Il-Lumen-Naughty

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Introduction

Humboldt State University (HSU) is routinely considered one of the more environmentally-oriented campuses in the CSU system, being listed one of the top North American green campuses by the Princeton Review (http://now.humboldt.edu/news/princeton-review-names-hsu-a-green-college/). Located in a pristine wilderness environment of coastal redwoods, natural resources are a major focus of studies at this institution and a part of this is the environmental science curriculum—a blend of environmental policy, energy and climate, and ecological restoration.

Being seniors in the energy and climate portion of this major, our group was fortunate enough to be involved in a project we enjoyed—solar lighting. Part of our project parameters was to assess light levels for safety, sustainability, and aesthetics.

Whilst completing an inventory of the outdoor campus lighting, the inadequate use of lighting on campus was revealed, which lead to the questioning of the supposed green rating that HSU has received. Many lights, such as the ones connected to Gist Hall and Science Building A, use 300 watt incandescent light bulbs, more of a heat source than a sustainable lighting source. Since sustainability is one of the core issues of HSU's Mission Statement, it seems prudent to see what kind of savings could be had with a simple upgrade of light bulbs.

Research into other campus lighting projects led to the UC Davis parking lot canopies which are fitted with solar panels. Attached to these solar panels are photo sensors which detect when cars are in spaces, lessening the light output when the space is empty (http://cltc.ucdavis.edu/content/view/1170/448).

Another campus project—light level measurements which find areas where light output could be cut, thereby saving electricity costs, by Princeton University—led us to the Humboldt Energy Independence Fund (HEIF), a fund whose mission is to lessen energy use at Humboldt State through student actions (http://humboldt.edu/heif/aboutHEIF). HEIF is in the process of doing the same type of light level measurements that Princeton University did, and they were able to provide data on how much energy the Humboldt State campus utilizes and an overall breakdown of the different buildings' energy consumptions.

As one travels up Harpst Street for the first time, it is hard not to notice the older style light fixtures that line both sides of the street. The fixtures have a feel of an earlier era when life was simpler and more laid back. What one might not notice is the 50 Watt Metal Halide bulbs that are glowing in the housing. These lamps have a life span of a mere 1.14 years, and produce 1,350 lumens. The five year cost to run these bulbs is $249.65. The five year cost of an LED bulb—a cool $118.85—is less than half the cost of the currently installed metal halides.

Financial Analysis for Luminaire Transitioning

The cost comparison and cost benefit analysis can be viewed in the tables and figures below.

Given:

4380 hr of light a year: this is half of a year's light shed, with half accounting for darkness

Cost of electricity for HSU: $0.135/kwh

Example of Watt Usage Calculation: (50 watt lamp + 8% wattage for ballast = 54W)

Metal Halide Lamp

Cost/Bulb	$13.00/lamp
Installation Cost (Labor)	$5.00/lamp
Average Lifespan (hours)	10,000 hours
Energy Required for Lamp (watts)	(50W lamp) + 1.08*(50W) = 54W
Consumption (kWh/yr)	(4380 hrs/yr)*0.054 kW = 236.52 kWh/yr
Cost per year ($/yr)	(236.52 kWh/yr)*$.135/kWh = $31.93/yr
Total Cost over a 5 year-period per lamp	5 yrs*($31.93/yr)+ (5*$13.00) + 5*$5.00 = $249.65
Savings Compared to Current Installation	$0.00
Payback Period	N/A (No savings with current installation)

This seemed to be a lot of money for one street light—one of many—on a campus touted as one of the greenest campuses in California. Comparable light sources were found that utilize different technologies. The first comparison was a 40 Watt LED bulb that produced between 1,200 and 1,400 lumens:

Light Emitting Diode (LED)

Cost/Bulb	$50.00/lamp
Installation Cost (Labor)	$5.00/lamp
Average Lifespan (hours)	50,000 hours
Energy Required for Lamp (watts)	(20W lamp) + 1.08*(20W) = 21.6W
Consumption (kWh/yr)	(4380 hrs/yr)*0.022 kW = 94.6 kWh/yr
Cost per year ($/yr)	(94.6 kWh/yr)*$.135/kWh = $12.77/yr
Total Cost over a 5 year-period per lamp	5 yrs*($12.77/yr) + (1*50.00) + 5.00 = $118.85

Savings Compared to Current Installation	$110.80 for 5 years or $22.16/yr per lamp
Payback Period	$55.00 ÷ $22.16 = 2.48 years

This leaves the total savings for 5 years of $249.65 - $118.85 = $130.80 for each light pole. When you multiply by the 10 poles lining Harpst Street's entrance to the campus, the savings becomes $130.80*10 lights = $1308.00. There are approximately 400 lights of this size around the HSU campus (HSU Plant Operations light schematic).

The second comparison was a 40 Watt compact fluorescent lamp (CFL) producing 2,300 lumens. While the numbers were not as encouraging, the final outcome was still better than the metal halides currently used.

Compact Fluorescent Lamp (CFL)

Cost/Bulb	$8.50/lamp
Installation Cost (Labor)	$5.00/lamp
Average Lifespan (hours)	10,000 hours
Energy Required for Lamp (watts)	(40W lamp) + 1.08*(40W) = 43.2W
Consumption (kWh/yr)	(4380 hrs/yr)*0.043 kW = 189.22 kWh/yr
Cost per year ($/yr)	(189.22 kWh/yr)*$.135/kWh = $25.54/yr
Total Cost over a 5 year-period per lamp	5 yrs*($25.54/yr) + (5*$8.50) + 5*5.00 = $195.20
Savings Compared to Current Installation	$54.45 for 5 years or $10.89/yr per lamp
Payback Period	(5*$13.50) ÷ $10.89 = 6.19 years

<u>Notes</u>: *The "Installation Cost" stems from a technician being paid $20 per hour, and being able to install four lamps each hour worked. Also, see figures in Appendix, Part C for graphic displays of some of these analyses, in addition to another extrapolation.*

This leaves a total savings for five years of $249.65 - $195.20 = $54.45 for each light pole. Multiplying by 10 light poles would save an extra $544.50 over a five-year timespan.

If one contemplates the possible savings that could be had with changing just a few light bulbs, then changing all of them seems to have an exponential fiscal difference. And so, information about how much energy Humboldt State University used would be necessary for extrapolations and other research entities. Numerous attempts were made to collect this data from HSU Plant Operations with proved unsuccessful. HEIF was of a much greater help in providing data, especially the data associated with the total output of electricity at HSU.

The numbers that were found were extremely sizable. Humboldt State consumes $2.8 million worth of electricity each year and contributes 12,000 metric tons of CO_2 to the atmosphere. The Natural Resources Building, a building utilized by a great deal of students, used 70,422.69 kWh of energy in 2008 (http://humboldt-dspace.calstate.edu/xmlui/bitstream/handle/2148/688/Chhimi_Dorji.pdf?sequence=1).

This misuse of electricity inspired the design and building of a new lighting system that was safe, sustainable, portable, aesthetically pleasing, and that could be used as outdoor lighting in the event of an emergency. All of our objectives were met, with the exception of aesthetics.

