.	30.	35.
EAST	0.	0.	0.	6.	12.	16.	20.	22.	23.	22.	20.	16.	12.	6.	0.	0.	0.	176.	39.	48.	30.	35.
SOUTHEAST	0.	0.	0.	6.	12.	16.	20.	22.	23.	22.	20.	16.	12.	6.	0.	0.	0.	176.	39.	48.	30.	35.
HORIZ.	0.	0.	0.	10.	19.	27.	33.	37.	38.	37.	33.	27.	19.	10.	0.	0.	0.	294.	46.	61.	34.	42.

LOCATION MATANUSKA, ALASKA LATITUDE 61 DEGREES 30 MINUTES

MONTH 4 HO 2629. TOD 39. TOT 35. KT .545 KD .182

ORIENTATION	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	DAILY TOTAL RADIATION	SAG/DAYTIME SATGS	SAG/DAYTIME SATGD	SAG/ALL DAY SATGS	SAG/ALL DAY SATGD
	HOURLY SOLAR RADIATION																					
SOUTH	0.	3.	10.	34.	77.	118.	150.	171.	179.	171.	150.	118.	77.	34.	10.	3.	0.	1307.	105.	160.	77.	112.
SOUTHWEST	0.	3.	10	18.	26.	33.	57.	102.	139.	165.	178.	174.	154.	117.	65.	8.	0.	1249.	102.	155.	75.	108.
WEST	0.	3.	10.	18.	26.	33.	38.	41.	42.	86.	123.	148.	156.	142.	96.	15.	0.	978.	89.	129.	67.	92.
NORTHWEST	0.	3.	10.	18.	26.	33.	38.	41.	42.	41.	38.	54.	82.	94.	77.	14.	0.	613.	70.	96.	55.	71.
NORTH	0.	7.	19.	18.	26.	33.	38.	41.	42.	41.	38.	33.	26.	18.	19.	7.	0.	408.	59.	76.	48.	59.
NORTHEAST	0.	14.	77.	94.	82.	54.	38.	41.	42.	41.	38.	33.	26.	18.	10.	3.	0.	613.	70.	96.	55.	71.
EAST	0.	15.	96.	142.	156.	148.	123.	86.	42.	41.	38.	33.	26.	18.	10.	3.	0.	978.	89.	129.	67.	92.
SOUTHEAST	0.	8.	65.	117.	154.	174.	178.	165.	139.	102.	57.	33.	26.	18.	10.	3.	0.	1249.	102.	155.	75.	108.
HORIZ.	0.	6.	30.	63.	97.	126.	148.	163.	168.	163.	148.	126.	97.	63.	30.	6.	0.	1433.	112.	172.	81.	119.

MONTH 5 HO 3393. TOD 50. TOT 46. KT .494 KD .188

ORIENTATION	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	DAILY TOTAL RADIATION	SAG/DAYTIME SATGS	SAG/DAYTIME SATGD	SAG/ALL DAY SATGS	SAG/ALL DAY SATGD
	HOURLY SOLAR RADIATION																					
SOUTH	4.	10.	18.	31.	66.	98.	124.	140.	146.	140.	124.	98.	66.	31.	18.	10.	4.	1127.	103.	143.	84.	114.
SOUTHWEST	4.	10.	18.	25.	33.	39.	52.	87.	117.	138.	148.	147.	133.	107.	73.	36.	7.	1174.	105.	146.	86.	117.
WEST	4.	10.	18.	25.	33.	39.	44.	47.	48.	83.	112.	132.	141.	135.	113.	72.	18.	1073.	100.	138.	82.	111.
NORTHWEST	4.	10.	18.	25.	33.	39.	44.	47.	48.	47.	44.	63.	86.	99.	97.	72.	20.	795.	87.	115.	73.	94.
NORTH	14.	36.	35.	25.	33.	39.	44.	47.	48.	47.	44.	39.	33.	25.	35.	36.	14.	590.	78.	99.	66.	81.
NORTHEAST	20.	72.	97.	99.	86.	63.	44.	47.	48.	47.	44.	39.	33.	25.	18.	10.	4.	795.	87.	115.	73.	94.
EAST	18.	72.	113.	135.	141.	132.	112.	83.	48.	47.	44.	39.	33.	25.	18.	10.	4.	1073.	100.	138.	82.	111.
SOUTHEAST	7.	36.	73.	107.	133.	147.	148.	138.	117.	87.	52.	39.	33.	25.	18.	10.	4.	1174.	105.	146.	86.	117.
HORIZ.	8.	28.	55.	85.	113.	138.	157.	169.	173.	169.	157.	138.	113.	85.	55.	28.	8.	1676.	128.	188.	103.	147.

MONTH 6 HO 3711. TOD 58. TOT 54. KT .466 KD .186

ORIENTATION	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	DAILY TOTAL RADIATION	SAG/DAYTIME SATGS	SAG/DAYTIME SATGD	SAG/ALL DAY SATGS	SAG/ALL DAY SATGD
	HOURLY SOLAR RADIATION																					
SOUTH	7.	13.	20.	29.	60.	89.	112.	127.	132.	127.	112.	89.	60.	29.	20.	13.	7.	1052.	103.	138.	90.	117.
SOUTHWEST	7.	13.	20.	27.	34.	40.	49.	81.	108.	126.	135.	134.	122.	100.	71.	39.	12.	1122.	106.	143.	92.	121.
WEST	7.	13.	20.	27.	34.	40.	45.	47.	48.	79.	106.	124.	132.	128.	110.	79.	36.	1079.	104.	140.	91.	119.
NORTHWEST	7.	13.	20.	27.	34.	40.	45.	47.	48.	47.	45.	65.	85.	97.	97.	80.	43.	845.	94.	122.	83.	105.
NORTH	29.	43.	39.	27.	34.	40.	45.	47.	48.	47.	45.	40.	34.	27.	39.	43.	29.	660.	86.	108.	76.	94.
NORTHEAST	43.	80.	97.	97.	85.	65.	45.	47.	48.	47.	45.	40.	34.	27.	20.	13.	7.	845.	94.	122.	83.	105.
EAST	36.	79.	110.	128.	132.	124.	106.	79.	48.	47.	45.	40.	34.	27.	20.	13.	7.	1079.	104.	140.	91.	119.
SOUTHEAST	12.	39.	71.	100.	122.	134.	135.	126.	108.	81.	49.	40.	34.	27.	20.	13.	7.	1122.	106.	143.	92.	121.
HORIZ.	15.	36.	62.	89.	115.	138.	155.	166.	170.	166.	155.	138.	115.	89.	62.	36.	15.	1730.	132.	189.	113.	158.

LOCATION MATANUSKA, ALASKA LATITUDE 61 DEGREES 30 MINUTES

MONTH 7 HO 3402. TOD 60. TOT 57. KT .434 KD .185

ORIENTATION	HOURLY SOLAR RADIATION																	DAILY TOTAL RADIATION	SAG/DAYTIME		SAG/ALL DAY	
	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20		SATGS	SATGD	SATGS	SATGD
SOUTH	4.	10.	17.	29.	57.	84.	106.	120.	125.	120.	106.	84.	57.	29.	17.	10.	4.	980.	105.	140.	91.	117.
SOUTHWEST	4.	10.	17.	24.	31.	37.	48.	77.	101.	118.	126.	124.	112.	90.	61.	30.	6.	1018.	107.	143.	92.	119.
WEST	4.	10.	17.	24.	31.	37.	41.	44.	45.	73.	97.	113.	119.	113.	93.	59.	15.	935.	103.	136.	89.	114.
NORTHWEST	4.	10.	17.	24.	31.	37.	41.	44.	45.	44.	41.	57.	74.	84.	81.	59.	17.	710.	93.	118.	82.	100.
NORTH	12.	31.	31.	24.	31.	37.	41.	44.	45.	44.	41.	37.	31.	24.	31.	31.	12.	545.	85.	105.	76.	90.
NORTHEAST	17.	59.	81.	84.	74.	57.	41.	44.	45.	44.	41.	37.	31.	24.	17.	10.	4.	710.	93.	118.	82.	100.
EAST	15.	59.	93.	113.	119.	113.	97.	73.	45.	44.	41.	37.	31.	24.	17.	10.	4.	935.	103.	136.	89.	114.
SOUTHEAST	6.	30.	61.	90.	112.	124.	126.	118.	101.	77.	48.	37.	31.	24.	17.	10.	4.	1018.	107.	143.	92.	119.
HORIZ.	8.	25.	49.	75.	99.	121.	137.	148.	151.	148.	137.	121.	99.	75.	49.	25.	8.	1476.	128.	180.	108.	146.

