THE PASSIVE SOLAR HOUSE

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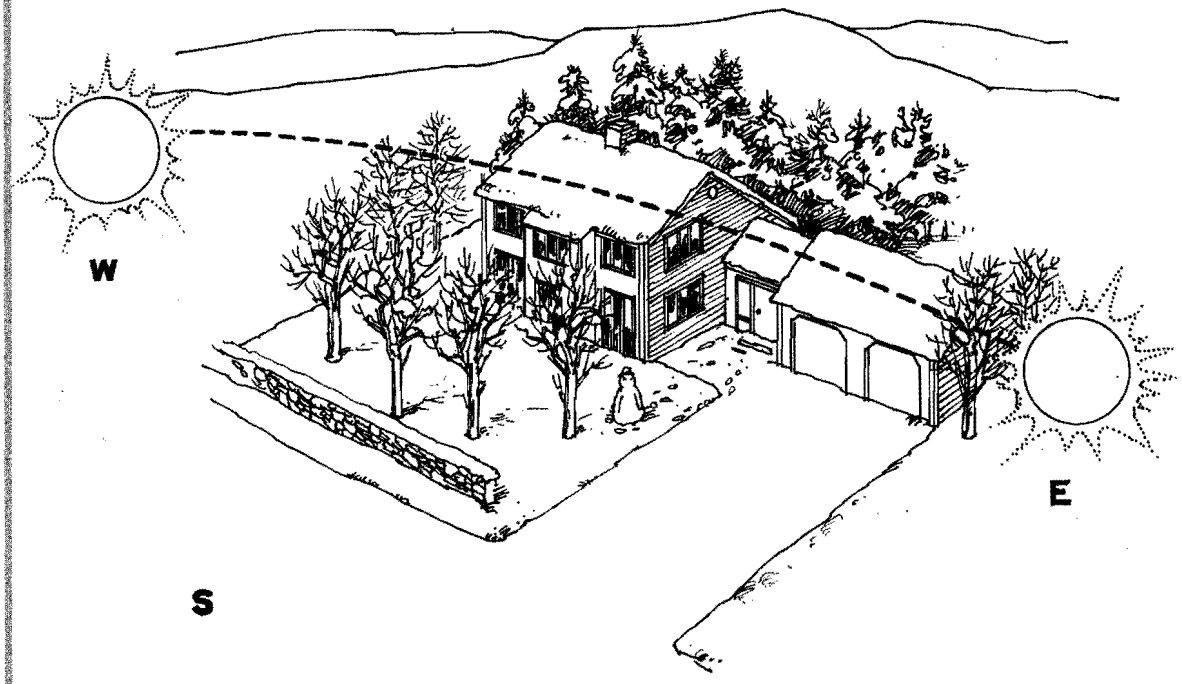
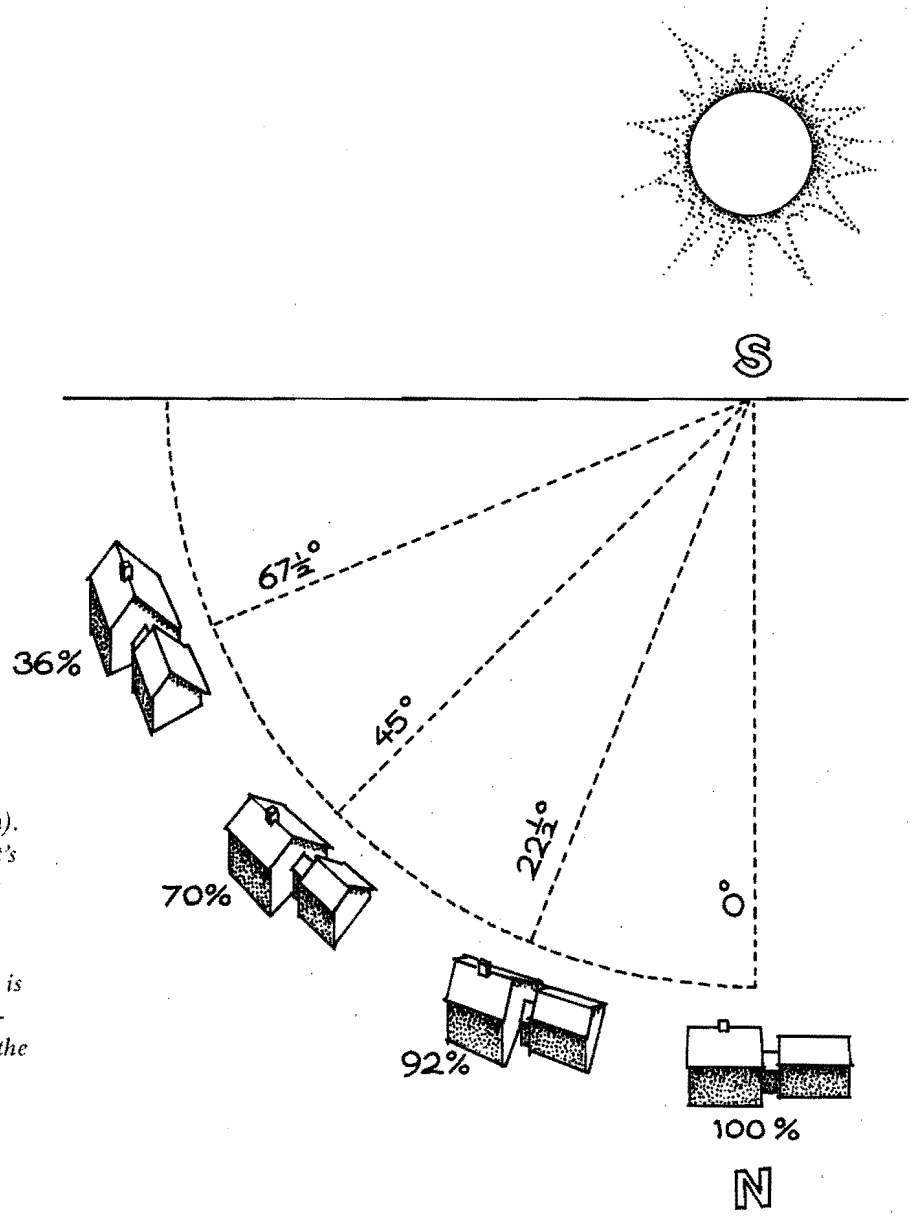
Not long after, Lea was working in her mother's grape arbor and noticed a stranger approaching. He had seen an ad for Green Mountain Homes in a magazine, but the return address was to our home, not our factory/model-home complex nearby. The gentleman explained that he had spent most of the day looking for Green Mountain Homes and had finally stopped at the post office for help. Since ours is a small town, the postmaster knew about our new venture and sent the gentleman to my mother-in-law's home. By coincidence, Lea happened to be there. It turned out that the gentleman was a graduate of Worcester Polytechnic Institute, and was most supportive of our new solar home business.