Objectives & Obstacles

Our first objective was to design a new outdoor lighting schematic utilizing PV arrays/cells. The current Plant Operations schematic does not include photovoltaics, or lights attached to buildings, such as flood lamps. Second, the electrical wiring may be simplified depending on the level of self-sustainability of each apparatus and the number of lights that can be removed from the overall scheme due to increased lighting radius and increased lumens.

Our next objective was to build a prototype of the outdoor lighting apparatus using an LED. The current lights on campus are HID, which are not as efficient or sustainable as LED. Also, each apparatus could be outfitted with its own power supply and or power storage unit. Campus lights do not use renewable energy at this point, whereas we believe solar power could be utilized to power the aforementioned outdoor lighting.

Another objective was to create a comprehensive plan for sustainable outdoor lighting on campus which focuses on the short term vs. long term economic gain through the use of renewable energy and more effective and efficient light bulbs. There is also a possibility of lowering the number of lights through a larger lighting radius of each apparatus.

A main focus of the sustainability initiative was to lower maintenance hours and labor costs by switching from metal halide bulbs that last 10,000 hours (1.14 years) to LED bulbs with a lifespan of 50,000 hours (5.7 years). Switching bulbs would save Plant Operations from having to change bulbs from every year to a five year period.

Our final objective is to provide the community with lighting that promotes safety and provides comfort for those that are walking down semi lit pathways. The Women's Resource Center asserted that most areas on campus are well lit; however, many students have asserted that an increase in lighting in certain parking areas and an increase in lighting near the borders of campus would create a safer environment in the aforementioned areas. A survey, if allowed by the university administration, could be taken to ask the general university population their opinion on the lighting, with respect to safety, sustainability, etc.

There were obstacles to our project as well, the first being the university administration. The Humboldt State administration will, more than likely, not consider any comprehensive outdoor lighting plan if it does not cost less than the current lighting plan. The HSU Master Plan must be consulted so that the lighting plan aligns with it, if the Master Plan seems reasonable and feasible in the given study areas. The project plan must include detailed financial forecasting in order to display the cost-benefit of the new outdoor lighting on campus.

Although Humboldt County has seen more sunshine lately, the clouds and fog are a definite factor that must be considered in the given environment. In the coming years, the climate will change in Humboldt County; however, the direction those changes will take is unknown. The precipitation, as well as cloud cover, could increase or decrease; the same can be said for the fog. We are fairly certain of some things such as earlier snowpack melt and rising sea level, but these other issues are up in the air. Therefore, we should err on the side of caution and assess the possibility of increased cloud cover and increased fog.

Solar panels work at their optimum when they are fairly clean. If particulate matter settles upon the panels, then a reduction in energy will most likely take place. As there is also a great deal of wildlife, issues such as bird excrement must be taken into consideration. These types of issues could cause an increase in the workload for Plant Operations, which would cause the derailment of Objective #4. Although panels and lights would need regular maintenance and cleaning, Plant Operations should not have to spend an exorbitant amount of time on upkeep of the outdoor lighting.

Some people are hesitant to switch from HIDs to LEDs because they feel there will be something more efficient and effective on the market soon, or that LEDs are not worth the long-term savings due to the short-term costs. These stigmas must be met with scientific evidence that backs the project's objectives and goals. LEDs should be compared to HIDs, in reference to their environmental impact, short-term and long-term cost/value, etc. Research backing such comparisons should be cited for credibility. A survey of the university community would be extremely beneficial for outreach purposes, as well as sustainability. The students most often leave after a short stint of time, however the faculty and staff are more apt to stay a longer period of time; therefore, these people must be on-board with the project for it to be implemented and sustained.

The materials that were acquired for this prototype were gathered and purchased from the South G Street junkyard, ebay.com, Hensel's Ace Hardware and a generous donor. The primary materials used for the prototype consists of four pieces of scrap plate steel which were used as stabilizing legs, one stainless steel pole, one 10 watt polycrystalline photovoltaic solar panel, two 12 volt, 7ah sealed lead acid batteries, one 1"x8"x6' wooden board, one keyed sash lock, and one pair of small hinges.

The first step was wiring the two 12 volt batteries into parallel (combining capacity) using the connector salvaged off the repurposed controller and some extra lengths of wire yielding a battery capacity of 14ah, giving a calculated run time of 16.8 hours. This was followed shortly thereafter with the design of a housing for both batteries and the charge controller. Using the 1" x 8" x 6' board, a box was designed that had a low profile and could mount to almost any pole. Using a miter saw, wood glue, and clamps, all the needed pieces were cut and the box was constructed. Once the box was completed holes were marked and drilled in order to mount the controller inside; this ensured that there was more than the necessary amount of clearance and, thus, the controller would not get damaged by the batteries. Once the box was completed and the controller was installed, a lock was added so as to prevent any unwanted access to the hardware inside. A stand was then fabricated to mount all of the components utilizing four pieces of scrap sheet steel which were welded together with a 110V gasless MIG welder, at near-right angles in order to form the base. The pole was then mounted by cutting slits down the base of the pole, using a 110V sawzall, so that the pole could be fitted onto the base and, if necessary, easily removed and made ready for transport. When completely assembled, the system will hold the battery box, PV panel and light.

Quantity	Item	Cost	Total	Running Total
1	1"x8"x6' wood	7.50	7.50	7.50
1	Plate Steel and Pole	25.00	25.00	32.5
1	10watt LED Flood	12.90	12.90	45.4
1	Lock	5.99	5.99	51.39
1	Hinges	7.99	7.99	59.38
1	Solar Panel	(Donated)	Free	59.38
1	Batteries	(Donated)	Free	59.38
1	Controller	(Donated)	Free	59.38
			Total	59.38

Implementation and Monitoring Plan for Outdoor Solar Lighting

Implementation, in the context of this project, can be discussed on several levels. First off, one can speak about fixture selection and installation of compact fluorescent lamps and/or light emitting diodes in the outdoor lighting scheme on campus. Another part of the possible implementation is the transition from a non-renewable energy source to a renewable one, in this instance solar power. Policy is the final level of implementation for the project. This should be preceded by surveys of the university community and citizens of Humboldt County (the Institutional Review Board [IRB] would be contacted for credibility purposes. However, as the financial analysis above served as the majority of the "implementation and monitoring plan" for the switch from HIDs to more energy efficient luminaires, the following discussion shall be focused upon the long-term goal of powering all outdoor lighting on campus with the sun.

An extremely intricate part of the successful, long-term implementation of the solar outdoor lighting would be student, faculty, and staff involvement. Parts of the campus could be sectioned off, and certain classes could undertake the transition from the current streetlamps to solar lighting. Many of the Environmental Science students studying Energy & Climate and the Environmental Resource Engineering students taking upper division courses would be more than capable to take on such a task, especially as there would be a basic blueprint for them to follow along with professor instruction. As issues arise in the future, adaptive management would be necessary to remedy the new problems. In this way, students would learn how to work on pieces of long-term projects, which would be very similar to many "real world" situations. Specifically, this project comes to mind when Bergen, who wrote about ecological engineering design principles, asserted that "designs are more likely to succeed and to be accepted by the local community when the people who live in a place are included in the design process" (Bergen, p.206).

