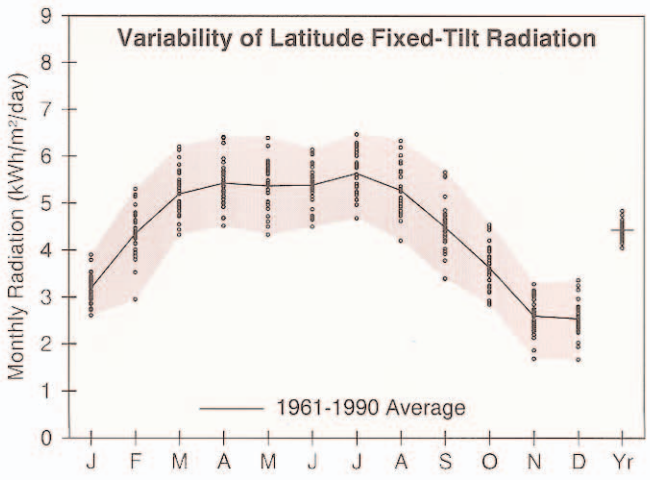


Duluth, MN

WBAN NO. 14913

LATITUDE: 46.83° N
LONGITUDE: 92.18° W
ELEVATION: 432 meters
MEAN PRESSURE: 964 millibars

STATION TYPE: Secondary

Solar Radiation for Flat-Plate Collectors Facing South at a Fixed Tilt (kWh/m²/day), Uncertainty ±9%

Tilt (°)		Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Year
0	Average	1.6	2.6	3.8	4.8	5.6	6.0	6.1	5.1	3.7	2.5	1.5	1.2	3.7
	Min/Max	1.5/1.8	2.1/2.9	3.3/4.4	4.2/5.5	4.6/6.6	5.1/6.8	5.1/6.8	4.2/5.9	3.0/4.4	2.1/2.9	1.3/1.7	1.0/1.5	3.5/4.0
Latitude -15	Average	2.8	4.0	5.0	5.5	5.7	5.9	6.1	5.5	4.5	3.4	2.4	2.2	4.4
	Min/Max	2.3/3.4	2.8/4.7	4.2/5.9	4.7/6.5	4.6/6.8	4.9/6.7	5.1/7.0	4.4/6.6	3.4/5.6	2.7/4.2	1.6/2.9	1.5/2.9	4.1/4.8
Latitude	Average	3.2	4.4	5.2	5.4	5.4	5.4	5.6	5.3	4.5	3.6	2.6	2.5	4.4
	Min/Max	2.6/3.9	3.0/5.3	4.3/6.2	4.5/6.4	4.3/6.4	4.5/6.1	4.7/6.5	4.2/6.3	3.4/5.7	2.8/4.5	1.7/3.3	1.7/3.4	4.0/4.8
Latitude +15	Average	3.4	4.5	5.2	5.1	4.7	4.7	4.9	4.8	4.3	3.6	2.7	2.7	4.2
	Min/Max	2.8/4.2	3.0/5.6	4.3/6.2	4.2/6.1	3.8/5.6	3.9/5.3	4.1/5.6	3.8/5.7	3.2/5.4	2.8/4.6	1.7/3.4	1.8/3.7	3.9/4.6
90	Average	3.4	4.3	4.6	3.9	3.0	2.9	3.0	3.2	3.3	3.1	2.5	2.7	3.3
	Min/Max	2.7/4.2	2.8/5.3	3.8/5.6	3.0/4.8	2.5/3.5	2.5/3.1	2.6/3.4	2.6/3.9	2.4/4.2	2.3/3.9	1.5/3.2	1.7/3.7	3.0/3.6

Solar Radiation for 1-Axis Tracking Flat-Plate Collectors with a North-South Axis (kWh/m²/day), Uncertainty ±9%

Axis Tilt (°)		Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Year
0	Average	2.4	3.8	5.4	6.6	7.4	7.8	8.1	6.9	5.1	3.4	2.1	1.9	5.1
	Min/Max	2.0/2.9	2.6/4.6	4.4/6.4	5.5/8.1	5.4/9.1	6.2/9.4	6.6/9.4	5.4/8.5	3.8/6.4	2.7/4.3	1.5/2.7	1.2/2.4	4.6/5.7
Latitude -15	Average	3.3	4.9	6.3	7.2	7.6	7.9	8.3	7.3	5.7	4.2	2.7	2.6	5.7
	Min/Max	2.7/4.1	3.2/6.0	5.1/7.6	6.0/8.9	5.6/9.5	6.2/9.5	6.7/9.7	5.6/9.1	4.1/7.3	3.2/5.3	1.7/3.6	1.7/3.5	5.1/6.4
Latitude	Average	3.7	5.2	6.5	7.1	7.4	7.6	8.0	7.2	5.7	4.3	2.9	2.9	5.7
	Min/Max	2.9/4.5	3.3/6.4	5.2/7.8	5.9/8.9	5.4/9.2	5.9/9.1	6.4/9.4	5.5/8.9	4.1/7.4	3.2/5.6	1.8/3.8	1.8/3.9	5.1/6.4
Latitude +15	Average	3.8	5.3	6.5	6.9	7.0	7.1	7.5	6.8	5.5	4.3	3.0	3.0	5.6
	Min/Max	3.0/4.8	3.3/6.6	5.1/7.8	5.7/8.6	5.0/8.7	5.5/8.5	6.0/8.8	5.2/8.5	3.9/7.2	3.2/5.6	1.8/4.0	1.9/4.1	5.0/6.3

Solar Radiation for 2-Axis Tracking Flat-Plate Collectors (kWh/m²/day), Uncertainty ±9%