Solar Principle #1

Orient the house properly with respect to the sun's relationship to the site.

Use a compass to find true south, and then by careful observation site the house so that it can utilize the sun's rays from the east, south, and west during as much of the day and year as possible. In orienting the house, take into account features of the landscape, including trees and natural land forms, which will buffer the house against harsher weather or winds from the north. Deciduous trees on the sunny sides of the site will shade the house from excess heat during the summer months, but will allow the winter sunlight to reach the house and deliver free solar energy.





The ideal orientation for a solar house is with its long axis perpendicular to true south (or 0° on the diagram). Because of various factors, it's sometimes necessary to shift the orientation somewhat. Within 20 degrees of true south, the cost in solar gain is minimal, but as the orientation shifts more drastically, the house will significantly lose solar benefits.

KNOW YOUR SITE

Spend some time on your proposed home site. Try camping on the site to learn about its sun conditions in different seasons. Make a point of being on the site at sunrise and sunset at different times of the year. Develop a sense for which direction the prevailing wind comes from. Use your imagination in order to picture the view from each room. Mark the footprint of your new home on the ground, and develop a "feel" for what each room will be like after the home is constructed. In addition to solar orientation, consider access, view, wind direction,

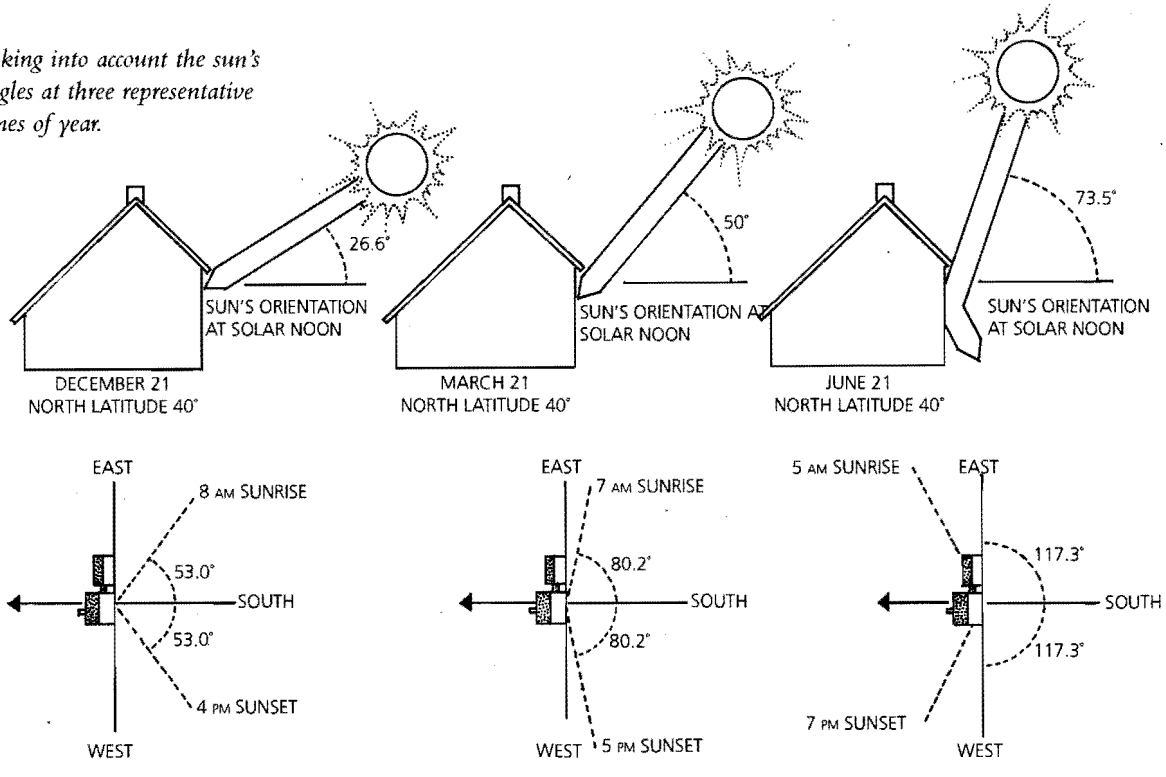
USE WINDOWS AND PATIO DOORS AS SOLAR COLLECTORS

If you locate the majority of the windows and patio doors on the east, south, and west elevations of the home, they can act as solar collectors. One often sees pictures of solar homes with huge expanses of south-facing glass tilted to be perpendicular to the sun rays. Let's remember that you want your home to be comfortable all year-round. Tilted glass, though technically favorable during certain heating months, is very detrimental in summer. One has to design on a 12-month basis, and understand where the sun is at each time of the year, in order to comprehend how the sun may be most beneficial to your home.

The diagram below shows the sun's angles at three different times of the year—December 21, March 21, and June 21, at north latitude 40 degrees (see also Appendix 2). We can see in December that the sun's low altitude almost directly strikes the south-facing vertical glass, which demonstrates again the importance of facing a home true south.

The March 21 and June 21 illustrations show that as the days grow longer, the breadth of solar aperture widens, meaning that a home will gain more solar heat and light from its eastern and western windows. Meanwhile, the altitude of solar noon rises to 50.0 degrees on March 21 and 73.5 degrees on June 21.