Much like the Natural Resources Building Restoration Project which utilized student volunteers, community donors and university resources to attain its goals and objectives, many senior projects and upper division labs should be focused on involving the campus members and the citizens from the surrounding community. By utilizing the many talents which the university has at their disposal, many campus issues could be solved. These improvements would range in scope depending on the line of study or service being undertaken; however, the emphasis for all these projects should be on identifying university and community issues, assessing the problems to the best of abilities learned at the university, and creating plans for the implementation and monitoring of the solutions for said issues. In this instance, a group of four students built a working prototype of an outdoor solar light that could be substituted for the streetlamps currently existing on campus. This source of “free labor and talent” must be utilized in order for the universities of the future to be run efficiently and effectively, with respect to economics. This will also aid students in gaining a greater understanding of the inner workings of the university, and how the university and its entities are connected to, or disconnected from, the surrounding community. These types of projects will also allow students to take a bigger role in their own education, creating a sense of ownership and pride that facilitates student retention and alumni involvement. If these types of projects are encouraged at the university, then many issues such as invasive plant monocultures and unsustainable outdoor lighting fixtures shall become a thing of the past.

Conclusion

As a result of the research undertaken for this project it is the recommendation of this group that the implementation of the LED floodlights replace the current framework for their metal halide counterparts. It is also our recommendation that all current lights be assessed for their sustainability and only the greenest solutions be implemented in accordance with HSU's Mission Statement. The following is an excerpt of Humboldt State University's "Green Commitment:"

> *Given our location in one of the world's most beautiful places, it's only natural that Humboldt State has a long-standing commitment to understanding and preserving our environment. This is more than a mission statement or slogan; it's a core principle that pervades much of that we do. Sustainability is incorporated throughout our curriculum, interwoven into our approach to campus operations…Humboldt State is a leader in researching clean, renewable energy, developing innovative green technologies and promoting an environmental ethic. This approach extends to our campus operations, where there are countless efforts to ensure our practices are sustainable and environmentally sound.*
>
> President Rollin C. Richmond
> Humboldt State University's "Green Commitment"

Because of this oath, pledge, and swearing of allegiance to the planet which we all hold dearest, it goes without saying that if there is a more appropriate manner to operate in accordance with the values we hold closest, it is our obligation to carry out said manner with the swiftest of priority. If the citation above is to represent the wishes of our University's highest sitting executive then it should be the modus operandi of all that succeed him.

Using techniques learned through our energy and technology curriculum, four students designed a standalone, portable, solar light apparatus for under $60.00. Our group looked into alternative lighting systems, compared two different forms of lights, one CFL and one LED, to the metal halides already in use and found that thousands of dollars a year could be saved with a simple changing of metal halide bulbs to LEDs.

There is a $2.8 million per year price tag on HSU's electricity consumption, which we feel could be put to better use by hiring more teachers and offering more classes. In a time of serious budget cuts, doing everything we can to save money is the only prudent idea. Helping the environment, as well, promotes our Mission Statement and provides firm evidence to future students, faculty, and staff that we stand behind our ethics. We envision an HSU that is one day completely independent of the electricity grid, relying solely on renewable energies.

With input from Plant Operations and an increase in education about greenhouse gas emissions and what produces them, as well as and economically viable labor force that is focused on campus and community betterment, we feel that HSU's Administration will be able to more readily assess the environmental degradation occurring on campus—a campus that is known nationwide for preserving natural resources. Anything less, regardless of cost, is a detriment to our education and a detriment to the environment we allegedly care to protect.

Annotated Bibliography

1. Arik, M. and Setlur, A. "Environmental and economical impact of LED lighting systems and effect of thermal management." *Int. J. Energy Res.*, 34: 1195–1204.

   a. Environmental and economic impacts are two of the most important factors that will be evaluated in our project planning process; this publication discusses these impacts in reference to LED lighting, which will be assessed in this paper.

2. Benya, James R. "Solar-Powered Outdoor Lighting." *Architectural Lighting*, 22.7 (2008): 57.

   a. Helpful if parking meters, existing lampposts, etc. are to be used as the majority of the paper discusses PV cells/arrays on the top of poles.

3. Bergen, S.D., Bolton, S.M., Fridley, J.L. *Design principles for ecological engineering*. Ecol. Eng. 18 (2001), 201–210.

   a. Contains design principles such as to design for site-specific content; this is germane to our research as we are taking an ecologically-based approach to outdoor lighting design on campus.

4. Huang, B.J, M.S Wu, P.C Hsu, J.W Chen, and K.Y Chen. "Development of High-performance Solar LED Lighting System." *Energy Conversion and Management*, 51.8 (2010): 1669-1675.

   a. Scholarly journal that would aid in LED research and development, especially coupled with the use of solar.

5. Huang, B.J, P.C Hsu, M.S Wu, and P.Y Ho. "System Dynamic Model and Charging Control of Lead-acid Battery for Stand-alone Solar PV System." *Solar Energy*, 84.5 (2010): 822-830.

   a. This article contains information on lead-acid battery systems for solar photovoltaic arrays. As many of the units may be stand-alone, this peer-reviewed article may help with designing/obtaining sustainable battery systems.

6. Wang, Chen, H Abdul-Rahman, and S.P Rao. "Development and Testing of a Fluorescent Fiber Solar Concentrator for Remote Daylighting." *Journal of Energy Engineering*, 136.3 (2010): 76-86.

   a. Helpful if outdoor lighting shall be placed onto building exteriors—for example, solar panels on the roof with a remote light underneath an overhang; this publication discussed remote day-lighting in great detail.

Appendix

A. *Research Literature*

1. Bao, Jia, Wei-dong Ding, and Zhou Lan. "The On-Grid Photovoltaic Power Generation Simulate System Design." *Advanced Materials Research*, 487 (2012): 181-185.

2. Bessho, Makoto, and Keiichi Shimizu. "Latest Trends in LED Lighting." *Electronics and Communications in Japan*, 95.1 (2012): 1-7.

3. Bierman, Andrew, Mark S Rea, Helen L Walls, Kelvin L Walls, and Geza Benke. "Climate Change, Fluorescent Lighting, and Eye Disease: A Little Too Light on the Science/walls Et Al. Respond." *American Journal of Public Health*, 102.8 (2012): E6.

4. Bourget, C. Michael. "An Introduction to Light-emitting Diodes." *HortScience*, 43.7 (2008): 1944.

5. Boxler, Larry. "Optical Design and Lighting Application of an LED-based Sports Lighting System." *Proceedings of SPIE*, 8123.1 (2011).

6. Choi, Jun-Ki, and Vasilis Fthenakis. "Design and Optimization of Photovoltaics Recycling Infrastructure." *Environmental Science & Technology*, 44.22 (2010): 8678.