MONTH 8 HO 2615. TOD 58. TOT 56. KT .419 KD .184

ORIENTATION	HOURLY SOLAR RADIATION																	DAILY TOTAL RADIATION	SAG/DAYTIME		SAG/ALL DAY	
	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20		SATGS	SATGD	SATGS	SATGD
SOUTH	0.	3.	10.	27.	56.	84.	107.	122.	127.	122.	107.	84.	56.	27.	10.	3.	0.	945.	110.	149.	88.	113.
SOUTHWEST	0.	3.	10.	17.	24.	30.	47.	76.	101.	118.	125.	121.	105.	79.	43.	6.	0.	903.	107.	145.	86.	110.
WEST	0.	3.	10.	17.	24.	30.	35.	38.	39.	67.	90.	104.	107.	94.	61.	9.	0.	726.	98.	128.	80.	99.
NORTHWEST	0.	3.	10.	17.	24.	30.	35.	38.	39.	38.	35.	44.	60.	64.	50.	9.	0.	494.	85.	106.	72.	85.
NORTH	0.	5.	15.	17.	24.	30.	35.	38.	39.	38.	35.	30.	24.	17.	15.	5.	0.	365.	78.	93.	68.	78.
NORTHEAST	0.	9.	50.	64.	60.	44.	35.	38.	39.	38.	35.	30.	24.	17.	10.	3.	0.	494.	85.	106.	72.	85.
EAST	0.	9.	61.	94.	107.	104.	90.	67.	39.	38.	35.	30.	24.	17.	10.	3.	0.	726.	98.	128.	80.	99.
SOUTHEAST	0.	6.	43.	79.	105.	121.	125.	118.	101.	76.	47.	30.	24.	17.	10.	3.	0.	903.	107.	145.	86.	110.
HORIZ.	0.	5.	24.	49.	74.	96.	113.	124.	127.	124.	113.	96.	74.	49.	24.	5.	0.	1096.	118.	163.	93.	122.

MONTH 9 HO 1653. TOD 50. TOT 48. KT .401 KD .183

ORIENTATION	HOURLY SOLAR RADIATION																	DAILY TOTAL RADIATION	SAG/DAYTIME		SAG/ALL DAY	
	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20		SATGS	SATGD	SATGS	SATGD
SOUTH	0.	0.	0.	16.	48.	79.	104.	120.	125.	120.	104.	79.	48.	16.	0.	0.	0.	859.	108.	153.	77.	100.
SOUTHWEST	0.	0.	0.	7.	14.	20.	44.	73.	97.	113.	118.	109.	85.	42.	0.	0.	0.	723.	99.	136.	73.	92.
WEST	0.	0.	0.	7.	14.	20.	25.	28.	29.	56.	77.	87.	81.	48.	0.	0.	0.	473.	82.	107.	64.	77.
NORTHWEST	0.	0.	0.	7.	14.	20.	25.	28.	29.	28.	25.	26.	38.	29.	0.	0.	0.	269.	68.	82.	57.	64.
NORTH	0.	0.	0.	7.	14.	20.	25.	28.	29.	28.	25.	20.	14.	7.	0.	0.	0.	217.	65.	76.	55.	61.
NORTHEAST	0.	0.	0.	29.	38.	26.	25.	28.	29.	28.	25.	20.	14.	7.	0.	0.	0.	269.	68.	82.	57.	64.
EAST	0.	0.	0.	48.	81.	87.	77.	56.	29.	28.	25.	20.	14.	7.	0.	0.	0.	473.	82.	107.	64.	77.
SOUTHEAST	0.	0.	0.	42.	85.	109.	118.	113.	97.	73.	44.	20.	14.	7.	0.	0.	0.	723.	99.	136.	73.	92.
HORIZ.	0.	0.	1.	16.	39.	61.	78.	89.	93.	89.	78.	61.	39.	16.	1.	0.	0.	662.	95.	129.	71.	88.

LOCATION MATANUSKA, ALASKA   LATITUDE 61 DEGREES 30 MINUTES

MONTH 10   HO 820.   TOD 38.   TOT 36.   KT .390   KD .183

ORIENTATION	HOURLY SOLAR RADIATION																	DAILY TOTAL RADIATION	SAG/DAYTIME		SAG/ALL DAY	
	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20		SATGS	SATGD	SATGS	SATGD
SOUTH	0.	0.	0.	0.	14.	60.	95.	117.	124.	117.	95.	60.	14.	0.	0.	0.	0.	696.	96.	143.	58.	77.
SOUTHWEST	0.	0.	0.	0.	4.	10.	38.	68.	93.	107.	105.	81.	22.	0.	0.	0.	0.	528.	82.	117.	53.	67.
WEST	0.	0.	0.	0.	4.	9.	14.	17.	18.	45.	62.	60.	20.	0.	0.	0.	0.	249.	58.	75.	44.	50.
NORTHWEST	0.	0.	0.	0.	4.	9.	14.	17.	18.	17.	14.	9.	8.	0.	0.	0.	0.	112.	47.	55.	40.	43.
NORTH	0.	0.	0.	0.	4.	9.	14.	17.	18.	17.	14.	9.	4.	0.	0.	0.	0.	107.	47.	54.	39.	42.
NORTHEAST	0.	0.	0.	0.	8.	9.	14.	17.	18.	17.	14.	9.	4.	0.	0.	0.	0.	112.	47.	55.	40.	43.
EAST	0.	0.	0.	0.	29.	60.	62.	45.	18.	17.	14.	9.	4.	0.	0.	0.	0.	249.	58.	75.	44.	50.
SOUTHEAST	0.	0.	0.	0.	22.	81.	105.	107.	93.	68.	38.	10.	4.	0.	0.	0.	0.	528.	82.	117.	53.	67.
HORIZ.	0.	0.	0.	0.	7.	26.	43.	55.	59.	55.	43.	26.	7.	0.	0.	0.	0.	320.	64.	86.	46.	55.

MONTH 11   HO 284.   TOD 23.   TOT 22.   KT .372   KD .182

ORIENTATION	HOURLY SOLAR RADIATION																	DAILY TOTAL RADIATION	SAG/DAYTIME		SAG/ALL DAY	
	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20		SATGS	SATGD	SATGS	SATGD
SOUTH	0.	0.	0.	0.	0.	1.	55.	106.	122.	106.	55.	1.	0.	0.	0.	0.	0.	446.	77.	120.	37.	48.
SOUTHWEST	0.	0.	0.	0.	0.	1.	22.	60.	89.	95.	60.	1.	0.	0.	0.	0.	0.	326.	62.	94.	33.	41.
WEST	0.	0.	0.	0.	0.	1.	5.	8.	9.	33.	32.	1.	0.	0.	0.	0.	0.	88.	34.	42.	25.	27.
NORTHWEST	0.	0.	0.	0.	0.	1.	5.	8.	9.	8.	5.	1.	0.	0.	0.	0.	0.	36.	27.	31.	23.	24.
NORTH	0.	0.	0.	0.	0.	1.	5.	8.	9.	8.	5.	1.	0.	0.	0.	0.	0.	36.	27.	31.	23.	24.
NORTHEAST	0.	0.	0.	0.	0.	1.	5.	8.	9.	8.	5.	1.	0.	0.	0.	0.	0.	36.	27.	31.	23.	24.
EAST	0.	0.	0.	0.	0.	1.	32.	33.	9.	8.	5.	1.	0.	0.	0.	0.	0.	88.	34.	42.	25.	27.
SOUTHEAST	0.	0.	0.	0.	0.	1.	60.	95.	89.	60.	22.	1.	0.	0.	0.	0.	0.	326.	62.	94.	33.	41.
HORIZ.	0.	0.	0.	0.	0.	1.	12.	25.	29.	25.	12.	1.	0.	0.	0.	0.	0.	106.	36.	46.	26.	28.

MONTH 12   HO 131.   TOD 14.   TOT 14.   KT .364   KD .182

ORIENTATION	HOURLY SOLAR RADIATION																	DAILY TOTAL RADIATION	SAG/DAYTIME		SAG/ALL DAY	
	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20		SATGS	SATGD	SATGS	SATGD
SOUTH	0.	0.	0.	0.	0.	0.	6.	89.	127.	89.	6.	0.	0.	0.	0.	0.	0.	316.	63.	104.	24.	32.
SOUTHWEST	0.	0.	0.	0.	0.	0.	3.	50.	91.	79.	6.	0.	0.	0.	0.	0.	0.	229.	50.	79.	21.	27.
WEST	0.	0.	0.	0.	0.	0.	1.	4.	5.	25.	4.	0.	0.	0.	0.	0.	0.	40.	20.	25.	15.	16.
NORTHWEST	0.	0.	0.	0.	0.	0.	1.	4.	5.	4.	1.	0.	0.	0.	0.	0.	0.	17.	17.	19.	14.	15.
NORTH	0.	0.	0.	0.	0.	0.	1.	4.	5.	4.	1.	0.	0.	0.	0.	0.	0.	17.	17.	19.	14.	15.
NORTHEAST	0.	0.	0.	0.	0.	0.	1.	4.	5.	4.	1.	0.	0.	0.	0.	0.	0.	17.	17.	19.	14.	15.
EAST	0.	0.	0.	0.	0.	0.	4.	25.	5.	4.	1.	0.	0.	0.	0.	0.	0.	40.	20.	25.	15.	16.
SOUTHEAST	0.	0.	0.	0.	0.	0.	6.	79.	91.	50.	3.	0.	0.	0.	0.	0.	0.	229.	50.	79.	21.	27.
HORIZ.	0.	0.	0.	0.	0.	0.	3.	12.	18.	12.	3.	0.	0.	0.	0.	0.	0.	48.	21.	28.	15.	17.