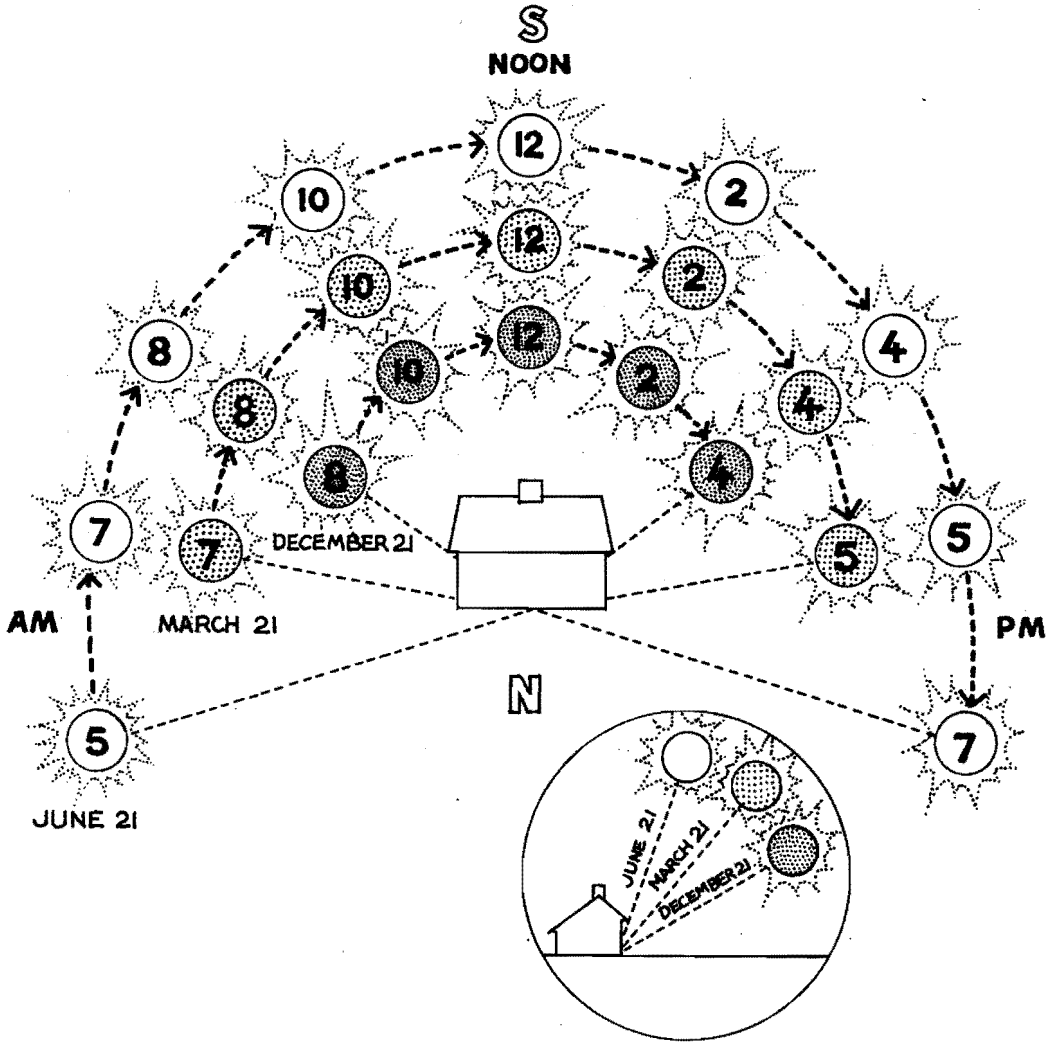
Taking into account the sun's angles at three representative times of year.



Solar Principle # 2

Design on a 12-month basis.

A home must be comfortable in summer as well as winter. When designing a solar home, carefully plan to accommodate and benefit from the sun's shifting patterns and other natural, seasonal cycles. Before finalizing a building plan, spend time at the site at different times of day and year, and pay attention to the sun, wind, and weather.



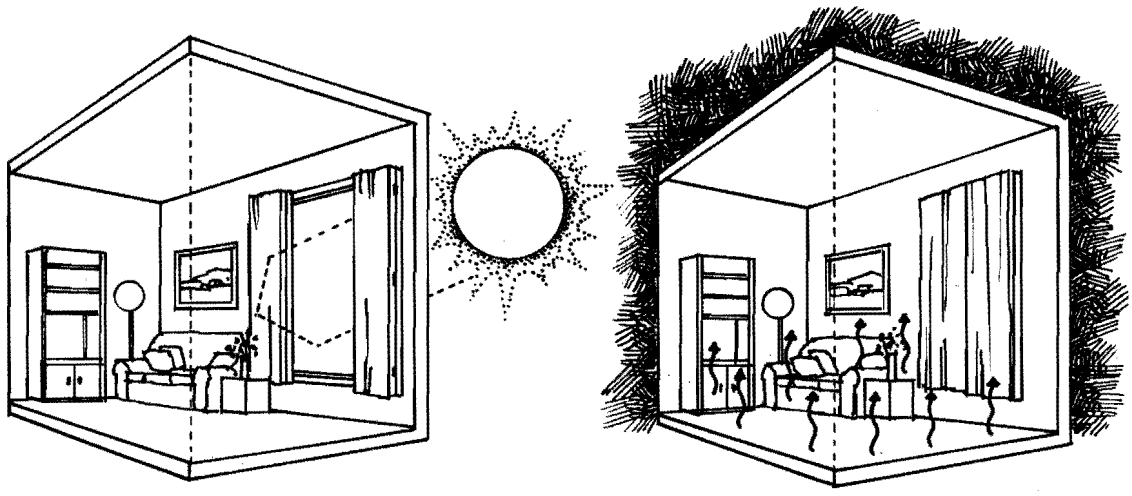
In addition, we also installed a device to measure the incoming solar energy (insolation).

All energy consumed by the building was documented. Meters measured the electricity consumed by the furnace and the second floor blower as well as the electricity used for all other purposes. A fuel meter was installed to measure the number of gallons of oil consumed by the furnace.

Solar Principle # 3

Provide effective thermal mass to store free solar heat in the daytime for nighttime use.

When sunlight strikes surfaces, the solar energy is converted from light to heat. Design a home's thermal mass to effectively absorb the warmth of sunlight as it enters the building in winter, thereby avoiding overheating. Achieve thermal balance by sizing the storage capacity of the thermal mass to provide for the heating needs of the building through the night. In summer, a properly sized thermal mass will serve to cool the building because of "thermal lag" — that is, excess heat will be absorbed during the daylight hours, and by the time the mass has heated up, the day is over and that stored heat can be discharged by opening windows to increase circulation during the night.