7. Devonshire, Robin. "The Competitive Technology Environment for LED Lighting." *Journal of Light & Visual Environment*, 32.3 (2008): 275-287

8. Garcia, J, M.A Dalla-Costa, J Cardesin, J.M Alonso, and M Rico-Secades. "Dimming of High-Brightness LEDs by Means of Luminous Flux Thermal Estimation." *IEEE Transactions on Power Electronics*, 24.4 (2009): 1107-1114.

9. Kang, B, B Yong, and K Park. "Performance Evaluations of LED Headlamps." *International Journal of Automotive Technology*, 11.5 (2010): 737-742.

10. "NREL Updates Solar Radiation Database." *News Rx Health & Science*, (2012): 395.

11. Paolo, Visconti, Romanello Daniele, Zizzari Giovanni, Ventura Vito, and Cavalera Giorgio. "Design, Measurements and Characterization of Smart Electronic Board for PV Streetlight Based on LED and High Intensity Discharge Lamps." *International Journal of Measurement Technologies and Instrumentation Engineering* (*IJMTIE*), 1.3 (2011): 1-13.

12. Polman, Albert, and Harry A Atwater. "Photonic Design Principles for Ultrahigh-efficiency Photovoltaics." *Nature Materials*, 11.3 (2012): 174.

13. Rehn, H, and U Hartwig. "A Solar Simulator Design for Concentrating Photovoltaics." *Proceedings of SPIE*, 7785.1 (2010).

14. Schoettle, B, M Sivak, and MJ Flannagan. "LED Headlamps: Glare and Colour Rendering." *Lighting Research & Technology*, 36.4 (2004): 295-303.

15. Sivak, Michael, Brandon Schoettle, Takako Minoda, and Michael Flannagan. "Short-Wavelength Content of LED Headlamps and Discomfort Glare." *Leukos*, 2.2 (2005): 145.

16. Tianze, Li, Lu Hengwei, Jiang Chuan, Hou Luan, and Zhang Xia. "Application and Design of Solar Photovoltaic System." *Journal of Physics: Conference Series*, 276 (2011): 012175.

B. *E-mails*

The following is an email from Caryle (Kay) Bradford of Plant Ops where we received the schematic for current outdoor lighting on campus:

Geoff,

Please find attached a pdf (full-size 24” x 26”) of the campus lighting system similar to

the one your team viewed at Plant Ops this morning.

Please let me know if I can be of further assistance to you.

Good luck with your senior capstone project!

C. Kay Bradford
HUMBOLDT STATE UNIVERSITY
Drafting Technician II - Plant Operations
707.826.5907
kay.bradford@humboldt.edu

The following is an email sent to Silas Biggins of Plant Operations for information:

Mr. Biggin,
My name is Augie and I'm an environmental science major doing my senior project on lighting on campus. Our last part is to compare the lights we want to use with lights already on campus to see the cost difference per life of different bulbs. We are interested in the wattage, company and any other information there is about the lights

that line Harpst street. Particularly the lights on the older looking light housings in front of college creek. If you have that information it would be greatly appreciated.
Thank You,
Augie
student ID 943496808

The following is an email sent to the Women's Resource Center:

My name is Augie Gonzalez and I came in a few weeks ago and talked with Corrine about places on campus where there is inadequate lighting for safety. If you could get back to me with areas that you feel need more lighting, our group will talk with Plant Ops to try and solve those lighting issues. Email is good or you can reach me at 831-869-0417.

Thank You,

Augie Gonzalez

The following is an attempt to obtain maintenance schedules and/or labor hours for the outdoor electrical lighting fixtures.

Good morning,

Kay said she spoke with you about my group's street lighting project. Is it feasible for you to pull maintenance records and/or schedules for the outdoor electrical lighting, or are those labor hours lumped in with other schedules, or is it on a work order basis, or...I could speculate for hours, but I'll stop there. We just want to make sure that if our proposal is implemented that there will be equal or less work for Plant Ops in the future. Please feel free to contact me via e-mail or phone (951.790.8639) with any questions and/or comments. Thanks for your time and have an awesome day.

Best Always,

Jeff Borum

Jeff,
I've been looking into this, and unfortunately there isn't a way to accurately capture our maintenance time for outdoor lighting. We do have a scheduled maintenance program, but for the most part we repair lights on an as-needed basis and the hours are potentially lumped together with other work. The records are kept in our Maintenance Management System, but they aren't categorized by outside lighting specifically. We could run a search with key words, but I don't think that would accurately reflect the total maintenance. We can however, track future maintenance. Hope this helps, let me know if there's anything else I can do to help out.

Zach

Zach Shelton
Construction Manager/ JOC Coordinator
Facilities Management
Humboldt State University
707.826.5902 office
707.267.4592 cell
707.826.5888 fax
zds6@humboldt.edu

The following are e-mails related to the CCAT grant (only source of funding):

Hey Jeff!

You should've seen another email CC'ed to you a second ago.

We have received your grant request -- it sounds like a great project! -- and I'm running it by Associated

Students for final approval. I'll let you know how it goes as soon as I can.

If you have any questions, please feel free to email or call me back at 707-674-5552.

Thanks!

From Roger to Liz S. in reference to funds allocation:

Hi Liz!

One of our classes, ENVS 411 (Sustainable Campus) would like to purchase some class materials for a group of theirs.

I believe these items are permissible under IRA criteria, but I just wanted to be 100% sure before I give them the OK to purchase. As part of an evaluation of campus lighting systems, they are building prototype units to show to Plant Ops.

They want to buy:

- 2 10W LED Flood Light $25.80
- 2 20W LED Flood Light w/ Motion Sensor $77.98
- Power Supply Parts $46.20
- Free Shipping! :)
- Total: $149.98

Does that seem acceptable to you?

Thanks!

Dear Jeffrey,

I spoke to the Associated Students and they have approved your purchase request for $150. You may go ahead and purchase the equipment.

The safest way to do this (but also the slowest) is to request a[n] invoice from the merchant, after which AS can send them a paper check. This will take at least 3-4 days for them to get the check, and longer if they need time to process/cash the check.

The quicker way is for you to buy the items yourself and then get reimbursed from AS. If you do this, please be ABSOLUTELY SURE that you get an official, itemized receipt from the vendor. You cannot get reimbursed without an itemized receipt. After you get that, provide me with the receipt and I will fill out a reimbursement form for you, and you should see get a check in about a week.

Please let me know if you have any questions regarding the process.

707-674-5552

Thanks!