Tracker		Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Year
2-Axis	Average	3.9	5.3	6.5	7.2	7.8	8.1	8.5	7.4	5.7	4.4	3.1	3.1	5.9
	Min/Max	3.1/4.8	3.4/6.6	5.2/7.8	6.0/9.0	5.7/9.6	6.4/9.7	6.8/9.9	5.7/9.1	4.1/7.4	3.3/5.6	1.8/4.0	1.9/4.2	5.3/6.6

Direct Beam Solar Radiation for Concentrating Collectors (kWh/m²/day), Uncertainty ±8%

Tracker		Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Year
1-Axis, E-W Horiz Axis	Average	2.1	2.6	2.7	3.1	3.5	3.6	3.9	3.4	2.7	2.2	1.6	1.6	2.8
	Min/Max	1.4/3.0	1.0/3.7	1.9/3.6	2.1/4.7	2.1/5.1	2.1/4.9	2.7/5.2	2.2/4.6	1.4/4.0	1.3/3.2	0.5/2.4	0.8/2.6	2.3/3.4
1-Axis, N-S Horiz Axis	Average	1.3	2.1	2.9	4.0	4.7	4.8	5.2	4.4	3.1	2.0	1.1	0.9	3.0
	Min/Max	0.9/1.9	0.8/3.0	1.9/3.9	2.7/6.0	2.6/6.6	2.8/6.5	3.6/6.8	2.8/6.1	1.7/4.6	1.2/2.9	0.3/1.7	0.5/1.5	2.6/3.8
1-Axis, N-S Tilt=Latitude	Average	2.2	3.1	3.6	4.4	4.7	4.6	5.1	4.6	3.6	2.8	1.8	1.7	3.5
	Min/Max	1.5/3.2	1.2/4.4	2.5/4.9	2.9/6.6	2.7/6.6	2.7/6.3	3.5/6.7	3.0/6.4	1.9/5.4	1.6/4.0	0.6/2.7	0.9/2.7	2.9/4.3
2-Axis	Average	2.4	3.2	3.6	4.4	4.9	5.0	5.5	4.8	3.7	2.8	1.8	1.8	3.7
	Min/Max	1.6/3.4	1.3/4.5	2.5/4.9	3.0/6.7	2.8/7.0	3.0/6.8	3.8/7.2	3.1/6.6	2.0/5.4	1.6/4.1	0.6/2.8	0.9/2.9	3.1/4.5

Average Climatic Conditions

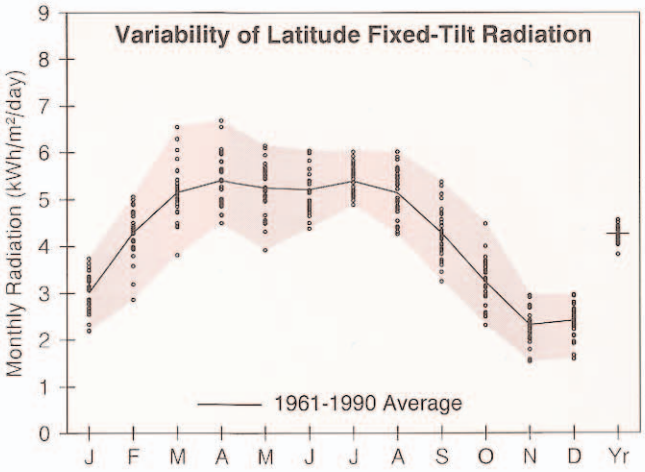
Element	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Year
Temperature (°C)	-13.9	-10.9	-4.2	3.7	10.4	15.4	18.9	17.6	12.3	6.5	-2.0	-10.7	3.6
Daily Minimum Temp	-19.0	-16.2	-9.1	-1.7	4.2	9.2	12.8	11.8	6.9	1.7	-5.8	-15.1	-1.7
Daily Maximum Temp	-8.8	-5.7	0.5	9.0	16.6	21.7	25.1	23.3	17.7	11.3	1.8	-6.3	8.8
Record Minimum Temp	-39.4	-36.1	-33.9	-20.6	-8.3	-2.8	1.7	0.0	-5.6	-13.3	-30.6	-36.7	-39.4
Record Maximum Temp	11.1	12.8	25.6	31.1	32.2	33.9	36.1	36.1	35.0	30.0	21.1	12.8	36.1
HDD, Base 18.3°C	999	820	699	440	247	94	33	63	183	367	610	899	5454
CDD, Base 18.3°C	0	0	0	0	0	8	52	40	0	0	0	0	100
Relative Humidity (%)	72	70	69	64	63	69	71	75	76	71	75	76	71
Wind Speed (m/s)	5.1	4.8	5.3	5.2	4.9	4.5	4.0	4.0	4.4	4.6	4.9	4.8	4.7

International Falls, MN

WBAN NO. 14918

LATITUDE: 48.57° N
LONGITUDE: 93.38° W
ELEVATION: 361 meters
MEAN PRESSURE: 972 millibars

STATION TYPE: Secondary



Solar Radiation for Flat-Plate Collectors Facing South at a Fixed Tilt (kWh/m²/day), Uncertainty ±9%