TABLE 6
Solar Angle of Incidence on Inclined Surfaces at 56° North Latitude

Date	Solar Time		0°	Solar Angle Of Incidence On Surfaces Tilted With Respect To The Horizontal																								
				46°					56°					66°					76°					90°				
	AM	PM		AM E	SE	S	SW	W	E	SE	S	SW	W	E	SE	S	SW	W	E	SE	S	SW	W	E	SE	S	SW	W
				PM W	SW	S	SE	E	W	SW	S	SE	E	W	SW	S	SE	E	W	SW	S	SE	E	W	SW	S	SE	E
Jan. 21	9	3	85.0	57.4	39.0	53.5	84.2	90.0	53.1	29.1	48.4	84.6	90.0	50.0	19.2	44.5	85.1	90.0	48.2	9.5	42.2	85.7	90.0	48.4	6.0	42.1	86.9	90.0
	10	2	80.1	62.8	37.0	42.1	71.3	90.0	61.0	28.5	35.5	70.8	90.0	60.1	21.2	30.6	71.0	90.0	60.2	16.7	28.2	71.7	90.0	62.0	19.2	30.0	73.7	90.0
	11	1	77.1	70.7	40.6	33.4	59.2	90.0	70.9	34.8	24.8	57.6	90.0	71.7	30.9	17.6	57.1	90.0	73.1	29.7	14.1	57.7	90.0	75.9	32.9	19.3	60.3	90.0
	12		76.0	80.3	48.6	30.0	48.6	80.3	82.2	45.2	20.0	45.2	82.2	84.4	43.5	10.0	43.5	84.4	86.6	43.6	90.0	43.6	86.6	90.0	46.7	14.0	46.7	90.0
Feb. 21	8	4	82.5	45.2	38.5	62.9	90.0	90.0	38.7	29.6	60.5	90.0	90.0	33.6	21.4	59.0	90.0	90.0	30.8	15.5	58.5	90.0	90.0	31.5	16.2	59.6	90.0	90.0
	9	3	75.8	47.8	29.8	49.0	80.8	90.0	44.4	19.8	45.9	82.9	90.0	42.6	9.8	44.3	85.1	90.0	42.7	.9	44.5	87.5	90.0	45.9	14.2	47.6	90.0	90.0
	10	2	70.6	54.2	27.0	35.9	67.1	90.0	53.5	18.9	31.5	68.3	90.0	54.2	13.4	29.5	70.3	90.0	56.1	14.0	30.6	72.9	90.0	60.5	23.5	36.5	77.3	90.0
	11	1	67.2	63.1	31.8	25.0	53.8	85.1	64.6	27.7	18.0	54.1	89.7	67.0	26.5	14.8	55.6	90.0	70.1	28.8	17.6	58.2	90.0	75.2	36.2	27.7	63.5	90.0
	12		66.0	73.6	41.6	20.0	41.6	73.6	76.9	40.3	10.0	40.3	76.9	80.5	40.9	90.0	40.9	80.5	84.4	43.5	10.0	43.5	84.4	90.0	49.8	24.0	49.8	90.0
Mar. 21	7	5	81.7	37.3	45.5	75.2	90.0	90.0	28.1	39.4	75.0	90.0	90.0	19.7	34.8	75.2	90.0	90.0	13.5	32.3	75.9	90.0	90.0	15.0	33.4	77.6	90.0	90.0
	8	4	73.8	35.2	32.3	60.5	90.0	90.0	29.0	24.9	60.0	90.0	90.0	25.2	19.8	60.5	90.0	90.0	24.8	18.9	62.0	90.0	90.0	30.0	25.1	65.5	90.0	90.0
	9	3	66.7	38.4	21.2	45.9	77.7	90.0	36.2	11.7	45.0	81.4	90.0	36.2	4.9	45.9	85.3	90.0	38.6	10.6	48.4	89.3	90.0	45.0	23.9	54.1	90.0	90.0
	10	2	61.0	45.9	17.1	31.5	63.4	90.0	46.7	10.0	30.0	66.5	90.0	49.2	10.3	31.5	70.3	90.0	53.0	17.7	35.5	74.5	90.0	60.0	30.5	44.1	81.1	90.0
	11	1	57.3	55.8	23.9	18.0	49.4	79.1	58.9	22.6	15.0	51.7	85.0	62.9	25.3	18.0	55.3	90.0	67.6	30.9	24.8	59.8	90.0	75.0	41.5	36.8	67.5	90.0
	12		56.0	67.1	35.9	10.0	35.9	67.1	71.8	37.0	90.0	37.0	71.8	76.9	40.3	10.0	40.3	76.9	82.2	45.2	20.0	45.2	82.2	90.0	54.1	34.0	54.1	90.0
Apr. 21	5	7	88.6	45.7	70.5	90.0	90.0	90.0	37.0	67.7	90.0	90.0	90.0	29.0	65.6	90.0	90.0	90.0	22.5	64.3	90.0	90.0	90.0	18.9	63.8	90.0	90.0	90.0
	6	6	80.4	34.9	56.2	88.0	90.0	90.0	25.1	53.0	90.0	90.0	90.0	15.7	51.1	90.0	90.0	90.0	7.8	50.6	90.0	90.0	90.0	11.6	52.2	90.0	90.0	90.0
	7	5	72.0	26.5	41.8	73.5	90.0	90.0	16.9	38.3	75.3	90.0	90.0	8.2	36.9	77.6	90.0	90.0	6.9	37.7	80.2	90.0	90.0	18.9	42.4	84.4	90.0	90.0
	8	4	63.9	23.6	27.5	58.9	88.6	90.0	18.3	23.7	60.7	90.0	90.0	17.4	23.5	63.4	90.0	90.0	21.6	27.1	67.0	90.0	90.0	32.0	36.1	72.9	90.0	90.0
	9	3	56.4	28.0	13.6	44.2	74.5	90.0	27.9	9.4	46.2	80.0	90.0	30.9	13.8	49.7	85.6	90.0	36.3	22.2	54.4	90.0	90.0	46.2	35.3	62.5	90.0	90.0
	10	2	50.1	37.1	5.7	29.5	60.2	84.7	40.1	7.3	32.0	65.3	90.0	44.9	16.5	36.8	71.0	90.0	50.9	26.3	43.2	77.0	90.0	60.7	40.2	53.8	85.9	90.0
	11	1	45.9	48.3	17.4	14.8	45.9	72.5	53.2	21.3	18.9	50.6	79.7	59.0	28.3	26.2	56.4	87.1	65.5	36.6	34.9	62.9	90.0	75.3	49.1	47.8	72.0	90.0
	12		44.4	60.2	31.5	1.6	31.5	60.2	66.5	35.9	11.6	35.9	66.5	73.1	42.0	21.6	42.0	73.1	80.0	49.2	31.6	49.2	80.0	90.0	60.3	45.6	60.3	90.0
May 21	4	8	88.8	53..	82.4	90.0	90.0	90.0	46.7	81.5	90.0	90.0	90.0	41.2	80.9	90.0	90.0	90.0	37.4	80.5	90.0	90.0	90.0	35.5	80.5	90.0	90.0	90.0
	5	7	81.5	40.9	68.6	90.0	90.0	90.0	33.4	67.4	90.0	90.0	90.0	27.2	66.9	90.0	90.0	90.0	23.6	67.1	90.0	90.0	90.0	24.8	68.7	90.0	90.0	90.0
	6	6	73.5	29.2	54.7	86.6	90.0	90.0	20.3	53.3	90.0	90.0	90.0	13.1	53.2	90.0	90.0	90.0	11.4	54.4	90.0	90.0	90.0	20.0	58.0	90.0	90.0	90.0
	7	5	65.2	19.2	40.7	72.6	90.0	90.0	9.2	39.4	75.9	90.0	90.0	1.0	40.2	79.6	90.0	90.0	10.8	43.0	83.6	90.0	90.0	24.8	49.5	89.4	90.0	90.0
	8	4	56.9	15.2	26.6	58.5	86.2	90.0	11.4	26.0	62.0	90.0	90.0	15.1	28.8	66.2	90.0	90.0	22.8	34.3	71.1	90.0	90.0	35.5	44.3	78.6	90.0	90.0
	9	3	49.1	21.1	12.6	44.5	72.5	90.0	23.5	14.8	48.4	79.2	90.0	29.1	21.9	53.5	86.0	90.0	36.6	30.6	59.5	90.0	90.0	48.4	43.6	68.9	90.0	90.0
	10	2	42.4	31.7	3.7	30.6	58.7	79.9	36.6	13.6	35.5	65.1	88.7	43.1	23.6	42.1	72.0	90.0	50.6	33.6	49.6	79.2	90.0	62.0	47.6	61.1	89.5	90.0
	11	1	37.7	43.6	16.5	17.6	44.7	68.0	49.9	23.9	24.8	51.0	76.1	57.0	32.7	33.4	58.2	84.3	64.7	42.0	42.6	65.3	90.0	75.9	55.3	55.9	77.0	90.0
	12		36.0	55.8	30.6	10.0	30.6	55.8	63.1	37.2	20.0	37.2	63.1	70.8	44.9	30.0	44.9	70.8	78.7	53.2	40.0	53.2	78.7	90.0	65.4	54.0	65.4	90.0
June 21	4	8	85.8	51.5	81.5	90.0	90.0	90.0	45.6	81.2	90.0	90.0	90.0	49.9	81.2	90.0	90.0	90.0	37.9	81.4	90.0	90.0	90.0	37.4	82.2	90.0	90.0	90.0
	5	7	78.6	39.3	68.0	90.0	90.0	90.0	32.3	67.4	90.0	90.0	90.0	27.2	67.6	90.0	90.0	90.0	24.8	68.4	90.0	90.0	90.0	27.6	70.7	90.0	90.0	90.0
	6	6	70.7	27.2	54.4	86.0	90.0	90.0	19.1	53.7	90.0	90.0	90.0	13.5	54.3	90.0	90.0	90.0	14.1	56.2	90.0	90.0	90.0	23.4	60.6	90.0	90.0	90.0
	7	5	62.4	16.5	40.6	72.4	90.0	90.0	6.6	40.3	76.3	90.0	90.0	3.9	41.9	80.5	90.0	90.0	13.6	45.4	88.0	90.0	90.0	27.6	52.5	90.0	90.0	90.0
	8	4	54.1	11.8	26.9	58.6	85.2	90.0	9.4	27.6	62.7	90.0	90.0	15.3	31.4	67.5	90.0	90.0	24.1	37.3	72.8	90.0	90.0	37.4	47.7	80.9	90.0	90.0
	9	3	46.2	18.6	13.7	44.9	71.8	89.2	22.3	17.7	49.6	78.9	90.0	29.0	25.3	55.3	86.2	90.0	37.2	34.0	61.7	90.0	90.0	49.6	47.0	71.6	90.0	90.0
	10	2	39.3	29.8	6.8	31.6	58.2	78.0	35.6	16.8	37.4	65.2	87.0	42.8	26.8	44.5	72.5	90.0	50.8	36.8	52.4	80.1	90.0	62.7	50.7	64.1	90.0	90.0
	11	1	34.[illegible]	41.9	17.1	19.6	44.5	66.3	48.8	25.7	27.6	51.5	74.6	56.5	34.9	36.5	59.1	83.2	64.5	44.4	45.8	67.2	90.0	76.3	58.0	59.2	78.8	90.0
	12		32.6	54.2	30.8	13.4	30.8	54.2	61.9	38.1	23.4	38.1	61.9	69.9	46.3	33.4	46.3	69.9	78.2	55.0	43.4	55.0	78.2	90.0	67.6	57.4	67.6	90.0