Roger

C. Figures, Tables & Diagrams

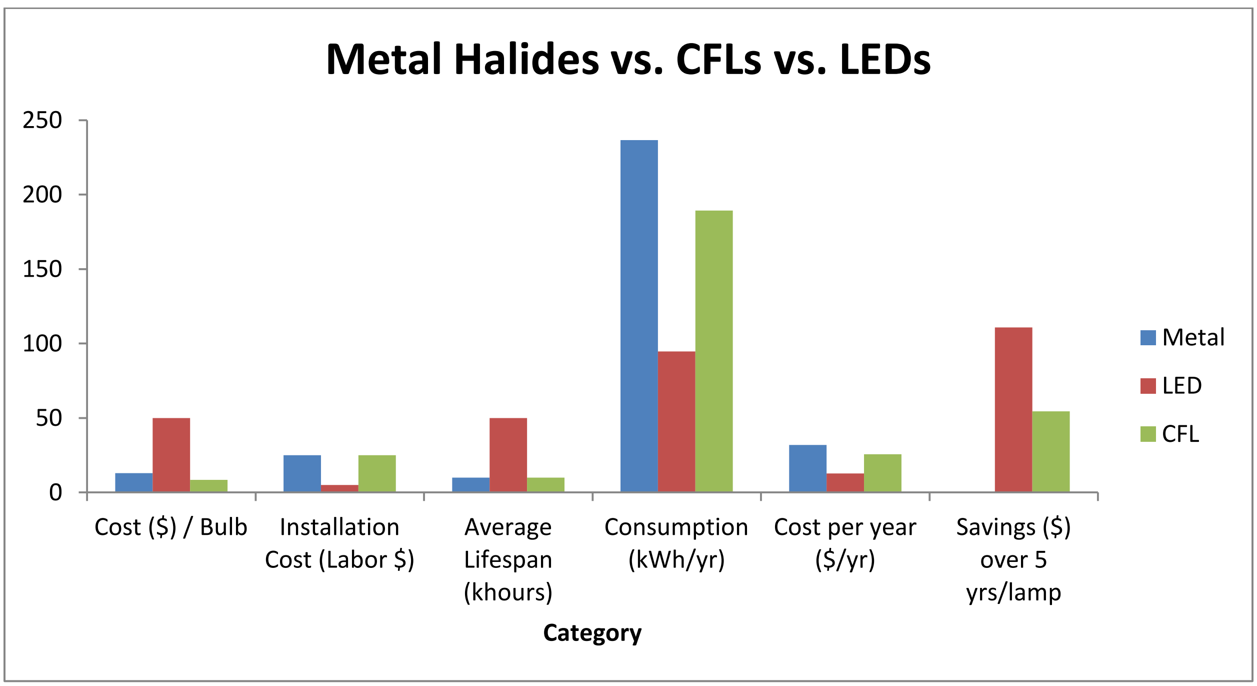


Figure 1: Comparison Analysis between metal halides, compact fluorescent lamps, and light emitting diodes.

	Cost ($) / Bulb	Installation Cost (Labor)	Average Lifespan (khours)	Consumption (kWh/yr)	Cost per year ($/yr)	Savings ($) over 5 yrs/lamp
Metal	$13.00	$25.00	10	236.52	31.93	
LED	$50.00	$5.00	50	94.6	12.77	110.8
CFL	$8.50	$25.00	10	189.22	25.54	54.45

Table 1: Data utilized for figure 1 comparison charts.

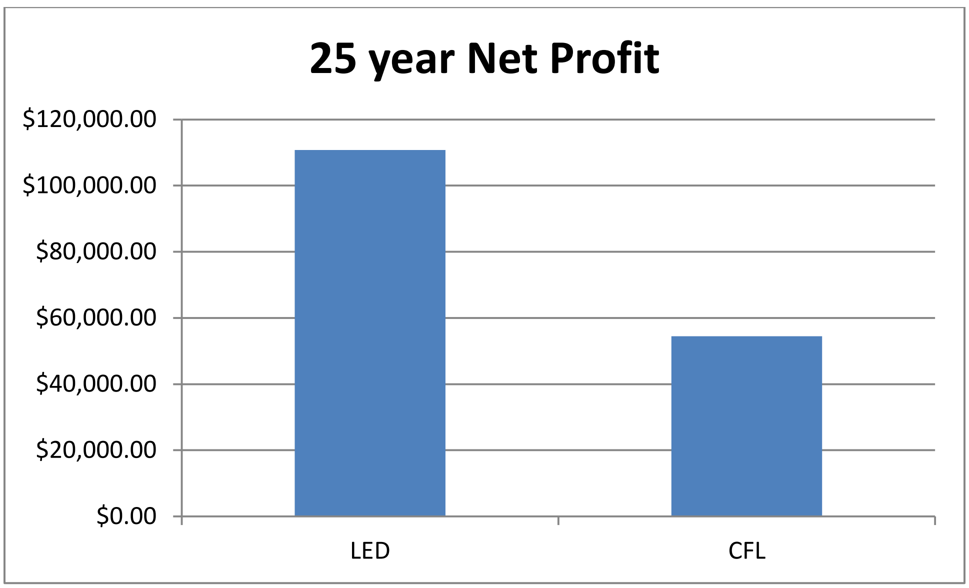
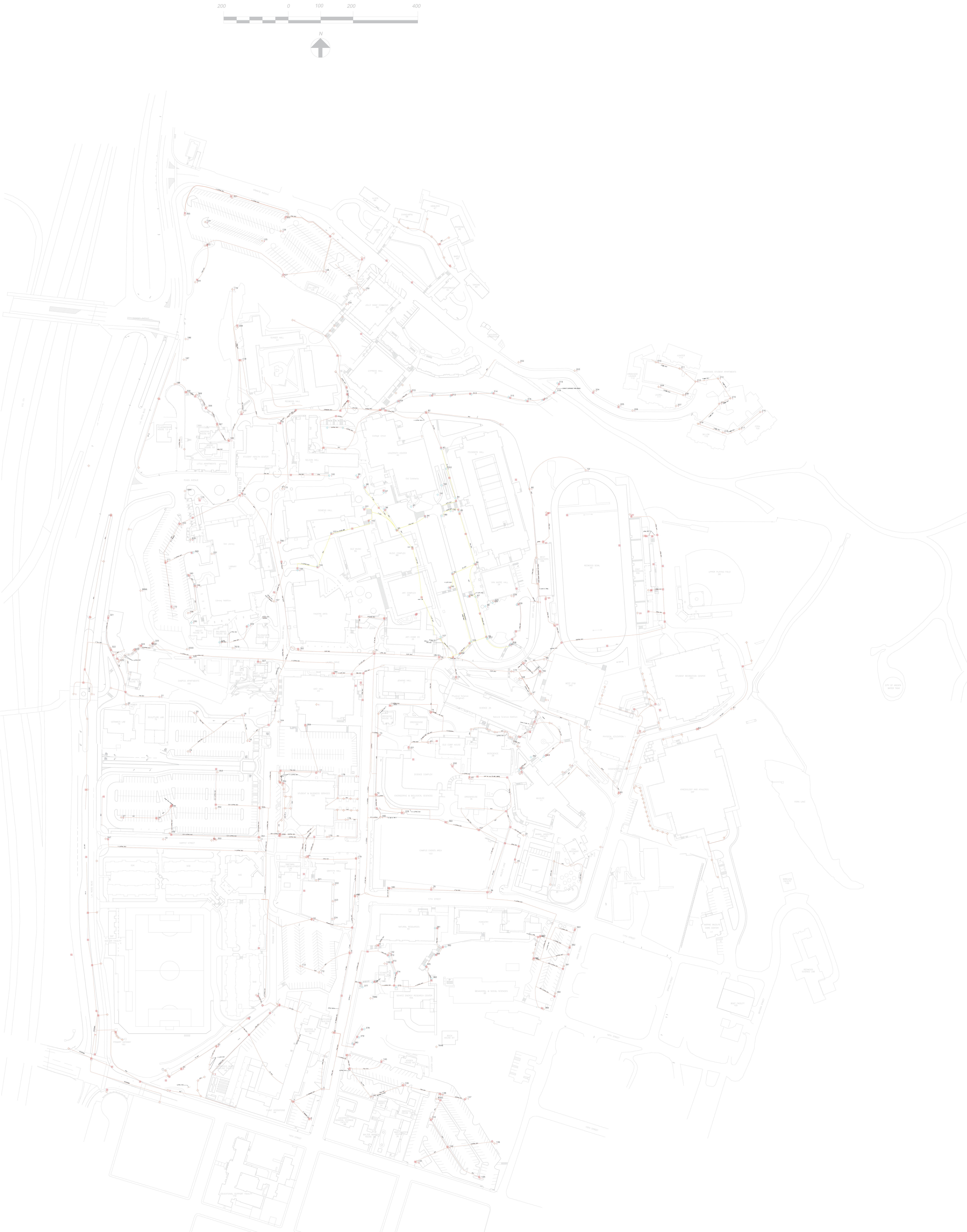