Tilt (°)		Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Year
0	Average	1.4	2.4	3.7	4.8	5.5	5.8	5.8	4.9	3.5	2.2	1.4	1.1	3.6
	Min/Max	1.2/1.6	1.9/2.7	3.0/4.3	4.1/5.6	4.3/6.3	5.0/6.7	5.3/6.4	4.3/5.6	2.8/4.1	1.9/2.7	1.2/1.5	0.8/1.3	3.3/3.8
Latitude -15	Average	2.6	3.9	4.9	5.5	5.6	5.7	5.9	5.4	4.3	3.1	2.1	2.1	4.3
	Min/Max	2.0/3.2	2.7/4.6	3.7/6.2	4.6/6.8	4.2/6.6	4.8/6.6	5.3/6.5	4.5/6.3	3.3/5.3	2.3/4.2	1.5/2.6	1.4/2.5	3.9/4.6
Latitude	Average	3.0	4.3	5.1	5.4	5.2	5.2	5.4	5.1	4.3	3.2	2.3	2.4	4.3
	Min/Max	2.2/3.7	2.9/5.1	3.8/6.5	4.5/6.7	3.9/6.2	4.4/6.0	4.9/6.0	4.3/6.0	3.3/5.4	2.3/4.5	1.5/3.0	1.6/3.0	3.8/4.6
Latitude +15	Average	3.2	4.5	5.1	5.1	4.6	4.5	4.7	4.6	4.1	3.2	2.4	2.6	4.0
	Min/Max	2.3/4.0	2.9/5.3	3.7/6.6	4.1/6.2	3.4/5.4	3.8/5.2	4.3/5.2	3.8/5.4	3.0/5.1	2.2/4.5	1.5/3.1	1.7/3.2	3.6/4.3
90	Average	3.2	4.3	4.6	3.9	3.1	2.9	3.0	3.3	3.2	2.8	2.2	2.6	3.2
	Min/Max	2.3/4.0	2.8/5.1	3.1/5.9	3.0/5.0	2.3/3.5	2.5/3.3	2.8/3.3	2.7/3.8	2.4/4.1	1.9/4.0	1.4/3.0	1.6/3.2	2.8/3.5

Solar Radiation for 1-Axis Tracking Flat-Plate Collectors with a North-South Axis (kWh/m²/day), Uncertainty ±9%

Axis Tilt (°)		Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Year
0	Average	2.2	3.7	5.3	6.7	7.4	7.7	7.9	6.8	4.8	3.1	1.8	1.7	4.9
	Min/Max	1.6/2.7	2.5/4.3	3.9/6.7	5.6/8.5	5.3/9.0	6.2/9.3	6.7/8.9	5.5/8.0	3.6/6.1	2.2/4.2	1.3/2.3	1.1/2.1	4.5/5.4
Latitude -15	Average	3.1	4.8	6.3	7.3	7.6	7.7	8.1	7.3	5.5	3.7	2.4	2.4	5.5
	Min/Max	2.2/3.8	3.1/5.7	4.5/8.0	6.0/9.5	5.4/9.4	6.2/9.4	6.8/9.2	5.7/8.7	4.0/7.0	2.5/5.3	1.5/3.1	1.6/3.0	4.9/6.1
Latitude	Average	3.4	5.1	6.4	7.2	7.4	7.4	7.8	7.1	5.5	3.8	2.6	2.7	5.5
	Min/Max	2.4/4.3	3.2/6.1	4.6/8.3	5.9/9.4	5.2/9.1	5.9/9.1	6.6/8.9	5.6/8.5	4.0/7.1	2.6/5.6	1.6/3.4	1.7/3.3	4.9/6.1
Latitude +15	Average	3.6	5.2	6.4	7.0	7.0	7.0	7.4	6.8	5.3	3.8	2.7	2.9	5.4
	Min/Max	2.5/4.5	3.3/6.3	4.5/8.3	5.7/9.1	4.9/8.6	5.6/8.5	6.1/8.4	5.3/8.1	3.8/6.9	2.5/5.6	1.6/3.5	1.8/3.6	4.7/5.9

Solar Radiation for 2-Axis Tracking Flat-Plate Collectors (kWh/m²/day), Uncertainty ±9%

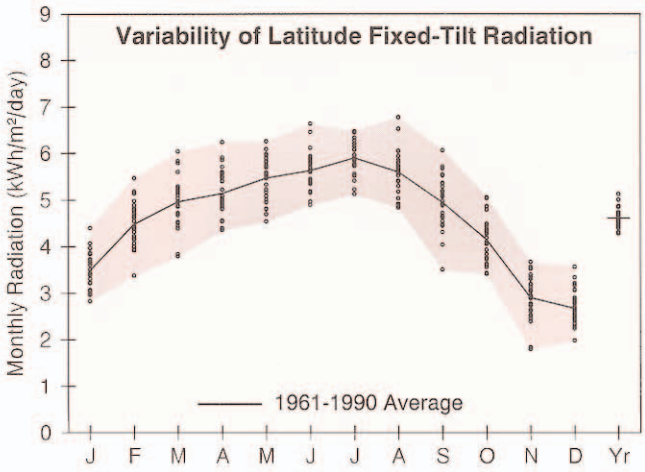
Tracker		Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Year
2-Axis	Average	3.6	5.2	6.4	7.3	7.7	8.0	8.3	7.3	5.5	3.9	2.7	2.9	5.7
	Min/Max	2.6/4.6	3.3/6.3	4.6/8.3	6.0/9.5	5.5/9.5	6.4/9.7	7.0/9.4	5.8/8.7	4.0/7.1	2.6/5.6	1.6/3.5	1.8/3.6	5.1/6.3

Direct Beam Solar Radiation for Concentrating Collectors (kWh/m²/day), Uncertainty ±8%

Tracker		Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Year
1-Axis, E-W Horiz Axis	Average	1.9	2.6	2.8	3.2	3.5	3.5	3.7	3.3	2.5	1.9	1.3	1.6	2.6
	Min/Max	1.1/2.7	1.2/3.5	1.8/4.1	2.2/5.1	1.8/4.9	2.2/4.9	2.7/4.6	2.1/4.4	1.4/3.6	0.8/3.3	0.4/2.0	0.8/2.2	2.2/3.1
1-Axis, N-S Horiz Axis	Average	1.2	2.1	2.9	4.1	4.6	4.6	5.0	4.3	2.9	1.7	0.9	0.8	2.9
	Min/Max	0.7/1.6	0.9/2.8	1.9/4.3	2.7/6.4	2.5/6.5	3.0/6.6	3.6/6.2	2.8/5.8	1.7/4.2	0.8/3.0	0.3/1.3	0.4/1.2	2.5/3.5
1-Axis, N-S Tilt=Latitude	Average	2.1	3.1	3.7	4.5	4.7	4.5	4.9	4.5	3.4	2.4	1.4	1.6	3.4
	Min/Max	1.2/2.8	1.4/4.2	2.4/5.4	3.0/7.2	2.5/6.5	2.9/6.3	3.5/6.1	3.0/6.1	2.0/5.0	1.0/4.2	0.5/2.2	0.9/2.2	2.9/4.0
2-Axis	Average	2.2	3.2	3.7	4.6	4.9	4.9	5.3	4.7	3.5	2.4	1.5	1.7	3.6
	Min/Max	1.3/3.0	1.5/4.3	2.4/5.5	3.1/7.3	2.6/6.9	3.2/6.9	3.8/6.5	3.1/6.3	2.0/5.0	1.1/4.3	0.5/2.3	0.9/2.4	3.0/4.1