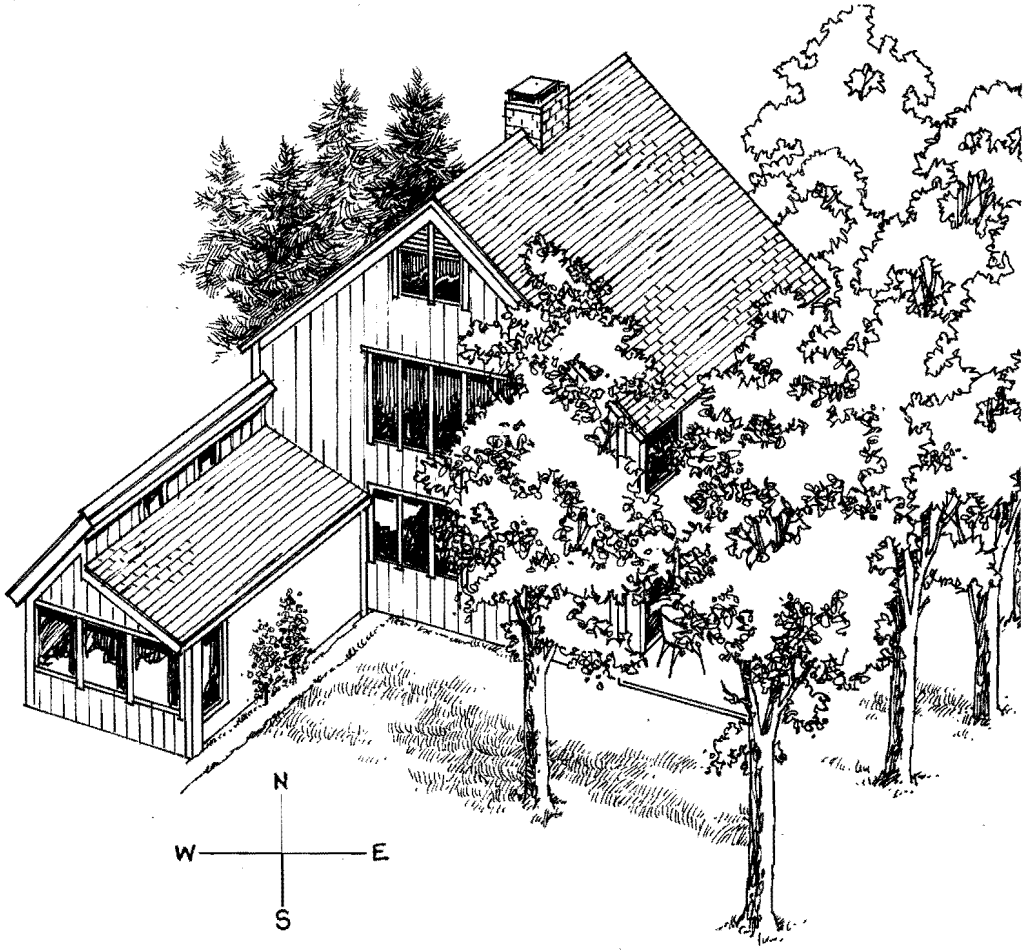


Solar Principle # 5

5

Utilize windows as solar collectors and cooling devices.

This idea sounds obvious, but many people overlook the obvious and spend large amounts of money purchasing, fueling, and maintaining furnaces and air-conditioners to address needs that high-quality windows can also address. Vertical, south-facing glass is especially effective for collecting solar heat in the winter when a home needs additional heat, whereas the same windows will let in much less heat in summer, because the sun's angle is more horizontal in winter and steeper in summer. Provide insulated window and patio door coverings to decrease nighttime heat loss in winter, and to control solar gain in spring, summer, and fall. Windows that open can be used to release excess heat and direct cooling breezes into the house.



too much of the sun's heat from entering the house. High-Performance Low-E glass with diminished values of SC most probably will be best used in passive solar homes located in the south or central climate zone, where cooling is of equal or greater concern than heating.

Readers are advised to find out the values of SC and U-Value for the windows and patio doors they plan to use in their design. For Pella Windows go to: http://pellaadm.com/HTML/search.html?shade%20coef

Test computer runs should be made using the CSOL program with the different options available, and the SC and U-Value that yield the best results should be used in the design.

Simply stated: Glass with a low SC value prevents too much of the sun's heat from entering a northern solar home. Be sure to find out the SC of your glazing.

Another consideration, which may be counterproductive, is the Department of Energy and the Environmental Protection Agency Energy Star program. U-Values for glass are published for four climate zones in the United States. The Northern Zone specifies a U-Value equal to or less than 0.35. As stated above, Andersen's Air-Filled Dual-Pane Glass produced favorable results in our solar home example calculation, but this window has a U-Value greater than 0.35 (0.48). This could present a problem if a lender requires that the new home meet the Energy Star program's guidelines.

The SHGF also assumes atmospheric clarity of 1.00 (see the map on page 68). If your location is high in elevation and has dry and clear atmosphere, the SHGF may be increased up to 15 percent. Conversely, if the location is hazy and humid, the SHGF should be reduced. To illustrate the calculation, I will use the figures for the September Solar Heat Gains.