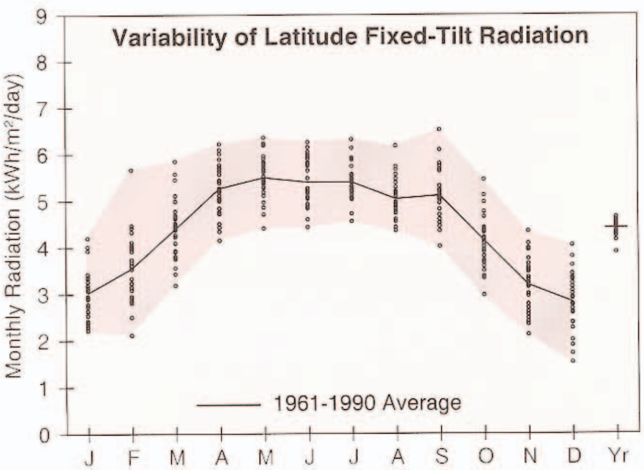
Figure 2: The total amount the university could profit over a 25 year period if the campus switched to LED or CFL bulbs. These extrapolations assume that 200, 5-yr lamp cycles shall be completed within the duration of the 25 years; this is based off of the lifespan of the bulbs and the number of outdoor streetlamps on campus.

HUMBOLDT STATE UNIVERSITY



STREET LIGHT SYSTEM LEGEND

SYMBOL	INDICATES
	STREET LIGHT SYSTEM
245 2	STREETLIGHT & POLE NUMBER NUMBER OF HEADS STREETLIGHT DATA
	STREETLIGHT PULLBOX



Arcata, CA

WBAN NO. 24283

LATITUDE: 40.98° N
LONGITUDE: 124.10° W
ELEVATION: 69 meters
MEAN PRESSURE: 1010 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	2.5	3.6	5.0	5.8	6.0	5.9	5.0	4.4	3.1	2.0	1.6	3.9
	Min/Max	1.5/2.2	1.8/3.4	2.8/4.5	4.1/5.8	4.8/6.6	5.0/7.0	5.1/6.8	4.5/6.0	3.7/5.3	2.5/3.7	1.6/2.4	1.1/2.0	3.6/4.1
Latitude -15	Average	2.7	3.3	4.3	5.4	5.9	5.9	5.8	5.3	5.1	3.9	2.9	2.5	4.4
	Min/Max	2.0/3.6	2.1/5.1	3.2/5.6	4.3/6.3	4.7/6.8	4.8/6.8	4.9/6.8	4.6/6.4	4.1/6.4	2.9/5.1	2.0/3.8	1.4/3.5	4.0/4.6
Latitude	Average	3.0	3.5	4.4	5.3	5.5	5.4	5.4	5.0	5.1	4.1	3.2	2.8	4.4
	Min/Max	2.2/4.2	2.1/5.7	3.2/5.8	4.2/6.2	4.4/6.4	4.4/6.3	4.6/6.3	4.4/6.2	4.0/6.5	3.0/5.4	2.1/4.3	1.5/4.0	3.9/4.6
Latitude +15	Average	3.2	3.6	4.3	4.9	4.9	4.7	4.7	4.6	4.9	4.1	3.3	3.0	4.2
	Min/Max	2.3/4.5	2.1/5.9	3.0/5.8	3.8/5.8	3.9/5.6	3.9/5.4	4.0/5.5	4.0/5.6	3.8/6.3	2.9/5.5	2.1/4.6	1.5/4.4	3.6/4.4
90	Average	2.9	3.0	3.2	3.2	2.8	2.5	2.6	2.8	3.4	3.3	2.9	2.8	3.0
	Min/Max	2.0/4.2	1.7/5.1	2.3/4.4	2.5/3.7	2.3/3.1	2.3/2.8	2.3/2.9	2.5/3.4	2.7/4.4	2.3/4.5	1.8/4.2	1.3/4.2	2.5/3.1

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	2.5	3.3	4.7	6.4	7.3	7.5	7.3	6.3	5.8	4.1	2.8	2.3	5.0
	Min/Max	1.9/3.5	1.9/5.4	3.2/6.5	4.8/7.9	5.5/8.8	5.7/9.2	5.9/9.0	5.2/8.0	4.4/7.7	3.0/5.6	1.9/3.8	1.3/3.2	4.5/5.4
Latitude -15	Average	3.2	3.9	5.3	6.8	7.5	7.5	7.4	6.5	6.4	4.8	3.4	2.9	5.5
	Min/Max	2.3/4.6	2.2/6.7	3.5/7.4	5.1/8.4	5.5/8.9	5.6/9.2	5.9/9.1	5.3/8.4	4.8/8.6	3.3/6.6	2.2/4.8	1.5/4.3	4.8/5.9
Latitude	Average	3.5	4.1	5.3	6.7	7.2	7.2	7.1	6.4	6.4	5.0	3.7	3.2	5.5
	Min/Max	2.4/5.0	2.2/7.1	3.5/7.6	4.9/8.4	5.3/8.7	5.3/8.8	5.6/8.8	5.2/8.2	4.7/8.7	3.3/6.9	2.3/5.2	1.6/4.7	4.7/5.9
Latitude +15	Average	3.6	4.2	5.2	6.4	6.8	6.7	6.6	6.0	6.3	5.0	3.8	3.4	5.3
	Min/Max	2.5/5.3	2.2/7.3	3.4/7.5	4.7/8.0	5.0/8.2	4.9/8.3	5.2/8.2	4.9/7.8	4.6/8.5	3.3/6.9	2.3/5.4	1.6/5.0	4.6/5.7