Average Climatic Conditions

Element	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Year
Temperature (°C)	-17.2	-13.5	-5.5	3.9	11.2	16.3	19.3	17.6	11.9	5.8	-3.9	-13.8	2.7
Daily Minimum Temp	-23.3	-20.0	-11.4	-2.3	4.2	9.7	12.6	10.9	5.8	0.5	-8.3	-19.0	-3.4
Daily Maximum Temp	-11.2	-7.1	0.4	10.1	18.1	23.0	26.0	24.2	17.9	11.0	0.4	-8.6	8.7
Record Minimum Temp	-43.3	-42.2	-38.9	-25.6	-11.7	-5.0	1.7	-1.1	-6.7	-16.7	-35.6	-40.6	-43.3
Record Maximum Temp	8.9	12.8	24.4	33.9	35.0	36.7	36.7	35.0	35.0	31.1	22.8	13.9	36.7
HDD, Base 18.3°C	1102	891	739	433	232	87	31	64	193	389	668	996	5826
CDD, Base 18.3°C	0	0	0	0	10	27	59	42	0	0	0	0	138
Relative Humidity (%)	71	67	66	61	61	68	71	75	77	74	79	77	71
Wind Speed (m/s)	3.9	3.8	4.2	4.3	4.1	3.7	3.3	3.4	3.7	4.0	4.1	3.9	3.9



Minneapolis, MN

WBAN NO. 14922

LATITUDE: 44.88° N
LONGITUDE: 93.22° W
ELEVATION: 255 meters
MEAN PRESSURE: 986 millibars

STATION TYPE: Secondary

Solar Radiation for Flat-Plate Collectors Facing South at a Fixed Tilt (kWh/m²/day), Uncertainty ±9%

Tilt (°)		Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Year
0	Average	1.8	2.7	3.8	4.7	5.7	6.3	6.3	5.4	4.1	2.8	1.7	1.4	3.9
	Min/Max	1.5/2.0	2.4/3.1	3.1/4.3	4.1/5.5	4.9/6.5	5.5/7.4	5.6/6.9	4.8/6.4	3.3/4.8	2.4/3.2	1.3/2.0	1.1/1.7	3.7/4.2
Latitude -15	Average	3.1	4.1	4.8	5.3	5.8	6.1	6.4	5.8	4.9	3.9	2.6	2.3	4.6
	Min/Max	2.5/3.8	3.2/4.9	3.7/5.7	4.4/6.3	4.9/6.7	5.3/7.3	5.6/7.0	5.1/7.0	3.6/6.0	3.3/4.7	1.7/3.3	1.8/3.1	4.3/5.1
Latitude	Average	3.5	4.5	5.0	5.1	5.5	5.6	5.9	5.6	5.0	4.1	2.9	2.7	4.6
	Min/Max	2.8/4.4	3.4/5.5	3.8/6.0	4.4/6.2	4.5/6.3	4.9/6.6	5.1/6.5	4.8/6.8	3.5/6.1	3.4/5.1	1.8/3.7	2.0/3.6	4.3/5.1
Latitude +15	Average	3.8	4.7	4.9	4.8	4.8	4.9	5.1	5.1	4.7	4.2	3.0	2.9	4.4
	Min/Max	3.0/4.8	3.5/5.8	3.7/6.1	4.0/5.8	4.0/5.5	4.3/5.7	4.5/5.6	4.4/6.2	3.3/5.8	3.4/5.1	1.8/3.9	2.1/3.9	4.0/4.9
90	Average	3.7	4.4	4.1	3.3	3.0	2.8	3.0	3.3	3.5	3.5	2.8	2.8	3.3
	Min/Max	2.8/4.8	3.2/5.4	2.9/5.3	2.8/4.0	2.5/3.3	2.5/3.2	2.7/3.3	2.9/4.0	2.4/4.4	2.8/4.3	1.6/3.6	2.0/3.9	3.0/3.7

Solar Radiation for 1-Axis Tracking Flat-Plate Collectors with a North-South Axis (kWh/m²/day), Uncertainty ±9%

Axis Tilt (°)		Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Year
0	Average	2.7	4.0	5.2	6.3	7.5	8.2	8.5	7.4	5.7	4.0	2.4	2.0	5.3
	Min/Max	2.2/3.5	3.0/4.9	3.9/6.4	5.0/7.8	6.2/8.9	6.9/10.4	7.3/9.6	6.3/9.1	4.0/7.0	3.2/4.9	1.5/3.1	1.5/2.6	4.9/6.1
Latitude -15	Average	3.7	5.0	6.0	6.8	7.8	8.3	8.7	7.8	6.3	4.8	3.1	2.7	5.9
	Min/Max	3.0/4.7	3.7/6.2	4.4/7.5	5.3/8.5	6.3/9.2	6.9/10.5	7.4/9.9	6.6/9.8	4.3/7.9	3.8/6.0	1.8/4.0	2.0/3.7	5.4/6.8
Latitude	Average	4.0	5.4	6.2	6.7	7.5	8.0	8.4	7.7	6.4	5.0	3.3	3.0	6.0
	Min/Max	3.2/5.2	3.8/6.7	4.4/7.7	5.3/8.5	6.1/8.9	6.6/10.1	7.1/9.5	6.4/9.6	4.3/8.0	4.0/6.3	1.9/4.3	2.2/4.1	5.4/6.8
Latitude +15	Average	4.3	5.5	6.1	6.5	7.1	7.4	7.9	7.3	6.2	5.0	3.4	3.2	5.8
	Min/Max	3.3/5.5	3.9/6.9	4.3/7.7	5.1/8.1	5.7/8.4	6.2/9.5	6.7/8.9	6.1/9.1	4.1/7.8	4.0/6.4	1.9/4.5	2.3/4.3	5.2/6.7