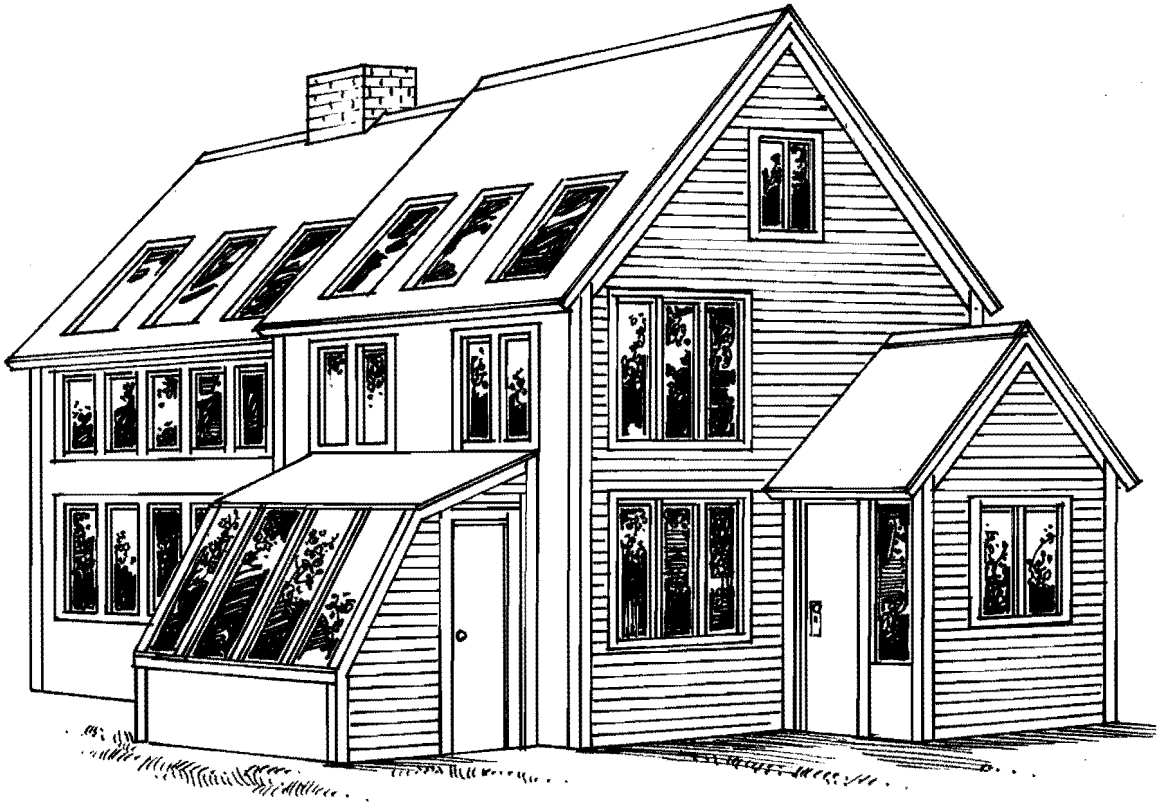
TABLE 6–7
SOLAR HEAT GAIN FACTORS
FOR 40 DEGREES NORTH LATITUDE

Month	% Sun	Days	East	South	West
Sep	57	30	787	1,344	787
Oct	55	31	623	1,582	623
Nov	46	30	445	1,596	445
Dec	46	31	374	1,114	374
Jan	46	31	452	1,626	452
Feb	55	28	648	1,642	648
Mar	56	31	832	1,388	832
Apr	54	30	957	976	957
May	57	31	1,024	716	1,024

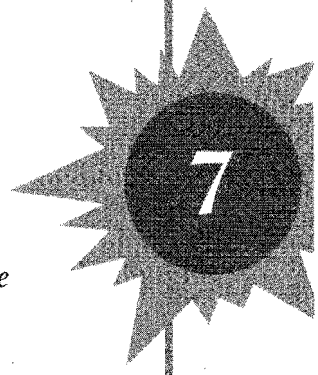
Solar Principle # 6

Do not over-glaze.

Incorporate enough windows to provide plenty of daylight, but do not make the mistake of assuming that solar heating requires extraordinary allocations of wall space to glass. An over-glazed building, as shown below, will probably overheat. A highly insulated and well-constructed home with a proper number and distribution of high-quality windows does not need much energy to maintain comfortable temperatures year-round.

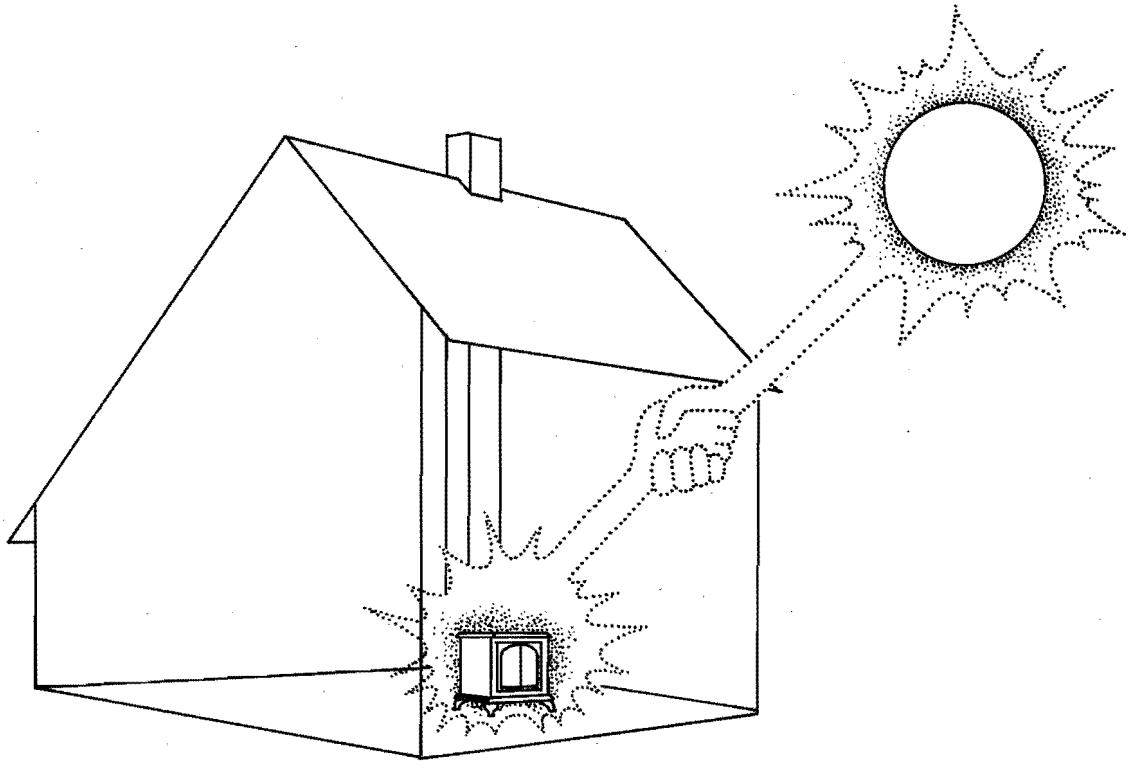


Solar Principle # 7



Consider the contribution of solar energy (indicated by insolation values for your region) and natural processes (including breezes and shade) to the heating and cooling of the home, in order to avoid oversizing a backup heating system or air conditioner. A home that is oriented to true south, is tightly constructed and well insulated, and has operable windows for air circulation should not require large fossil-fuel burning equipment to maintain thermal comfort.