(Based on data in Table 1, pp. 387, 1972 ASHRAE HANDBOOK OF FUNDAMENTALS; 0% ground reflectance, 1.0 clearness factor)

TABLE 6 (continued)

Date	Solar Time AM	Solar Time PM	Solar Angle Of Incidence On Surfaces Tilted With Respect To The Horizontal: 0°	46°					56°					66°					76°					90°				
	AM			E	SE	S	SW	W	E	SE	S	SW	W	E	SE	S	SW	W	E	SE	S	SW	W	E	SE	S	SW	W
	PM			W	SW	S	SE	E	W	SW	S	SE	E	W	SW	S	SE	E	W	SW	S	SE	E	W	SW	S	SE	E
July 21	4	8	88.	52.8	82.2	90.0	90.0	90.0	46.5	81.4	90.0	90.0	90.0	41.2	80.9	90.0	90.0	90.0	37.5	80.7	90.0	90.0	90.0	35.8	80.8	90.0	90.0	90.0
	5	7	81.9	40.6	68.5	90.0	90.0	90.0	33.2	67.4	90.0	90.0	90.0	27.2	67.0	90.0	90.0	90.0	23.8	67.3	90.0	90.0	90.0	25.3	69.0	90.0	90.0	90.0
	6	6	73.0	28.8	54.6	86.5	90.0	90.0	20.1	53.4	90.0	90.0	90.0	13.2	53.4	90.0	90.0	90.0	11.8	54.7	90.0	90.0	90.0	20.6	58.5	90.0	90.0	90.0
	7	5	64.7	18.7	40.6	72.6	90.0	90.0	8.7	39.5	76.0	90.0	90.0	1.3	40.5	79.8	90.0	90.0	11.3	43.4	83.8	90.0	90.0	25.3	50.0	89.8	90.0	90.0
	8	4	56.4	14.6	26.6	58.5	86.0	90.0	11.0	26.3	62.1	90.0	90.0	15.1	29.3	66.4	90.0	90.0	23.0	34.8	71.4	90.0	90.0	35.8	44.9	79.0	90.0	90.0
	9	3	48.6	20.6	12.7	44.5	72.4	90.0	23.2	15.3	48.6	79.1	90.0	29.1	22.5	53.8	86.0	90.0	36.6	31.2	59.9	90.0	90.0	48.6	44.2	69.4	90.0	90.0
	10	2	41.8	31.3	4.2	30.7	58.6	79.6	36.4	14.2	35.8	65.1	88.4	43.1	24.2	42.5	72.1	90.0	50.6	34.2	50.1	79.3	90.0	62.1	48.2	61.6	89.7	90.0
	11	1	37.1	43.3	16.6	17.9	44.6	67.7	49.7	24.2	25.3	51.1	75.8	56.9	33.1	34.0	58.3	84.1	64.7	42.4	43.2	66.6	90.0	76.0	55.8	56.4	77.3	90.0
	12		35.4	55.5	30.6	10.6	30.6	55.5	62.9	37.3	20.6	37.3	62.9	70.6	45.1	30.6	45.1	70.6	78.6	53.5	40.6	53.5	78.6	90.0	65.8	54.6	65.8	90.0
Aug. 21	5	7	88.0	45.3	70.3	90.0	90.0	90.0	36.7	67.7	90.0	90.0	90.0	28.8	65.7	90.0	90.0	90.0	22.4	64.5	90.0	90.0	90.0	19.3	64.2	90.0	90.0	90.0
	6	6	79.8	34.4	56.0	87.9	90.0	90.0	24.7	53.0	90.0	90.0	90.0	15.3	51.2	90.0	90.0	90.0	7.8	50.9	90.0	90.0	90.0	12.3	52.7	90.0	90.0	90.0
	7	5	71.5	25.9	71.7	73.4	90.0	90.0	16.2	38.4	75.4	90.0	90.0	7.5	37.1	77.8	90.0	90.0	6.9	38.1	80.5	90.0	90.0	19.3	43.0	84.8	90.0	90.0
	8	4	63.3	22.9	27.3	58.8	58.4	90.0	17.6	23.8	60.8	90.0	90.0	17.1	23.9	63.6	90.0	90.0	21.6	27.7	67.3	90.0	90.0	32.2	36.8	73.4	90.0	90.0
	9	3	55.7	27.4	13.3	44.2	74.3	90.0	27.4	9.7	46.3	79.9	90.0	30.7	14.5	50.0	85.7	90.0	36.2	22.9	54.8	90.0	90.0	46.3	36.0	63.0	90.0	90.0
	10	2	49.5	36.6	5.1	29.5	60.1	84.3	39.8	7.6	32.2	65.3	90.0	44.7	17.1	37.2	71.0	90.0	50.9	26.9	43.8	77.2	90.0	60.8	40.8	54.4	86.2	90.0
	11	1	45.2	47.8	17.2	14.9	45.7	72.1	52.9	21.4	19.3	50.6	79.4	58.8	28.6	26.8	56.5	86.8	65.4	37.0	35.5	63.1	90.0	75.4	49.6	48.4	73.1	90.0
	12		43.7	59.9	31.4	2.3	31.4	59.9	66.2	36.0	12.3	36.0	66.2	72.9	42.2	22.3	42.2	72.9	79.9	49.5	32.3	49.5	79.9	90.0	60.8	46.3	60.8	90.0
Sept. 21	7	5	81.7	37.3	45.5	75.2	90.0	90.0	28.1	39.4	75.0	90.0	90.0	19.7	34.8	75.2	90.0	90.0	13.5	32.3	75.9	90.0	90.0	15.0	33.4	77.6	90.0	90.0
	8	4	73.8	35.2	32.3	60.5	90.0	90.0	29.0	24.9	60.0	90.0	90.0	25.2	19.8	60.5	90.0	90.0	24.8	18.9	62.0	90.0	90.0	30.0	25.1	65.5	90.0	90.0
	9	3	66.7	38.4	21.2	45.9	77.7	90.0	36.2	11.7	45.0	81.4	90.0	36.2	4.9	45.9	85.3	90.0	38.6	10.6	48.4	89.3	90.0	45.0	23.9	54.1	90.0	90.0
	10	2	61.0	45.9	17.1	31.5	63.4	90.0	46.7	10.0	30.0	66.5	90.0	49.2	10.3	31.5	70.3	90.0	53.0	17.7	35.5	74.5	90.0	60.0	30.5	44.1	81.1	90.0
	11	1	57.3	5[illegible].8	23.9	18.0	49.4	79.1	58.9	22.6	15.0	51.7	85.0	62.9	25.3	18.0	55.3	90.0	67.6	30.9	24.8	59.8	90.0	75.0	41.5	36.8	67.5	90.0
	12		56.0	67.1	35.9	10.0	35.9	67.1	71.8	37.0	90.0	37.0	71.8	76.9	40.3	10.0	40.3	76.9	82.2	45.2	20.0	45.2	82.2	90.0	54.1	34.0	54.1	90.0
Oct. 21	8	4	82.9	45.7	38.9	63.1	90.0	90.0	39.2	29.9	60.6	90.0	90.0	34.1	21.6	58.9	90.0	90.0	31.1	15.5	58.4	90.0	90.0	31.6	15.8	59.4	90.0	90.0
	9	3	76.2	48.3	30.3	49.2	81.0	90.0	44.8	20.3	46.0	82.9	90.0	43.0	10.3	44.2	85.1	90.0	42.9	0.7	44.3	87.4	90.0	46.0	13.8	47.3	90.0	90.0
	10	2	71.0	54.6	27.5	36.2	67.3	90.0	53.9	19.3	31.6	68.5	90.0	54.5	13.7	29.5	70.3	90.0	56.2	14.0	30.4	72.8	90.0	60.6	23.2	36.1	77.1	90.0
	11	1	67.7	63.4	32.2	25.4	54.1	85.4	64.9	28.0	18.2	54.2	89.9	67.2	26.7	14.8	55.6	90.0	70.2	28.8	17.3	58.2	90.0	75.3	36.0	27.2	63.3	90.0
	12		66.5	73.9	42.0	20.5	42.0	73.9	77.1	40.5	10.5	40.5	77.1	80.7	41.0	0.5	41.0	80.7	84.5	43.5	9.5	43.5	84.5	90.0	49.6	23.5	49.6	90.0
Nov. 21	9	3	84.8	57.2	38.9	53.4	84.2	90.0	52.9	28.9	48.3	84.5	90.0	49.8	19.0	44.4	85.1	90.0	48.1	9.3	42.2	85.8	90.0	48.3	6.1	42.2	86.9	90.0
	10	2	79.9	62.6	36.8	42.0	71.2	90.0	60.8	28.3	35.4	70.8	90.0	59.9	21.0	30.5	71.0	90.0	60.1	16.6	28.2	71.8	90.0	61.9	19.2	30.1	73.0	90.0
	11	1	76.9	70.5	40.4	33.3	59.1	90.0	70.8	34.7	24.7	57.5	90.0	71.6	30.8	17.5	57.0	90.0	73.1	29.7	14.1	57.7	90.0	75.9	33.0	19.5	60.4	90.0
	12		75.8	80.2	48.4	29.8	48.4	80.2	82.1	45.1	19.8	45.1	82.1	84.3	43.4	9.8	43.4	84.3	86.5	43.6	0.2	43.6	86.6	90.0	46.7	14.2	46.7	90.0
Dec. 21	9	3	88.1	60.7	43.3	55.3	85.4	90.0	56.2	32.4	49.6	85.2	90.0	52.7	22.5	44.9	85.1	90.0	50.4	12.9	41.8	85.2	90.0	49.6	4.9	40.5	85.5	90.0
	10	2	83.4	65.8	40.4	44.5	72.9	90.0	63.6	31.9	37.4	71.8	90.0	62.3	24.2	31.6	71.4	90.0	61.8	18.7	28.0	71.5	90.0	62.7	18.7	28.2	72.6	90.0
	11	1	80.5	73.4	43.7	36.5	61.2	90.0	73.2	37.5	27.6	59.0	90.0	73.5	33.0	19.6	57.8	90.0	74.3	30.7	14.3	57.7	90.0	76.3	32.4	16.8	59.4	90.0
	12		79.4	82.7	51.2	33.4	51.2	82.7	84.1	47.3	23.4	47.3	84.1	85.7	44.8	13.5	44.8	85.7	87.5	44.0	3.4	44.0	87.5	90.0	46.0	10.5	46.0	90.0