Solar Radiation for 2-Axis Tracking Flat-Plate Collectors (kWh/m²/day), Uncertainty ±9%

Tracker		Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Year
2-Axis	Average	4.3	5.5	6.2	6.8	7.9	8.5	8.9	7.9	6.4	5.1	3.4	3.2	6.2
	Min/Max	3.4/5.6	3.9/6.9	4.4/7.7	5.3/8.6	6.4/9.3	7.1/10.8	7.5/10.0	6.6/9.8	4.3/8.0	4.0/6.4	2.0/4.5	2.3/4.4	5.6/7.1

Direct Beam Solar Radiation for Concentrating Collectors (kWh/m²/day), Uncertainty ±8%

Tracker		Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Year
1-Axis, E-W Horiz Axis	Average	2.4	2.8	2.8	3.1	3.6	4.0	4.3	3.7	3.1	2.7	1.9	1.8	3.0
	Min/Max	1.4/3.5	1.4/4.0	1.7/4.0	1.7/4.5	2.4/4.7	2.7/5.8	3.3/5.3	2.8/5.3	1.5/4.2	1.9/3.8	0.7/2.7	1.1/2.6	2.5/3.7
1-Axis, N-S Horiz Axis	Average	1.6	2.4	3.1	3.9	4.8	5.2	5.6	4.9	3.7	2.5	1.3	1.1	3.3
	Min/Max	0.9/2.3	1.2/3.3	1.8/4.4	2.1/5.6	3.2/6.2	3.6/7.7	4.4/6.9	3.7/6.8	1.8/5.0	1.7/3.6	0.5/2.0	0.7/1.6	2.8/4.2
1-Axis, N-S Tilt=Latitude	Average	2.6	3.4	3.8	4.3	4.7	5.0	5.5	5.1	4.3	3.4	2.1	1.9	3.8
	Min/Max	1.5/3.8	1.7/4.7	2.2/5.4	2.3/6.1	3.2/6.1	3.5/7.4	4.2/6.7	3.8/7.1	2.1/5.8	2.3/4.8	0.8/3.0	1.2/2.8	3.1/4.8
2-Axis	Average	2.8	3.5	3.8	4.3	5.0	5.4	5.9	5.2	4.3	3.5	2.2	2.0	4.0
	Min/Max	1.6/4.1	1.7/4.9	2.2/5.4	2.3/6.2	3.3/6.5	3.8/8.0	4.5/7.2	4.0/7.3	2.1/5.8	2.4/4.8	0.8/3.2	1.3/3.0	3.3/5.0

Average Climatic Conditions

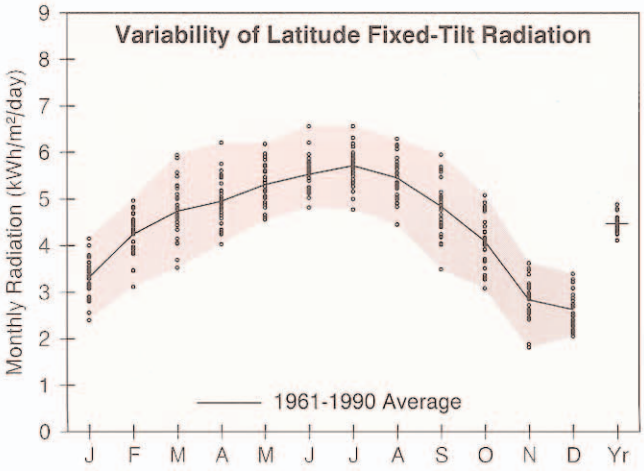
Element	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Year
Temperature (°C)	-11.2	-7.8	-0.6	8.0	14.7	20.1	23.1	21.4	15.8	9.3	0.7	-7.8	7.2
Daily Minimum Temp	-16.2	-12.7	-5.2	2.3	8.7	14.2	17.3	15.7	10.2	3.8	-3.8	-12.1	1.8
Daily Maximum Temp	-6.3	-3.0	4.0	13.6	20.8	26.0	28.9	27.1	21.5	14.9	5.0	-3.6	12.4
Record Minimum Temp	-36.7	-33.3	-35.6	-16.7	-7.8	1.1	6.1	3.9	-3.3	-9.4	-27.2	-33.9	-36.7
Record Maximum Temp	14.4	15.6	28.3	35.0	35.6	38.9	40.6	38.9	36.7	31.7	23.9	17.2	40.6
HDD, Base 18.3°C	916	733	586	310	136	23	6	12	93	279	530	811	4434
CDD, Base 18.3°C	0	0	0	0	24	76	154	107	18	0	0	0	379
Relative Humidity (%)	70	70	67	60	60	64	65	68	71	68	73	74	67
Wind Speed (m/s)	4.7	4.6	5.1	5.4	4.8	4.6	4.2	4.1	4.3	4.6	4.7	4.6	4.6

Rochester, MN

WBAN NO. 14925

LATITUDE: 43.92° N
LONGITUDE: 92.50° W
ELEVATION: 402 meters
MEAN PRESSURE: 968 millibars