Size the conventional backup systems to suit the small, day-to-day heating and cooling needs of the home. Do not oversize backup oil or gas furnaces, as they are inefficient, cycling on and off, when not supplying heat at their full potential. Air conditioners are likewise expensive and wasteful when operated inefficiently.



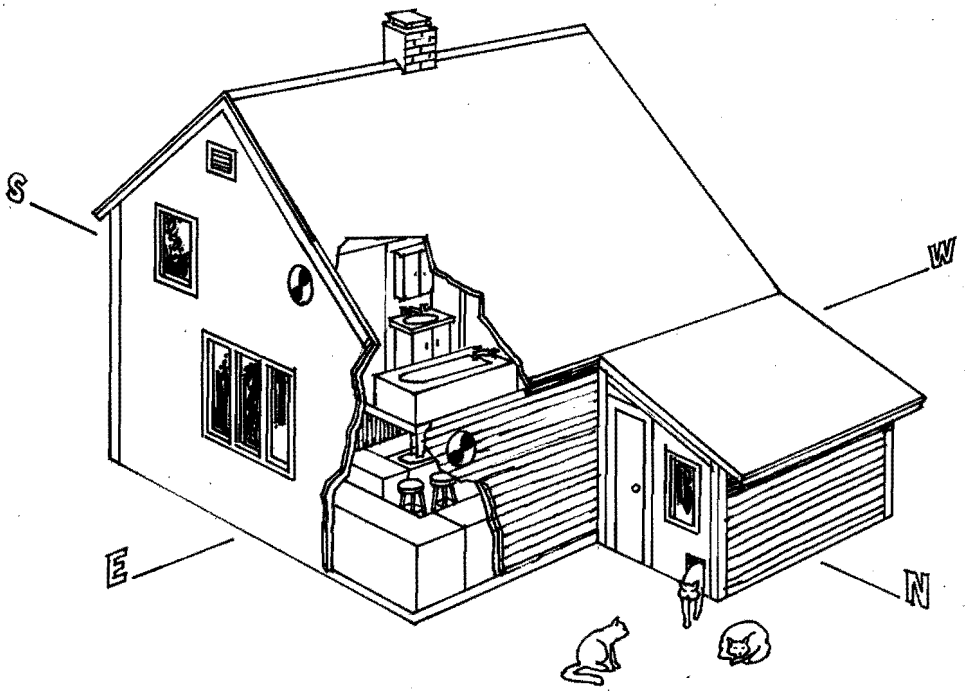
3. Work toward the goal of keeping the conventional furnace and air conditioner switched off by using alternative backup fuels and free solar heat.

A 2,085-square-foot home burning 431 gallons of oil per year in Ann Arbor, Michigan, doesn't sound as good as the same kind of home burning 249 gallons of oil per year in Cheyenne, Wyoming, which is a colder place. And yet, if you live in Michigan, then you did the best you could with the solar energy available to you. That 431 gallons of

Solar Principle # 8

Provide fresh air to the home without compromising thermal integrity.

To maintain a high level of indoor air quality, a well-insulated and tightly constructed home needs a continual supply of fresh air equivalent to replacing no less than ⅔ of the building's total volume of air every hour. This exchange of air should occur through intended openings, for instance an exterior-wall fan in both the kitchen and bathroom, rather than through leakage around poorly sealed doors and windows.

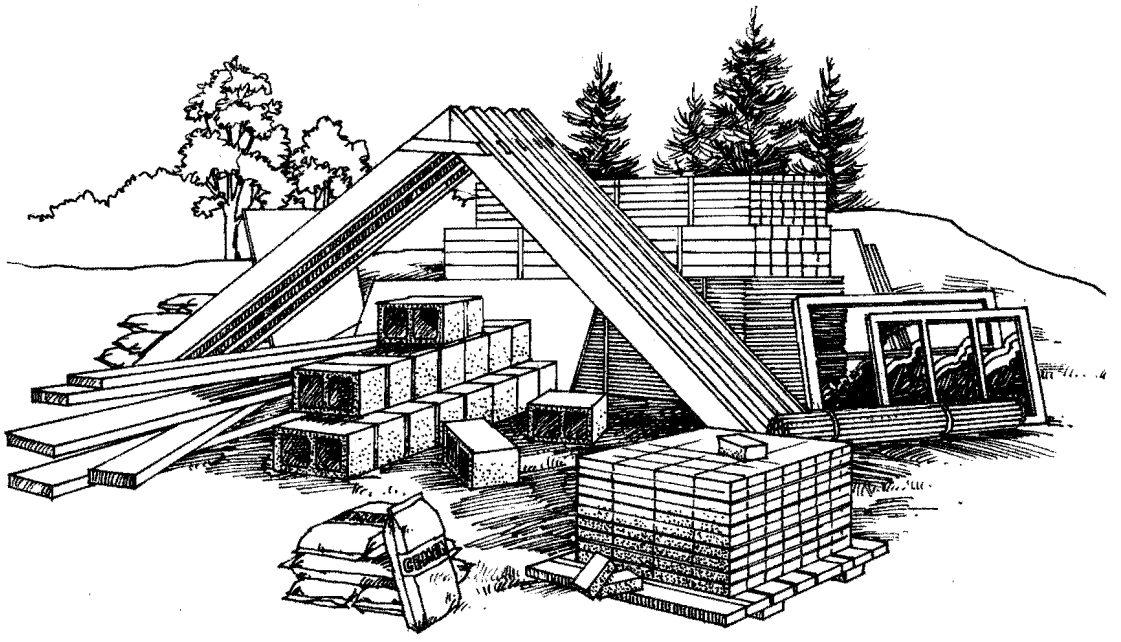


Sometimes energy goals requirements appear to conflict. A library, for example, needs to provide a high degree of quality lighting to meet standards; but these lights give off excess heat. By circulating the air that has been warmed with already purchased electric-light energy through the Solar Slab, heat can be stored for later use rather than vented to the outside.