(Based on data in Table 1, pp. 387, 1972 ASHRAE HANDBOOK OF FUNDAMENTALS; 0% ground reflectance, 1.0 clearness factor)

TABLE 7
Solar Angle of Incidence on Inclined Surfaces at 64° North Latitude

Date	Solar Time		0°	Solar Angle Of Incidence On Surfaces Tilted With Respect To The Horizontal																						
	AM	PM		54°					64°					74°					84°					90°		
				AM E / PM W	SE / SW	S / S	SW / SE	W / E	E / W	SE / SW	S / S	SW / SE	W / E	E / W	SE / SW	S / S	SW / SE	W / E	E / W	SE / SW	S / S	SW / SE	W / E	E / W	SE / SW	S / S	SW / SE	W / E
Jan. 21	10	2	87.2	65.9	36.7	42.1	74.7	90.0	63.6	28.3	35.5	73.6	90.0	62.3	21.2	30.6	72.9	90.0	61.8	17.2	28.2	72.9	90.0	62.0	17.2	28.2	73.1	90.0
	11	1	84.8	75.5	41.9	33.4	62.2	90.0	75.0	36.1	24.8	60.1	90.0	75.0	32.1	17.6	58.9	90.0	75.4	30.7	14.1	58.8	90.0	75.9	31.3	15.0	59.3	90.0
	12		84.0	86.5	50.9	30.0	50.9	86.5	87.4	47.3	20.0	47.3	87.4	88.3	45.2	10.0	45.2	88.3	89.4	44.7	90.0	44.7	89.4	90.0	45.3	6.0	45.3	90.0
Feb. 21	8	4	86.6	43.5	34.9	62.9	90.0	90.0	37.6	26.1	60.5	90.0	90.0	33.2	18.4	59.0	90.0	90.0	31.3	13.9	58.5	90.0	90.0	31.5	14.1	58.8	90.0	90.0
	9	3	81.4	49.4	27.4	49.0	84.8	90.0	46.3	17.4	45.9	86.0	90.0	44.7	7.4	44.3	87.4	90.0	44.9	2.6	44.5	88.9	90.0	45.9	8.6	45.4	89.8	90.0
	10	2	77.4	58.2	26.9	35.9	70.8	90.0	57.4	19.3	31.5	71.5	90.0	57.8	14.6	29.5	72.7	90.0	59.2	15.9	30.6	74.4	90.0	60.5	19.3	32.6	75.7	90.0
	11	1	74.9	68.9	33.7	25.0	57.3	90.0	69.9	29.8	18.0	57.0	90.0	71.5	28.6	14.8	57.9	90.0	73.7	30.5	17.6	59.8	90.0	75.2	33.0	21.4	61.4	90.0
	12		74.0	80.7	44.6	20.0	44.6	80.7	83.1	43.0	10.0	43.0	83.1	85.6	43.2	90.0	43.2	85.6	88.3	45.2	10.0	45.2	88.3	90.0	47.2	16.0	47.2	90.0
Mar. 21	7	5	83.5	32.0	41.2	75.2	90.0	90.0	23.4	35.8	75.0	90.0	90.0	16.3	32.2	75.2-	90.0	90.0	13.5	31.3	75.9	90.0	90.0	15.0	32.1	76.5	90.0	90.0
	8	4	77.3	34.0	28.2	60.5	90.0	90.0	29.0	21.2	60.0	90.0	90.0	26.8	17.3	60.5	90.0	90.0	27.8	18.6	62.0	90.0	90.0	30.0	21.5	63.3	90.0	90.0
	9	3	71.9	41.0	18.1	45.9	81.9	90.0	39.5	8.4	45.0	84.8	90.0	40.1	3.6	45.9	87.9	90.0	42.6	12.4	48.4	90.0	90.0	45.0	18.3	50.5	90.0	90.0
	10	2	67.7	51.1	17.4	31.5	67.5	90.0	52.0	11.8	30.0	69.9	90.0	54.2	13.2	31.5	72.9	90.0	57.5	20.2	35.5	76.4	90.0	60.0	25.3	38.9	78.6	90.0
	11	1	64.9	62.7	26.7	18.0	53.3	87.7	65.3	25.6	15.0	55.0	90.0	68.6	28.0	18.0	57.9	90.0	72.4	33.2	24.8	61.8	90.0	75.0	37.2	29.8	64.5	90.0
	12		64.0	75.1	39.5	10.0	39.5	75.1	78.9	40.2	90.0	40.2	78.9	83.1	43.0	10.0	43.0	83.1	87.4	47.3	20.0	47.3	87.4	90.0	50.5	26.0	50.5	90.0
Apr. 21	5	7	86.0	36.3	66.3	90.0	90.0	90.0	28.2	64.5	90.0	90.0	90.0	21.8	63.4	90.0	90.0	90.0	18.5	63.2	90.0	90.0	90.0	18.9	63.5	90.0	90.0	90.0
	6	6	79.6	26.0	52.0	98.0	90.0	90.0	16.3	49.8	90.0	90.0	90.0	7.5	49.0	90.0	90.0	90.0	6.7	49.8	90.0	90.0	90.0	11.6	50.9	90.0	90.0	90.0
	7	5	73.0	20.4	37.6	73.5	90.0	90.0	11.9	35.1	75.3	90.0	90.0	8.1	35.1	77.6	90.0	90.0	13.7	37.4	80.2	90.0	90.0	18.9	39.8	82.0	90.0	90.0
	8	4	66.7	23.3	23.2	58.9	90.0	90.0	20.6	20.6	60.7	90.0	90.0	22.4	22.3	63.4	90.0	90.0	27.7	27.7	67.0	90.0	90.0	32.0	31.9	69.4	90.0	90.0
	9	3	61.0	32.3	9.4	44.2	78.8	90.0	33.4	7.2	46.2	83.6	90.0	36.9	14.6	49.7	88.5	90.0	42.3	24.0	54.4	90.0	90.0	46.2	29.8	57.7	90.0	90.0