STATION TYPE: Secondary



Solar Radiation for Flat-Plate Collectors Facing South at a Fixed Tilt (kWh/m²/day), Uncertainty ±9%

Tilt (°)		Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Year
0	Average	1.8	2.7	3.7	4.6	5.6	6.2	6.2	5.3	4.0	2.8	1.7	1.4	3.8
	Min/Max	1.5/2.1	2.3/3.0	3.0/4.3	3.9/5.5	4.8/6.5	5.4/7.3	5.3/7.0	4.5/6.0	3.3/4.7	2.3/3.3	1.4/2.0	1.2/1.7	3.7/4.1
Latitude -15	Average	2.9	3.9	4.6	5.1	5.7	6.0	6.2	5.7	4.8	3.8	2.6	2.3	4.5
	Min/Max	2.2/3.6	2.9/4.5	3.5/5.6	4.1/6.3	4.9/6.6	5.3/7.1	5.2/7.1	4.7/6.5	3.6/5.8	3.0/4.7	1.7/3.2	1.8/2.9	4.1/4.9
Latitude	Average	3.3	4.2	4.7	4.9	5.3	5.5	5.7	5.5	4.8	4.1	2.8	2.6	4.5
	Min/Max	2.4/4.2	3.1/5.0	3.5/5.9	4.0/6.2	4.6/6.2	4.8/6.6	4.8/6.6	4.4/6.3	3.5/5.9	3.1/5.1	1.8/3.6	2.0/3.4	4.1/4.9
Latitude +15	Average	3.6	4.4	4.7	4.6	4.7	4.8	5.0	4.9	4.6	4.1	2.9	2.8	4.3
	Min/Max	2.5/4.5	3.2/5.2	3.4/6.0	3.8/5.8	4.1/5.4	4.2/5.6	4.2/5.7	4.0/5.7	3.3/5.7	3.0/5.1	1.8/3.8	2.2/3.7	3.9/4.6
90	Average	3.5	4.1	3.9	3.2	2.8	2.7	2.9	3.2	3.4	3.4	2.7	2.7	3.2
	Min/Max	2.4/4.4	2.9/4.9	2.7/5.3	2.7/3.9	2.6/3.2	2.5/3.1	2.5/3.2	2.6/3.6	2.4/4.2	2.5/4.3	1.5/3.5	2.1/3.7	2.9/3.5

Solar Radiation for 1-Axis Tracking Flat-Plate Collectors with a North-South Axis (kWh/m²/day), Uncertainty ±9%

Axis Tilt (°)		Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Year
0	Average	2.7	3.9	5.0	6.1	7.3	8.0	8.2	7.1	5.5	4.0	2.4	2.0	5.2
	Min/Max	1.9/3.3	2.8/4.5	3.6/6.3	4.7/7.7	5.8/8.9	6.8/9.9	6.7/9.6	5.7/8.3	3.9/6.9	2.9/4.9	1.5/3.0	1.6/2.5	4.8/5.8
Latitude -15	Average	3.5	4.8	5.7	6.5	7.5	8.0	8.3	7.5	6.1	4.7	3.0	2.7	5.7
	Min/Max	2.5/4.4	3.3/5.7	4.0/7.3	5.0/8.4	5.9/9.1	6.8/10.0	6.7/9.7	5.9/8.8	4.2/7.7	3.4/6.0	1.8/3.9	2.1/3.5	5.2/6.4
Latitude	Average	3.8	5.1	5.8	6.4	7.2	7.7	8.0	7.4	6.2	4.9	3.2	2.9	5.7
	Min/Max	2.7/4.9	3.5/6.1	4.1/7.6	4.9/8.3	5.7/8.9	6.5/9.6	6.5/9.4	5.7/8.7	4.2/7.8	3.5/6.3	1.9/4.3	2.3/3.9	5.2/6.4
Latitude +15	Average	4.0	5.2	5.8	6.1	6.8	7.2	7.5	7.0	6.0	5.0	3.3	3.1	5.6
	Min/Max	2.8/5.2	3.5/6.2	4.0/7.6	4.7/8.0	5.3/8.4	6.1/9.0	6.1/8.8	5.4/8.3	4.0/7.6	3.5/6.3	1.9/4.4	2.4/4.1	5.0/6.3

Solar Radiation for 2-Axis Tracking Flat-Plate Collectors (kWh/m²/day), Uncertainty ±9%

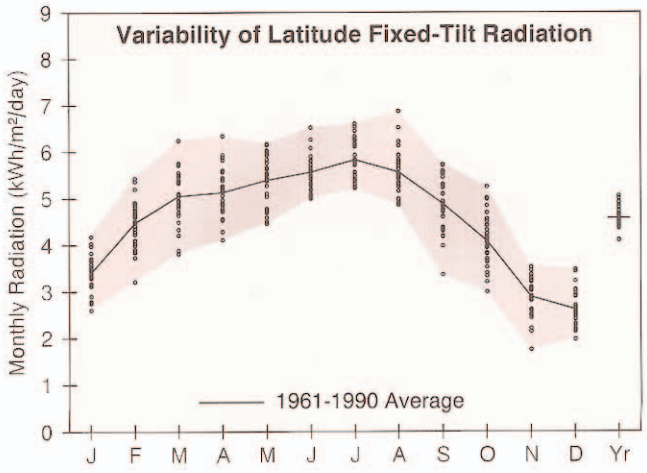
Tracker		Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Year
2-Axis	Average	4.1	5.2	5.8	6.5	7.6	8.2	8.5	7.6	6.2	5.0	3.3	3.1	5.9
	Min/Max	2.8/5.2	3.6/6.2	4.1/7.6	5.0/8.4	6.0/9.3	7.0/10.3	6.9/9.9	5.9/8.9	4.2/7.8	3.6/6.3	1.9/4.4	2.4/4.2	5.3/6.6