Solar Principle # 9

Use the materials you would use for a conventional home, but in ways that maximize energy efficiency and solar gain.

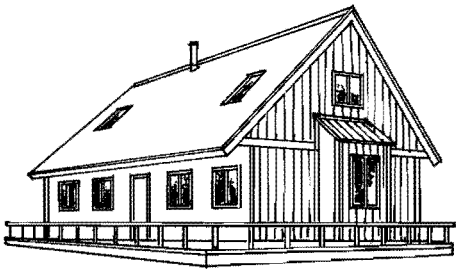
With exactly the same construction materials, it is possible to build an energy-efficient, sunny, and easy-to-maintain solar home or a energy-gluttonous, dark, and costly-to-maintain house. When designing a solar home, rearrange and reallocate materials to serve dual functions - adding solar benefits as well as addressing architectural or aesthetic goals. Placing a majority of the home's windows on the south side is an example. The carefully designed and constructed solar home need not cost any more to build than a comparably sized non-solar conventional home.

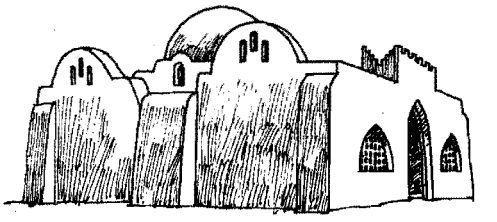


Solar Principle # 10

Remember that the principles of solar design are compatible with diverse styles of architecture and building techniques.

Solar homes need not look experimental or futuristic, nor do they require complicated, expensive, and hard-to-maintain gadgetry to function well and be comfortable year-round. In solar design, good planning and sensitivity to the surrounding environment are worth far more than special technologies or equipment.





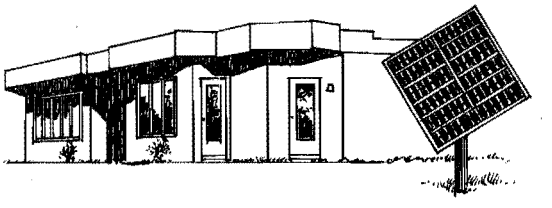


Table 16 Solar Intensity (E_{DN}) and Solar Heat Gain Factors (SHGF) for 48° North Latitude