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	3.6	4.2	5.4	6.8	7.5	7.7	7.5	6.5	6.5	5.0	3.8	3.4	5.7
	Min/Max	2.5/5.3	2.2/7.3	3.5/7.6	5.1/8.4	5.6/9.1	5.7/9.4	6.0/9.2	5.3/8.4	4.8/8.7	3.3/6.9	2.3/5.4	1.6/5.1	4.9/6.1

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	2.0	2.1	2.4	3.1	3.5	3.5	3.4	2.8	3.1	2.5	2.1	2.0	2.7
	Min/Max	1.2/3.6	0.7/4.8	1.2/4.3	1.7/4.4	1.9/4.7	1.8/4.9	2.0/4.9	1.7/4.5	1.8/4.9	1.2/4.1	0.8/3.4	0.6/3.4	2.2/3.1
1-Axis, N-S Horiz Axis	Average	1.5	1.8	2.7	3.9	4.5	4.5	4.4	3.6	3.7	2.5	1.6	1.3	3.0
	Min/Max	0.8/2.6	0.6/4.3	1.3/4.8	2.1/5.6	2.5/6.2	2.3/6.4	2.7/6.4	2.2/5.7	2.1/5.9	1.2/4.1	0.7/2.6	0.4/2.3	2.5/3.5
1-Axis, N-S Tilt=Latitude	Average	2.2	2.5	3.2	4.2	4.4	4.2	4.3	3.7	4.2	3.2	2.4	2.1	3.4
	Min/Max	1.3/4.0	0.8/5.8	1.5/5.7	2.3/5.9	2.4/6.1	2.2/6.0	2.5/6.2	2.3/5.9	2.4/6.7	1.5/5.2	0.9/3.9	0.6/3.6	2.7/3.9
2-Axis	Average	2.4	2.6	3.2	4.2	4.7	4.6	4.6	3.9	4.3	3.3	2.5	2.3	3.5
	Min/Max	1.3/4.3	0.8/5.9	1.5/5.7	2.3/6.1	2.5/6.5	2.3/6.5	2.7/6.6	2.3/6.1	2.4/6.7	1.5/5.3	1.0/4.1	0.7/3.9	2.8/4.0

Average Climatic Conditions

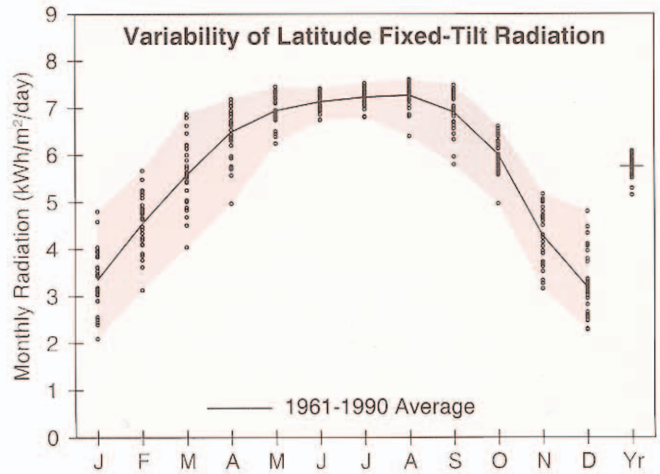
Element	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Year
Temperature (°C)	7.8	8.7	8.9	9.5	11.2	12.8	13.6	13.8	13.2	11.7	9.9	8.0	10.8
Daily Minimum Temp	3.8	4.7	5.0	5.3	7.2	9.0	10.1	10.4	9.1	7.5	5.9	4.1	6.8
Daily Maximum Temp	12.2	12.7	12.7	13.4	14.7	16.3	17.2	17.4	17.7	16.1	14.2	12.2	14.7
Record Minimum Temp	-6.7	-5.0	-3.9	-1.7	0.0	1.7	2.8	4.4	0.6	-3.3	-2.8	-8.3	-8.3
Record Maximum Temp	23.9	25.6	23.9	25.6	31.1	27.2	27.8	31.7	32.2	29.4	24.4	23.3	32.2
HDD, Base 18.3°C	329	276	295	269	226	171	151	144	157	211	257	324	2809
CDD, Base 18.3°C	0	0	0	0	0	0	0	0	0	0	0	0	0
Relative Humidity (%)	82	81	82	81	83	85	85	87	87	87	84	83	84
Wind Speed (m/s)	2.9	3.2	3.5	3.4	3.4	3.0	2.8	2.4	2.3	2.3	2.8	2.8	2.9

Bakersfield, CA

WBAN NO. 23155

LATITUDE: 35.42° N
LONGITUDE: 119.05° W
ELEVATION: 150 meters
MEAN PRESSURE: 998 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	2.3	3.3	4.7	6.2	7.4	8.1	8.0	7.2	5.9	4.4	2.9	2.1	5.2
	Min/Max	1.8/2.9	2.6/3.9	3.6/5.5	4.8/6.8	6.7/7.9	7.6/8.4	7.4/8.4	6.4/7.6	5.1/6.4	3.8/4.8	2.4/3.3	1.8/2.7	4.8/5.4
Latitude -15	Average	3.0	4.2	5.4	6.6	7.4	7.8	7.8	7.5	6.8	5.5	3.8	2.8	5.7
	Min/Max	2.0/4.2	3.0/5.1	4.0/6.5	5.1/7.3	6.7/7.9	7.3/8.1	7.3/8.2	6.6/7.9	5.7/7.3	4.7/6.1	2.9/4.5	2.1/4.1	5.2/6.0
Latitude	Average	3.3	4.5	5.6	6.5	6.9	7.1	7.2	7.3	6.9	6.0	4.3	3.2	5.7
	Min/Max	2.1/4.8	3.1/5.7	4.0/6.9	5.0/7.2	6.2/7.4	6.7/7.4	6.8/7.5	6.4/7.6	5.8/7.5	5.0/6.6	3.2/5.2	2.3/4.8	5.2/6.1
Latitude +15	Average	3.5	4.7	5.5	6.0	6.1	6.1	6.2	6.6	6.7	6.1	4.5	3.4	5.4
	Min/Max	2.1/5.2	3.1/5.9	3.9/6.8	4.6/6.7	5.5/6.5	5.8/6.3	5.9/6.4	5.8/6.9	5.6/7.2	5.0/6.8	3.2/5.5	2.3/5.2	4.8/5.8
90	Average	3.0	3.8	3.8	3.4	2.8	2.4	2.6	3.3	4.3	4.7	3.9	3.0	3.4
	Min/Max	1.7/4.6	2.4/4.8	2.7/4.8	2.7/3.8	2.6/2.9	2.3/2.4	2.5/2.6	3.0/3.4	3.6/4.6	3.8/5.3	2.7/4.8	2.0/4.8	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	3.0	4.5	6.3	8.4	10.1	11.0	11.1	10.1	8.5	6.3	3.9	2.7	7.2
	Min/Max	1.9/4.3	3.1/5.6	4.4/7.9	6.0/9.5	8.8/11.1	10.2/11.8	10.0/11.9	8.5/10.9	6.9/9.4	5.2/7.1	2.8/4.8	2.0/4.1	6.3/7.6
Latitude -15	Average	3.5	5.1	6.8	8.7	10.2	11.0	11.1	10.5	9.1	7.2	4.7	3.3	7.6
	Min/Max	2.1/5.2	3.4/6.5	4.7/8.7	6.2/9.9	8.8/11.2	10.1/11.7	10.0/11.9	8.7/11.2	7.4/10.1	5.8/8.0	3.3/5.7	2.3/5.1	6.7/8.1
Latitude	Average	3.8	5.4	7.0	8.7	9.9	10.5	10.7	10.3	9.2	7.5	5.0	3.6	7.6
	Min/Max	2.2/5.7	3.5/6.9	4.8/8.9	6.1/9.9	8.6/10.9	9.7/11.2	9.6/11.5	8.6/11.0	7.4/10.3	6.1/8.4	3.5/6.2	2.5/5.7	6.7/8.1
Latitude +15	Average	3.9	5.5	6.9	8.3	9.3	9.8	10.0	9.8	9.0	7.6	5.2	3.8	7.4
	Min/Max	2.2/6.0	3.5/7.1	4.7/8.9	5.9/9.5	8.1/10.3	9.1/10.4	9.0/10.8	8.1/10.5	7.3/10.1	6.1/8.5	3.6/6.5	2.5/6.0	6.4/7.9