	10	2	56.5	43.9	7.8	29.5	64.5	90.0	47.0	10.9	32.0	68.9	90.0	51.5	19.3	36.8	73.9	90.0	57.0	28.8	43.2	79.2	90.0	60.7	34.6	47.6	82.5	90.0
	11	1	53.5	56.3	21.4	14.8	50.1	81.7	60.7	25.0	18.9	54.2	88.1	65.9	31.3	26.2	59.3	90.0	71.7	39.0	34.9	65.2	90.0	75.3	44.1	40.3	68.9	90.0
	12		52.4	69.0	35.7	1.6	35.7	69.0	74.5	39.6	11.6	39.6	74.5	80.3	45.0	21.6	45.0	80.3	86.3	51.6	31.6	51.6	86.3	90.0	55.9	37.6	55.9	90.0
May 21	4	8	84.2	44.1	78.6	90.0	90.0	90.0	39.1	78.6	90.0	90.0	90.0	35.9	78.9	90.0	90.0	90.0	34.9	79.6	90.0	90.0	90.0	35.5	80.2	90.0	90.0	90.0
	5	7	78.4	31.[illegible]	64.8	90.0	90.0	90.0	25.3	64.5	90.0	90.0	90.0	21.9	65.1	90.0	90.0	90.0	22.5	66.4	90.0	90.0	90.0	24.8	67.6	90.0	90.0	90.0
	6	6	72.1	19.8	50.8	86.6	90.0	90.0	11.7	50.5	90.0	90.0	90.0	8.9	51.6	90.0	90.0	90.0	14.8	54.0	90.0	90.0	90.0	20.0	56.1	90.0	90.0	90.0
	7	5	65.5	12.1	36.7	72.6	90.0	90.0	4.2	36.7	75.9	90.0	90.0	9.4	38.9	79.6	90.0	90.0	18.9	43.1	83.6	90.0	90.0	24.8	46.3	86.1	90.0	90.0
	8	4	59.1	16.2	22.6	58.5	90.0	90.0	17.0	23.7	62.0	90.0	90.0	22.5	28.4	66.2	90.0	90.0	30.3	35.2	71.1	90.0	90.0	35.5	39.8	74.2	90.0	90.0
	9	3	53.2	27.2	8.9	44.5	76.8	90.0	30.7	14.3	48.4	82.9	90.0	36.5	23.0	53.5	89.0	90.0	43.7	32.4	59.5	90.0	90.0	48.4	38.2	63.4	90.0	90.0
	10	2	48.4	39.6	7.3	30.6	63.0	89.4	44.5	16.4	35.5	68.8	90.0	50.6	26.1	42.1	75.0	90.0	57.5	36.0	49.6	81.5	90.0	62.0	42.0	54.4	85.5	90.0
	11	1	45.1	52.3	20.8	17.6	49.0	77.4	58.1	27.5	24.8	54.7	84.8	64.6	35.7	33.4	61.2	90.0	71.6	44.5	42.6	68.2	90.0	75.9	50.0	48.3	72.6	90.0
	12		44.0	65.0	34.9	10.0	34.9	65.0	71.6	40.8	20.0	40.8	71.6	78.6	47.9	30.0	47.9	78.6	85.7	55.7	40.0	55.7	85.7	90.0	60.6	46.0	60.6	90.0
June 21	3	9	85.8	55.4	90.0	90.0	90.0	90.0	52.0	90.0	90.0	90.0	90.0	49.9	90.0	90.0	90.0	90.0	49.2	90.0	90.0	90.0	90.0	49.6	90.0	90.0	90.0	90.0
	4	8	81.0	42.7	77.8	90.0	90.0	90.0	38.5	78.4	90.0	90.0	90.0	36.2	79.4	90.0	90.0	90.0	36.2	80.6	90.0	90.0	90.0	37.4	81.6	90.0	90.0	90.0
	5	7	75.3	30.0	64.3	90.0	90.0	90.0	24.8	64.7	90.0	90.0	90.0	22.8	65.9	90.0	90.0	90.0	24.8	67.9	90.0	90.0	90.0	27.6	69.4	90.0	90.0	90.0
	6	6	69.0	17.7	50.6	86.0	90.0	90.0	11.1	51.0	90.0	90.0	90.0	11.3	52.9	90.0	90.0	90.0	18.2	56.0	90.0	90.0	90.0	23.4	58.3	90.0	90.0	90.0
	7	5	62.5	8.8	36.8	72.4	90.0	90.0	2.7	37.8	76.3	90.0	90.0	11.7	40.9	80.5	90.0	90.0	21.6	45.7	85.0	90.0	90.0	27.6	49.1	87.8	90.0	90.0
	8	4	56.0	13.8	23.2	58.6	89.4	90.0	16.5	25.7	62.7	90.0	90.0	23.4	31.2	67.5	90.0	90.0	31.9	38.3	72.8	90.0	90.0	37.4	43.1	76.2	90.0	90.0
	9	3	50.1	25.6	10.8	44.9	76.1	90.0	30.2	17.6	49.6	82.6	90.0	36.8	26.4	55.3	89.2	90.0	44.6	35.8	61.7	90.0	90.0	49.6	41.6	65.9	90.0	90.0
	10	2	45.1	38.2	9.6	31.6	62.5	87.5	43.8	19.3	37.4	68.8	90.0	50.5	29.2	44.5	75.5	90.0	58.0	39.1	52.4	82.5	90.0	62.7	45.1	57.3	86.7	90.0
	11	1	41.7	50.9	21.5	19.6	48.8	75.7	57.3	29.2	27.6	55.1	83.5	64.3	37.8	36.5	62.2	90.0	71.7	47.0	45.8	69.6	90.0	76.3	52.6	51.5	74.2	90.0
	12		40.6	63.5	35.1	13.5	35.1	63.5	70.5	43.7	23.4	41.7	70.5	77.9	49.4	33.4	49.4	77.9	85.4	57.5	43.4	57.5	85.4	90.0	62.6	49.4	62.6	90.0

(Based on data in Table 1, pp. 387, 1972 ASHRAE HANDBOOK OF FUNDAMENTALS; 0% ground reflectance, 1.0 clearness factor)

TABLE 7 (continued)