Date	Solar Time	Direct Normal Btu/(h·ft²)	Solar Heat Gain Factors, Btu/(h·ft²) N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	Hor.	Solar Time
Jan	0800	37	1	1	4	18	29	34	35	30	20	6	1	1	1	1	1	1	2	1600
	0900	185	8	8	8	53	118	160	176	166	129	69	10	8	8	8	8	8	25	1500
	1000	239	12	12	12	22	106	175	216	223	195	136	50	12	12	12	12	12	55	1400
	1100	261	14	14	14	15	53	144	208	239	233	190	116	26	14	14	14	14	77	1300
	1200	267	15	15	15	15	16	86	171	226	245	226	171	86	16	15	15	15	85	1200
HALF DAY TOTALS			43	43	46	117	316	567	729	776	701	512	259	85	43	43	43	43	203	
Feb	0700	4	0	0	1	3	3	3	3	2	1	0	0	0	0	0	0	0	0	1700
	0800	180	8	8	36	103	149	170	166	136	82	17	8	8	8	8	8	8	25	1600
	0900	247	13	13	16	90	168	216	230	209	155	71	14	13	13	13	13	13	66	1500
	1000	275	17	17	17	38	131	203	242	244	207	138	44	18	17	17	17	17	105	1400
	1100	288	19	19	19	20	65	158	221	249	239	192	113	27	19	19	19	19	130	1300
	1200	292	20	20	20	20	22	89	176	231	250	231	176	89	22	20	20	20	138	1200
HALF DAY TOTALS			68	68	107	274	541	816	968	967	813	531	261	104	68	68	68	68	395	
Mar	0700	153	7	22	80	123	145	145	123	80	23	7	7	7	7	7	7	7	20	1700
	0800	236	14	15	76	154	204	222	206	158	82	15	14	14	14	14	14	14	68	1600
	0900	270	19	19	3	121	193	234	239	207	142	52	20	19	19	19	19	19	118	1500
	1000	287	23	23	24	58	146	208	237	231	189	115	33	23	23	23	23	23	156	1400
	1100	295	25	25	25	26	74	156	210	232	218	172	94	28	25	25	25	25	180	1300
	1200	298	26	26	26	26	27	83	161	211	228	211	161	83	27	26	26	26	188	1200
HALF DAY TOTALS			100	118	250	494	775	1012	1100	1014	767	465	244	126	101	100	100	100	636	
Apr	0600	108	12	53	86	105	107	93	64	23	6	6	6	6	6	6	6	6	15	1800
	0700	205	15	61	132	180	199	189	148	84	18	14	14	14	14	14	14	14	60	1700
	0800	247	20	32	111	179	219	225	196	138	55	21	20	20	20	20	20	20	114	1600
	0900	268	25	26	60	141	197	223	215	176	106	33	25	25	25	25	25	25	161	1500
	1000	280	28	28	31	77	148	193	209	194	150	80	31	28	28	28	28	28	196	1400
	1100	286	31	31	31	33	78	140	181	193	177	133	69	33	31	31	31	31	218	1300
	1200	288	31	31	31	31	34	71	131	172	186	172	131	71	34	31	31	31	226	1200
HALF DAY TOTALS			147	242	461	724	957	1098	1081	895	605	370	226	156	141	140	140	140	875	
May	0500	41	17	31	40	42	39	29	14	3	3	3	3	3	3	3	3	3	5	1900
	0600	162	35	97	141	162	160	133	85	24	12	12	12	12	12	12	12	13	40	1800
	0700	219	23	90	158	200	212	191	142	68	21	19	19	19	19	19	19	19	91	1700
	0800	248	26	54	132	190	218	214	178	113	38	25	25	25	25	25	25	25	142	1600
	0900	264	29	32	82	151	194	208	192	147	77	32	29	29	29	29	29	29	185	1500
	1000	274	33	34	39	90	145	178	184	163	116	57	35	33	33	33	33	33	219	1400
	1100	279	35	35	36	40	79	126	155	160	142	101	54	37	35	35	35	35	240	1300
	1200	280	35	35	35	36	38	63	107	139	150	139	107	63	38	36	35	35	247	1200
HALF DAY TOTALS			215	388	645	893	1065	1114	1007	749	483	316	225	184	174	173	173	174	1045	
Jun	0500	77	35	61	76	80	72	53	24	6	5	5	5	5	5	5	5	8	12	1900
	0600	172	46	110	155	175	169	138	84	22	14	14	14	14	14	14	14	16	51	1800
	0700	220	29	101	165	204	211	187	135	60	23	21	21	21	21	21	21	21	103	1700
	0800	246	29	64	139	191	215	206	168	101	34	27	27	27	27	27	27	27	152	1600
	0900	261	31	36	91	153	190	199	180	133	66	33	31	31	31	31	31	31	193	1500
	1000	269	34	36	45	94	143	169	171	148	101	50	36	34	34	34	34	34	225	1400
	1100	274	36	36	38	44	79	118	142	145	126	88	49	38	36	36	36	36	246	1300
	1200	275	37	37	37	38	40	60	96	124	134	124	96	60	40	38	37	37	252	1200
HALF DAY TOTALS			257	459	722	955	1095	1102	955	678	436	299	228	197	189	188	188	191	1108	
Jul	0500	43	18	33	42	45	41	30	15	3	3	3	3	3	3	3	3	4	6	1900
	0600	156	37	96	138	159	156	129	82	24	13	13	13	13	13	13	13	14	41	1800
	0700	211	25	90	156	196	207	186	138	66	22	20	20	20	20	20	20	20	92	1700
	0800	240	27	56	132	187	214	209	174	110	38	26	26	26	26	26	26	26	142	1600
	0900	256	30	34	83	149	191	204	187	143	75	33	30	30	30	30	30	30	184	1500
	1000	266	34	35	41	90	143	174	180	158	113	56	36	34	34	34	34	34	217	1400
	1100	271	36	36	37	42	79	124	151	156	138	99	54	38	36	36	36	36	237	1300
	1200	272	36	36	36	37	39	63	104	136	146	136	104	63	39	37	36	36	244	1200
HALF DAY TOTALS			223	395	646	886	1050	1092	983	730	474	315	229	190	181	179	179	180	1042	
Aug	0600	99	13	51	81	98	100	87	60	22	7	7	7	7	7	7	7	7	16	1800
	0700	190	17	61	128	172	190	179	141	79	19	15	15	15	15	15	15	15	61	1700
	0800	232	22	34	110	174	211	216	188	132	53	23	22	22	22	22	22	22	114	1600
	0900	154	27	28	63	139	192	216	108	169	102	34	27	27	27	27	27	27	159	1500
	1000	266	30	30	33	78	145	188	203	188	144	78	33	30	30	30	30	30	193	1400
	1100	272	32	32	32	36	78	137	175	187	171	129	68	35	32	32	32	32	215	1300
	1200	274	33	33	33	33	36	71	128	167	189	167	128	71	36	33	33	33	223	1200
HALF DAY TOTALS			157	251	459	709	929	1060	1040	862	587	366	231	165	151	149	149	149	869	
Sep	0700	131	8	21	71	108	128	128	108	71	21	8	7	7	7	7	7	7	20	1700
	0800	215	15	16	72	144	191	207	193	148	77	16	15	15	15	15	15	15	65	1600
	0900	251	20	20	34	116	184	223	227	197	136	52	21	20	20	20	20	20	114	1500
	1000	269	24	24	25	58	141	200	228	221	182	112	34	24	24	24	24	24	151	1400
	1100	278	26	26	26	28	73	151	203	223	210	166	92	29	26	26	26	26	174	1300
	1200	280	27	27	27	27	29	82	156	204	220	204	156	82	29	27	27	27	182	1200
HALF DAY TOTALS			105	121	240	465	729	953	1040	963	737	453	243	131	106	105	105	105	614	
Oct	0700	4	0	0	2	3	4	4	3	2	1	0	0	0	0	0	0	0	0	1700
	0800	165	8	9	35	96	139	159	155	126	77	16	8	8	8	8	8	8	25	1600
	0900	233	14	14	16	88	161	207	220	199	148	68	15	14	14	14	14	14	66	1500
	1000	262	18	18	18	39	128	196	233	234	199	133	43	18	18	18	18	18	104	1400
	1100	274	20	20	20	21	64	153	213	241	231	186	109	27	20	20	20	20	128	1300
	1200	278	21	21	21	21	23	87	171	223	242	223	171	87	23	21	21	21	136	1200
HALF DAY TOTALS			71	71	108	266	519	780	925	925	779	513	256	106	72	71	71	71	391	
Nov	0800	36	1	1	4	18	29	34	35	30	20	6	1	1	1	1	1	1	2	1600
	0900	179	8	8	9	52	115	156	171	161	125	67	10	8	8	8	8	8	26	1500
	1000	233	12	12	12	22	104	172	212	218	191	133	49	13	12	12	12	12	55	1400
	1100	255	15	15	15	15	52	142	204	234	228	186	114	26	15	15	15	15	77	1300
	1200	261	15	15	15	15	17	85	168	222	240	222	168	85	17	15	15	15	85	1200
HALF DAY TOTALS			44	44	47	117	310	555	713	760	686	502	255	85	44	44	44	44	204	
Dec	0900	140	5	5	6	36	86	120	133	127	100	56	8	5	5	5	5	5	13	1500
	1000	214	10	10	10	16	91	156	194	201	179	126	49	10	10	10	10	10	38	1400
	1100	242	12	12	12	13	46	134	195	225	220	180	111	25	12	12	12	12	57	1300
	1200	250	13	13	13	13	14	81	163	215	233	215	168	81	14	13	13	13	65	1200
HALF DAY TOTALS			33	33	34	73	233	458	610	665	616	468	247	76	34	33	33	33	141	

	N	NNW	NW	WNW	W	WSW	SW	SSW	S	SSE	SE	ESE	E	ENE	NE	NNE	Hor.	PM

Notes: 1. Clearness number = 1.00; Ground reflectance = 0.20. 2. Figures shown are for 21st day of each month.