Direct Beam Solar Radiation for Concentrating Collectors (kWh/m²/day), Uncertainty ±8%

Tracker		Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Year
1-Axis, E-W Horiz Axis	Average	2.2	2.6	2.6	2.8	3.4	3.7	3.9	3.5	2.9	2.6	1.8	1.7	2.8
	Min/Max	1.2/3.1	1.2/3.5	1.4/3.6	1.6/4.4	2.2/4.7	2.6/5.4	2.6/5.0	2.2/4.5	1.4/4.2	1.7/3.8	0.6/2.7	1.1/2.4	2.3/3.4
1-Axis, N-S Horiz Axis	Average	1.5	2.2	2.8	3.6	4.4	4.9	5.2	4.6	3.5	2.5	1.3	1.0	3.1
	Min/Max	0.8/2.1	0.9/3.0	1.5/3.9	2.0/5.5	2.8/6.3	3.6/7.1	3.6/6.6	3.0/5.9	1.7/5.0	1.5/3.6	0.4/2.0	0.7/1.5	2.6/3.8
1-Axis, N-S Tilt=Latitude	Average	2.4	3.1	3.4	3.9	4.4	4.7	5.0	4.7	4.0	3.3	2.0	1.8	3.6
	Min/Max	1.2/3.3	1.4/4.3	1.8/4.8	2.2/6.0	2.8/6.2	3.4/6.8	3.5/6.4	3.1/6.1	2.0/5.7	2.1/4.7	0.6/3.0	1.1/2.5	2.9/4.3
2-Axis	Average	2.6	3.2	3.4	3.9	4.7	5.1	5.4	4.9	4.0	3.4	2.1	1.9	3.7
	Min/Max	1.3/3.5	1.4/4.4	1.8/4.8	2.2/6.1	3.0/6.5	3.7/7.4	3.7/6.8	3.2/6.3	2.0/5.8	2.1/4.8	0.7/3.1	1.2/2.8	3.1/4.5

Average Climatic Conditions

Element	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Year
Temperature (°C)	-11.4	-8.3	-1.2	7.2	13.8	19.2	21.6	20.1	15.1	8.8	0.3	-8.2	6.4
Daily Minimum Temp	-16.3	-13.3	-5.9	1.4	7.5	12.9	15.6	14.2	9.2	3.1	-4.2	-12.6	0.9
Daily Maximum Temp	-6.6	-3.3	3.4	12.9	20.1	25.4	27.7	26.0	21.0	14.6	4.9	-3.9	11.8
Record Minimum Temp	-35.6	-33.9	-35.0	-15.0	-6.1	1.7	5.6	2.8	-5.0	-11.7	-28.9	-36.1	-36.1
Record Maximum Temp	12.8	17.2	26.1	32.8	33.3	38.3	38.9	37.2	35.0	31.1	22.8	16.7	38.9
HDD, Base 18.3°C	922	745	606	335	157	31	9	18	103	294	540	823	4583
CDD, Base 18.3°C	0	0	0	0	16	56	111	74	6	0	0	0	262
Relative Humidity (%)	77	76	75	68	67	69	72	75	75	72	77	80	74
Wind Speed (m/s)	6.6	6.3	6.6	6.6	6.0	5.7	4.9	4.9	5.4	5.9	6.2	6.3	5.9



Saint Cloud, MN

WBAN NO. 14926

LATITUDE: 45.55° N
LONGITUDE: 94.07° W
ELEVATION: 313 meters
MEAN PRESSURE: 978 millibars

STATION TYPE: Secondary

Solar Radiation for Flat-Plate Collectors Facing South at a Fixed Tilt (kWh/m²/day), Uncertainty ±9%

Tilt (°)		Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Year
0	Average	1.7	2.7	3.8	4.7	5.6	6.2	6.3	5.4	4.0	2.7	1.7	1.3	3.8
	Min/Max	1.4/1.9	2.2/3.0	3.1/4.4	4.0/5.6	4.7/6.4	5.6/7.2	5.6/7.1	4.8/6.5	3.2/4.5	2.2/3.2	1.3/1.9	1.1/1.6	3.6/4.2
Latitude -15	Average	3.0	4.1	4.8	5.3	5.8	6.1	6.3	5.8	4.8	3.8	2.6	2.3	4.6
	Min/Max	2.3/3.6	3.0/4.8	3.7/5.9	4.3/6.4	4.8/6.6	5.5/7.1	5.6/7.1	5.1/7.1	3.4/5.6	2.9/4.9	1.7/3.1	1.8/3.0	4.1/5.0
Latitude	Average	3.4	4.5	5.0	5.1	5.4	5.6	5.8	5.6	4.9	4.1	2.9	2.6	4.6
	Min/Max	2.6/4.2	3.2/5.4	3.8/6.2	4.1/6.3	4.5/6.2	5.0/6.5	5.2/6.6	4.9/6.9	3.4/5.7	3.0/5.3	1.8/3.5	2.0/3.5	4.1/5.1
Latitude +15	Average	3.7	4.7	5.0	4.7	4.8	4.8	5.1	5.0	4.6	4.1	3.0	2.8	4.4
	Min/Max	2.7/4.5	3.3/5.7	3.7/6.3	3.8/5.9	4.0/5.4	4.3/5.6	4.6/5.7	4.4/6.2	3.1/5.5	3.0/5.3	1.8/3.7	2.1/3.8	3.9/4.8
90	Average	3.6	4.4	4.3	3.4	3.0	2.8	3.0	3.3	3.5	3.5	2.8	2.7	3.3
	Min/Max	2.6/4.4	3.1/5.4	3.0/5.6	2.7/4.1	2.6/3.3	2.6/3.2	2.8/3.4	2.9/4.0	2.3/4.2	2.5/4.6	1.6/3.4	2.0/3.8	2.9/3.7