Date	Solar Time AM PM	0°	Solar Angle Of Incidence On Surfaces Tilted With Respect To The Horizontal																								
			54°					64°					74°					84°					90°				
			AM E	SE	S	SW	W	E	SE	S	SW	W	E	SE	S	SW	W	E	SE	S	SW	W	E	SE	S	SW	W
			PM W	SW	S	SE	E	W	SW	S	SE	E	W	SW	S	SE	E	W	SW	S	SE	E	W	SW	S	SE	E
July 21	4 8	83.6	43.9	78.5	90.0	90.0	90.0	39.0	78.5	90.0	90.0	90.0	35.9	79.0	90.0	90.0	90.0	35.1	79.8	90.0	90.0	90.0	35.8	80.4	90.0	90.0	90.0
	5 7	77.9	31.2	64.7	90.0	90.0	90.0	25.2	64.5	90.0	90.0	90.0	22.0	65.2	90.0	90.0	90.0	22.9	66.7	90.0	90.0	90.0	25.3	67.9	90.0	90.0	90.0
	6 6	71.6	19.4	50.7	86.5	90.0	90.0	11.5	50.5	90.0	90.0	90.0	9.3	51.8	90.0	90.0	90.0	15.4	54.3	90.0	90.0	90.0	20.6	56.4	90.0	90.0	90.0
	7 5	65.0	11.5	36.7	72.6	90.0	90.0	3.8	36.9	76.0	90.0	90.0	9.7	39.3	79.8	90.0	90.0	19.4	43.6	83.8	90.0	90.0	25.3	46.8	86.4	90.0	90.0
	8 4	58.6	15.8	22.7	58.5	90.0	90.0	16.8	24.1	62.1	90.0	90.0	22.6	28.9	66.4	90.0	90.0	30.6	35.7	71.4	90.0	90.0	35.8	40.4	74.5	90.0	90.0
	9 3	52.7	26.9	9.2	44.5	76.7	90.0	30.6	14.9	48.6	82.8	90.0	36.5	23.6	53.8	89.0	90.0	43.8	33.0	59.9	90.0	90.0	48.6	38.8	63.9	90.0	90.0
	10 2	47.8	39.3	7.7	30.7	62.9	89.1	44.4	16.9	35.8	68.8	90.0	50.6	26.7	42.5	75.1	90.0	57.6	36.6	50.1	81.7	90.0	62.1	42.5	54.9	85.7	90.0
	11 1	44.6	52.1	20.9	17.9	48.9	77.1	58.0	27.8	25.3	54.8	84.6	64.6	36.0	34.0	61.4	90.0	71.6	44.9	43.2	68.5	90.0	76.0	50.4	48.8	72.9	90.0
	12	43.4	64.7	34.9	10.6	34.9	64.7	71.4	41.0	20.6	41.0	71.4	78.4	48.1	30.6	48.1	78.4	85.6	56.0	40.6	56.0	85.6	90.0	60.9	46.6	60.9	90.0
Aug. 21	5 7	85.4	35.8	66.2	90.0	90.0	90.0	27.9	64.4	90.0	90.0	90.0	21.7	63.5	90.0	90.0	90.0	18.7	63.5	90.0	90.0	90.0	19.3	63.9	90.0	90.0	90.0
	6 6	79.0	25.4	51.8	87.9	90.0	90.0	15.8	49.8	90.0	90.0	90.0	7.3	49.2	90.0	90.0	90.0	7.4	50.1	90.0	90.0	90.0	12.3	51.3	90.0	90.0	90.0
	7 5	72.4	19.7	37.4	73.4	90.0	90.0	11.3	35.2	75.4	90.0	90.0	7.9	35.3	77.8	90.0	90.0	14.0	37.9	80.5	90.0	90.0	19.3	40.4	82.3	90.0	90.0
	8 4	66.1	22.6	23.0	58.8	90.0	90.0	20.2	20.7	60.8	90.0	90.0	22.3	22.8	63.6	90.0	90.0	27.9	28.3	67.3	90.0	90.0	32.2	32.6	69.8	90.0	90.0
	9 3	60.4	31.8	9.0	44.2	78.6	90.0	33.1	7.7	46.3	83.5	90.0	36.8	15.3	50.0	88.6	90.0	42.4	24.7	54.8	90.0	90.0	46.3	30.5	58.2	90.0	90.0
	10 2	55.8	41.5	7.4	29.5	64.4	90.0	46.7	11.2	32.2	68.9	90.0	51.3	19.9	37.2	74.0	90.0	57.0	29.4	43.8	79.4	90.0	60.8	35.2	48.2	82.7	90.0
	11 1	52.8	55.9	21.2	14.9	50.0	81.3	60.5	25.1	19.3	54.2	87.8	65.8	31.6	26.8	59.5	90.0	71.7	39.5	35.5	65.4	90.0	75.4	44.6	41.0	69.2	90.0
	12	51.7	68.6	35.6	2.3	35.6	68.6	74.2	39.6	12.3	39.6	74.2	80.2	45.2	22.3	45.2	80.2	86.3	51.9	32.3	51.9	86.3	90.0	56.3	38.3	56.3	90.0
Sept. 21	7 5	83.5	32.0	41.2	75.2	90.0	90.0	23.4	35.8	75.0	90.0	90.0	16.3	32.2	75.2	90.0	90.0	13.5	31.3	75.9	90.0	90.0	15.0	32.1	76.5	90.0	90.0
	8 4	77.3	34.0	28.2	60.5	90.0	90.0	29.0	21.2	60.0	90.0	90.0	26.8	17.3	60.5	90.0	90.0	27.8	18.6	62.0	90.0	90.0	30.0	21.5	63.3	90.0	90.0
	9 3	71.9	41.0	18.1	45.9	81.9	90.0	39.5	8.4	45.0	84.8	90.0	40.1	3.6	45.9	87.9	90.0	42.6	12.4	48.4	90.0	90.0	45.0	18.3	50.5	90.0	90.0
	10 2	67.7	51.1	17.4	31.5	67.5	90.0	52.0	11.8	30.0	69.9	90.0	54.2	13.2	31.5	72.9	90.0	57.5	20.2	35.5	76.4	90.0	60.0	25.3	38.9	78.6	90.0
	11 1	64.9	62.7	26.7	18.0	53.3	87.7	65.3	25.6	15.0	55.0	90.0	68.6	28.0	18.0	57.9	90.0	72.4	33.2	24.8	61.8	90.0	75.0	37.2	29.8	64.5	90.0
	12	64.0	75.	39.5	10.0	39.5	75.1	78.9	40.2	90.0	40.2	78.9	83.1	43.0	10.0	43.0	83.1	87.4	47.3	20.0	47.3	87.4	90.0	50.5	26.0	50.5	90.0
Oct. 21	8 4	87.0	44.0	35.3	61.1	90.0	90.0	38.0	26.4	60.6	90.0	90.0	33.6	18.6	58.9	90.0	90.0	31.5	13.8	58.4	90.0	90.0	31.6	13.8	58.5	90.0	90.0
	9 3	81.9	49.8	27.9	49.2	84.9	90.0	46.6	17.9	46.0	86.1	90.0	45.0	7.9	44.2	87.4	90.0	45.1	2.1	44.3	88.8	90.0	46.0	8.1	45.2	89.6	90.0
	10 2	77.9	58.6	27.4	36.2	71.0	90.0	57.7	19.7	31.6	71.5	90.0	58.0	14.9	29.5	72.7	90.0	59.3	15.8	30.4	74.3	90.0	60.6	19.0	32.3	75.5	90.0
	11 1	75.4	69.2	34.1	25.4	57.5	90.0	70.2	30.0	18.2	57.2	90.0	71.7	28.7	14.8	57.9	90.0	73.8	30.5	17.3	59.7	90.0	75.3	32.9	21.0	61.3	90.0
	12	74.5	81.0	44.9	20.5	44.9	81.0	83.3	43.1	10.5	43.1	83.3	85.8	43.2	0.5	43.2	85.8	88.4	45.1	9.5	45.1	88.4	90.0	47.0	15.5	47.0	90.0
Nov. 21	10 2	87.0	65.7	36.5	42.0	74.6	90.0	63.5	28.1	35.4	73.5	90.0	62.2	21.1	30.5	72.9	90.0	61.7	17.1	28.2	72.9	90.0	61.9	17.2	28.3	73.1	90.0
	11 1	84.6	75.4	41.7	33.3	62.1	90.0	74.9	36.0	24.7	60.0	90.0	74.9	32.1	17.5	58.9	90.0	75.4	30.7	14.1	56.8	90.0	75.9	31.3	15.1	59.3	90.0
	12	83.8	86.4	50.8	29.8	50.8	86.4	87.3	47.2	19.8	47.2	87.3	88.3	45.1	9.8	45.1	88.3	89.4	44.7	0.2	44.7	89.4	90.0	45.3	6.2	45.3	90.0
Dec. 21	11 1	88.2	77.9	44.8	36.5	64.0	90.0	76.9	38.6	27.6	61.3	90.0	76.3	33.9	19.6	59.5	90.0	76.2	31.5	14.3	58.7	90.0	76.3	31.3	13.9	58.8	90.0
	12	87.4	88.5	53.3	33.4	53.3	88.5	88.9	49.1	23.4	49.1	88.9	89.3	46.3	13.5	46.3	89.3	89.7	45.0	3.4	45.0	89.7	90.0	45.1	2.5	45.1	90.0

(Based on data in Table 1, pp. 387, 1972 ASHRAE HANDBOOK OF FUNDAMENTALS; 0% ground reflectance, 1.0 clearness factor)

APPENDIX C
SURVEY RESULTS

As an element of this study, four surveys were made in order to determine the present characteristics of the Alaskan marketplace for solar energy. The groups surveyed were: (1) mechanical contracting establishments, (2) plumbing and heating equipment suppliers, (3) banking institutions, and (4) consulting engineers and architects. The addresses of the surveyed establishments were obtained from the Alaska Petroleum and Industrial Directory and the Fairbanks and Anchorage telephone directories.

The results are tabulated on the questionnaire sheets which follow. Many interesting conclusions can be drawn from the survey. All groups expressed a strong need for more information concerning solar space and hot-water heating design and economic information in Alaska. An overwhelming majority of respondents did not know that at present a 10% tax credit exists in Alaska for installation of nonfossil fuel alternative sources of energy. (At present, however, the tax credit statute, AK 49.20, is tied up in litigation and may not be allowed for the 1977 tax year.)