Solar Radiation for 1-Axis Tracking Flat-Plate Collectors with a North-South Axis (kWh/m²/day), Uncertainty ±9%

Axis Tilt (°)		Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Year
0	Average	2.6	4.0	5.3	6.4	7.5	8.2	8.5	7.4	5.6	3.9	2.4	1.9	5.3
	Min/Max	2.0/3.1	2.8/4.8	3.9/6.5	4.8/8.1	5.6/8.8	7.1/10.1	7.5/10.0	6.2/9.7	3.8/6.7	2.8/5.1	1.5/2.9	1.5/2.5	4.7/5.9
Latitude -15	Average	3.6	5.0	6.2	6.8	7.7	8.2	8.7	7.8	6.3	4.8	3.1	2.7	5.9
	Min/Max	2.7/4.4	3.4/6.2	4.4/7.7	5.1/8.8	5.8/9.1	7.1/10.2	7.6/10.2	6.5/10.3	4.1/7.6	3.3/6.3	1.8/3.8	2.0/3.6	5.2/6.7
Latitude	Average	3.9	5.4	6.3	6.8	7.4	7.9	8.4	7.7	6.3	5.0	3.3	2.9	5.9
	Min/Max	3.0/4.9	3.6/6.7	4.5/7.9	5.0/8.8	5.6/8.9	6.8/9.8	7.3/9.8	6.3/10.1	4.0/7.7	3.5/6.6	1.9/4.1	2.2/4.0	5.2/6.7
Latitude +15	Average	4.1	5.5	6.3	6.5	7.0	7.4	7.9	7.3	6.1	5.0	3.4	3.1	5.8
	Min/Max	3.1/5.2	3.7/6.9	4.4/7.9	4.8/8.4	5.2/8.4	6.3/9.2	6.9/9.3	6.0/9.7	3.9/7.5	3.4/6.6	1.9/4.3	2.2/4.3	5.0/6.6

Solar Radiation for 2-Axis Tracking Flat-Plate Collectors (kWh/m²/day), Uncertainty ±9%

Tracker		Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Year
2-Axis	Average	4.2	5.5	6.3	6.9	7.8	8.5	8.9	7.9	6.3	5.0	3.4	3.1	6.1
	Min/Max	3.1/5.2	3.7/6.9	4.5/7.9	5.1/8.9	5.9/9.2	7.3/10.4	7.8/10.4	6.5/10.4	4.1/7.7	3.5/6.6	1.9/4.3	2.3/4.3	5.4/7.0

Direct Beam Solar Radiation for Concentrating Collectors (kWh/m²/day), Uncertainty ±8%

Tracker		Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Year
1-Axis, E-W Horiz Axis	Average	2.4	2.9	2.9	3.1	3.5	3.9	4.2	3.7	3.0	2.7	1.9	1.8	3.0
	Min/Max	1.4/3.6	1.4/4.1	1.9/4.2	1.3/4.7	2.2/4.6	2.9/5.4	3.4/5.3	2.7/5.7	1.4/4.1	1.6/4.1	0.7/2.7	1.0/2.8	2.4/3.7
1-Axis, N-S Horiz Axis	Average	1.5	2.4	3.1	3.9	4.7	5.2	5.6	4.9	3.6	2.5	1.3	1.0	3.3
	Min/Max	0.9/2.3	1.1/3.4	1.9/4.5	1.6/6.0	2.8/6.1	3.8/7.3	4.4/7.1	3.5/7.6	1.7/4.9	1.5/3.8	0.4/1.9	0.6/1.7	2.7/4.1
1-Axis, N-S Tilt=Latitude	Average	2.5	3.4	3.9	4.3	4.7	4.9	5.5	5.1	4.2	3.4	2.1	1.8	3.8
	Min/Max	1.5/3.9	1.6/4.9	2.4/5.6	1.8/6.6	2.9/6.1	3.7/6.9	4.3/6.9	3.6/7.9	1.9/5.6	2.0/5.1	0.7/3.0	1.1/3.0	3.1/4.7
2-Axis	Average	2.7	3.5	3.9	4.3	4.9	5.4	5.9	5.3	4.2	3.4	2.2	2.0	4.0
	Min/Max	1.6/4.2	1.7/5.0	2.4/5.6	1.8/6.7	3.0/6.5	4.0/7.5	4.6/7.4	3.8/8.2	1.9/5.7	2.0/5.2	0.8/3.2	1.2/3.2	3.2/4.9

Average Climatic Conditions

Element	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Year
Temperature (°C)	-13.3	-9.8	-2.4	6.4	13.3	18.2	21.2	19.5	14.1	7.7	-1.3	-9.9	5.3
Daily Minimum Temp	-19.1	-15.7	-8.0	0.0	6.3	11.2	14.2	12.7	7.4	1.3	-6.5	-15.0	-0.9
Daily Maximum Temp	-7.5	-4.0	3.1	12.8	20.2	25.2	28.1	26.3	20.6	14.1	3.9	-4.9	11.5
Record Minimum Temp	-41.7	-37.2	-35.6	-19.4	-7.2	0.6	4.4	0.6	-7.8	-15.0	-28.9	-40.6	-41.7
Record Maximum Temp	12.8	12.8	26.1	35.6	36.1	38.9	39.4	39.4	36.7	32.2	23.3	15.6	39.4
HDD, Base 18.3°C	980	789	644	358	171	48	13	30	133	329	588	877	4960
CDD, Base 18.3°C	0	0	0	0	14	45	101	66	5	0	0	0	231
Relative Humidity (%)	72	70	70	64	63	68	69	72	74	70	75	76	70
Wind Speed (m/s)	4.7	3.7	5.0	4.7	4.4	3.7	3.2	3.3	3.4	3.9	4.2	4.4	4.1