A majority of respondents said they did not know where or if they could get solar energy information or equipment. A few plumbing supply companies said they had been approached by wholesalers as to the availability of solar equipment, but 16 out of the 22 who responded said they had never been approached about solar energy equipment. Most commercial (mechanical contractors and plumbing supply) companies wanted to be involved in marketing solar heating equipment (15 out of 23) but were cautious and expressed a need for more economic information or felt that at the present they were too uninformed to decide about entering the solar market (11 out of 33).

As to deterrents, the engineers and architects rated the high cost of solar equipment as the number-one deterrent to its use and the lack of solar energy second. Plumbing supply companies felt that the lack of information was the greatest deterrent to the use of solar energy, and that the lack of solar energy was second. The response was the same for the mechanical contractors. Bankers felt that lack of information was also the greatest deterrent, but that lack of experience was next in importance. Each of the deterrents listed was rated first by someone, but generally lack of public interest and the public's attitude were not rated highly as deterrents. There was general support from the respondents for both technical workshops on solar energy design and applications (86 of 97) and for codes and certification programs for solar equipment (75 of 97), both supported with the qualification that they should be done if solar energy applications prove economically feasible in Alaska.

Percentage of responses were excellent. Each respondent was sent an explanatory letter, a questionnaire and a stamped self-addressed envelope from the Institute of Water Resources. The responses by group were as follows (Table 8).

TABLE 8
Survey Results

Group	Surveys sent	# of Responses	% Responses
Engineers and Architects	103	64	62
Plumbing Supply Companies	33	23	69
Mechanical Contractors	33	11	33
Banking Institutions	17	6	35

Comments from respondents are included after each survey tally.

INSTITUTE OF WATER RESOURCES

UNIVERSITY OF ALASKA
COLLEGE, ALASKA 99701

October 20, 1977

Dear Fellow Alaskan,

Recently a federal program has been initiated to assess the potential of solar energy use in the western United States, Alaska, a member state of the western region, has been asked to determine its solar energy utilization potential and state of solar development. As part of this effort, we need your input as an architectural/engineering firm. In order to make your reply easier and less time consuming, we have included a questionnaire concerning the information we would like to know. Please fill out this questionnaire and return it to us in the self-addressed stamped envelope enclosed. Any further comments you may have concerning solar energy in Alaska are welcome, and please add them at the end of the questionnaire. At the conclusion of the study we will send you a final report summarizing our work. We appreciate your time and consideration.

Sincerely,

Richard Seifert
Richard D. Seifert
Research Associate
Institute of Water Resources

John P. Zarling
John P. Zarling
Assoc. Prof. of Mechanical Engineering

RDS/JPZ/sa

PLEASE REPLY BY AIRMAIL

ENGINEERS AND ARCHITECTS
QUESTIONNAIRE RESULTS

1. Have you ever considered the use of passive or active solar heating in building design?

   33 YES 31 NO

2. Are you able to get access to solar energy equipment information in Alaska?

   22 YES 10 NO 32 DON'T KNOW

3. What is your company's present attitude toward the use of solar energy as a source for domestic water/space heating in Alaska? (More than one answer may be appropriate.)

   40 Need to know more about solar engineering
   16 Don't know enough to decide
   1 Not interested in solar possibilities
   44 Need more economic information
   ___ Other (explain) Need demonstration project for owner information

4. What do you see as the major deterrent(s) to solar energy use in Alaska? (Please rank these with 1 the greatest deterrent, 2 next most important deterrent, etc.)

   5th Lack of detailed information
   3rd Lack of experience
   4th Lack of public interest
   6th Public attitude
   2nd Lack of adequate solar energy
   1st High cost of solar equipment
   ___ Other (please list)

5. Are you aware of any present solar energy systems or applications operating in Alaska?

   5 YES 56 NO

   If yes, where and who owns/operates it? ___

6. If solar energy becomes economically feasible, do you feel there is a need for

   a) Technical workshops on solar energy design and applications

      59 YES 2 NO

   b) Codes and certification programs for solar equipment

      45 YES 11 NO

7. Are you aware that present Alaska law allows a 10% tax credit per year for installation of nonfossil fuel alternative sources of energy?

   10 YES 54 NO

Comments:

Cloudy 50% of time, hard to justify expense (Anchorage).

Have serious questions about the economic feasibility of solar energy in Northern Regions such as Alaska.

It will involve a higher first cost; we believe it is worth it. Still hard to pay for at first.

Am considering [solar] use in my residence, to be built next summer.

Need information related to knowledge of Alaskan environment.

Are solar systems reliable?

Have doubts about economic viability at present energy costs.

Am participating in solar energy designs of several of our projects.

Storage difficulty over long periods of time.

PLUMBING CONTRACTORS
QUESTIONNAIRE RESULTS

1. Has your company had any experience with solar energy systems or installations?

 1 YES 22 NO

2. Have you been approached by wholesalers as to the availability of solar equipment?

 6 YES 16 NO

3. Are you able to get access to solar equipment in Alaska should a job specify it?

 11 YES 1 NO 11 DON'T KNOW

4. What is your company's present attitude toward the solar energy market potential in Alaska? (More than one answer may be appropriate)

 15 Want to be involved
 7 Don't know enough to decide
 0 Not interested
 10 Need more economic information
 ____ Other (explain) ______

5. What do you see as the major deterrent(s) to solar energy use in Alaska? (Please rank these with 1 the greatest deterrent, 2 next most important deterrent, etc.)

 1st Lack of information
 3rd Lack of experience
 5th Lack of public interest
 6th Public attitude
 2nd Lack of adequate solar energy
 4th High cost of solar equipment
 ____ Other (please list) ______

6. Are you aware of any present solar energy systems or applications operating in Alaska?

 2 YES 21 NO

 If yes, where and who owns/operates it? ______

7. If solar energy becomes economically feasible, do you feel there is a need for

 a) Training programs for installers of solar equipment

 17 YES 5 NO

 b) Codes and certification programs for solar equipment

 21 YES 0 NO

Comments:

Solar must be proven before private money will invest.

Systems will probably be too costly at present energy rates.

Need basic information on solar energy.

Present low cost of energy makes solar noncompetitive.

Limited application economically.

I am most interested in anything I can find out about applying solar energy to Alaskan purposes.

MECHANICAL CONTRACTORS QUESTIONNAIRE RESULTS

1. Have you ever considered the use of passive or active solar heating in building design?

   _1_ YES   _10_ NO

2. Are you able to get access to solar energy equipment information in Alaska?

   _2_ YES   _3_ NO   _6_ DON'T KNOW

3. What is your company's present attitude toward the use of solar energy as a source for domestic water/space heating in Alaska? (More than one answer may be appropriate)

   _7_ Need to know more about solar engineering

   _4_ Don't know enough to decide

   _1_ Not interested in solar possibilities

   _5_ Need more economic information

   ____ Other (explain) ____________________

4. What do you see as the major deterrent(s) to solar energy use in Alaska? (Please rank these with 1 the greatest deterrent, 2 next most important deterrent, etc.)

   _1st_ Lack of detailed information   _2nd_ Lack of adequate solar energy

   _3rd_ Lack of experience   _4th_ High cost of solar equipment

   _5th_ Lack of public interest   ____ Other (please list)

   _6th_ Public attitude

5. Are you aware of any present solar energy systems or applications operating in Alaska?

   _3_ YES   _7_ NO

   If yes, where and who owns/operates it? ____________________

6. If solar energy becomes economically feasible, do you feel there is a need for

   a) Technical workshops on solar energy design and applications

      _10_ YES   _0_ NO

   b) Codes and certification programs for solar equipment

      _9_ YES   _0_ NO

7. Are you aware that present Alaska law allows a 10% tax credit per year for installation of nonfossil fuel alternative sources of energy?

   _2_ YES   _9_ NO

Comments:

No sunlight in winter.

Is our area a practical one for solar heat?

Banking Institutions
QUESTIONNAIRE RESULTS

1. Have you ever been approached about a loan for the use of a passive or active solar heating system in an Alaskan home?

   1 YES   5 NO

2. Are you able to get access to solar energy economic information in Alaska?

   1 YES   ___ NO   5 DON'T KNOW

3. What is your bank's present attitude toward the use of solar energy as a source for domestic water/space heating in Alaska? (More than one answer may be appropriate)

   5 Need to know more about solar engineering possibilities
   4 Don't know enough to decide
   ___ Not interested in loaning for solar energy applications
   2 Need more economic information
   ___ Other (explain) ___

4. What do you see as the major deterrent(s) to solar energy use in Alaska? (Please rank these with 1 the greatest deterrent, 2 next most important deterrent, etc.)

   1st Lack of detailed information
   2nd Lack of experience
   4th Lack of public interest
   7th Public attitude
   6th Lack of adequate solar energy
   5th High cost of solar equipment
   3rd Economic uncertainty as to its value in Alaska
   ___ Other (please list) ___

5. Are you aware that present Alaska law allows a 10% tax credit per year for installation of nonfossil fuel alternative sources of energy?

   2 YES   4 NO

6. Will this tax credit provide a further incentive for you to loan money for solar energy applications?

   1 YES   5 NO   If no, please explain ___

Comments:

Depends on marketability of loans.

Don't know.

Tax credit would accrue to individual, not lender.