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

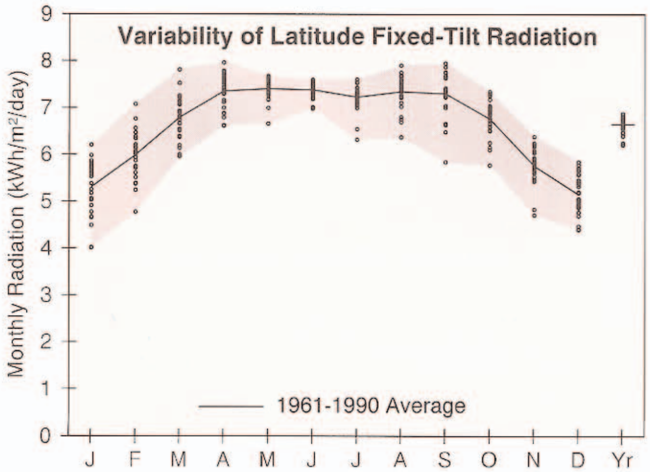
Tracker		Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Year
2-Axis	Average	4.0	5.5	7.0	8.8	10.3	11.2	11.3	10.5	9.2	7.6	5.2	3.8	7.9
	Min/Max	2.2/6.1	3.5/7.1	4.8/9.0	6.2/10.0	8.9/11.4	10.4/11.9	10.1/12.1	8.8/11.3	7.5/10.3	6.2/8.5	3.6/6.5	2.5/6.1	6.9/8.4

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	2.9	3.5	4.5	5.6	6.5	6.5	5.9	5.2	4.4	3.0	2.0	4.3
	Min/Max	0.6/3.8	1.4/4.2	1.8/5.1	2.5/5.5	4.6/6.6	5.7/7.1	5.6/7.3	4.5/6.6	3.7/6.1	3.3/5.2	1.6/4.0	0.9/3.9	3.5/4.8
1-Axis, N-S Horiz Axis	Average	1.6	2.7	4.0	5.8	7.5	8.6	8.7	7.9	6.5	4.6	2.5	1.5	5.2
	Min/Max	0.5/3.0	1.3/3.9	2.1/5.9	3.2/7.2	6.0/8.8	7.5/9.5	7.3/9.9	5.8/8.9	4.6/7.7	3.4/5.5	1.3/3.3	0.7/2.9	4.1/5.6
1-Axis, N-S Tilt=Latitude	Average	2.2	3.5	4.6	6.0	7.2	8.0	8.2	7.9	7.1	5.5	3.4	2.2	5.5
	Min/Max	0.6/4.2	1.7/5.0	2.4/6.7	3.3/7.4	5.8/8.5	7.1/8.9	6.9/9.4	5.9/8.9	5.0/8.4	4.2/6.6	1.8/4.6	1.0/4.2	4.3/6.0
2-Axis	Average	2.4	3.5	4.6	6.1	7.7	8.7	8.9	8.2	7.1	5.6	3.5	2.3	5.7
	Min/Max	0.7/4.4	1.7/5.1	2.4/6.8	3.4/7.6	6.1/9.0	7.7/9.6	7.4/10.1	6.1/9.2	5.0/8.4	4.2/6.7	1.9/4.8	1.1/4.6	4.5/6.3

Average Climatic Conditions

Element	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Year
Temperature (°C)	8.8	11.8	14.1	17.2	21.7	25.7	28.9	28.1	24.9	19.9	13.2	8.6	18.6
Daily Minimum Temp	3.7	5.9	7.7	10.1	14.1	17.8	20.9	20.3	17.5	12.7	7.1	3.5	11.8
Daily Maximum Temp	13.8	17.7	20.5	24.4	29.2	33.6	36.9	35.9	32.3	27.1	19.3	13.6	25.4
Record Minimum Temp	-6.7	-3.9	-0.6	1.1	2.8	7.2	11.1	11.1	7.2	-1.7	-2.2	-7.2	-7.2
Record Maximum Temp	27.8	30.6	33.3	38.3	41.7	45.6	46.1	44.4	44.4	39.4	32.8	28.3	46.1
HDD, Base 18.3°C	296	184	137	80	16	3	0	0	4	33	157	302	1212
CDD, Base 18.3°C	0	0	6	47	119	223	329	303	201	82	4	0	1314
Relative Humidity (%)	76	69	61	51	41	36	34	39	44	50	65	76	53
Wind Speed (m/s)	2.5	2.7	3.0	3.3	3.6	3.5	3.3	3.1	2.9	2.7	2.5	2.5	3.0



Daggett, CA

WBAN NO. 23161

LATITUDE: 34.87° N
LONGITUDE: 116.78° W
ELEVATION: 588 meters
MEAN PRESSURE: 947 millibars

STATION TYPE: Primary

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	3.2	4.2	5.5	7.0	7.9	8.4	8.0	7.3	6.3	4.9	3.6	2.9	5.8
	Min/Max	2.6/3.5	3.5/4.7	4.9/6.2	6.3/7.5	7.2/8.2	7.9/8.7	6.9/8.5	6.4/7.9	5.1/6.8	4.3/5.2	3.1/3.9	2.6/3.2	5.5/6.0
Latitude -15	Average	4.6	5.4	6.5	7.5	7.9	8.1	7.8	7.6	7.1	6.2	5.0	4.4	6.5
	Min/Max	3.5/5.3	4.4/6.3	5.7/7.4	6.7/8.1	7.1/8.2	7.7/8.4	6.8/8.3	6.6/8.2	5.7/7.8	5.3/6.7	4.2/5.5	3.8/4.9	6.1/6.7
Latitude	Average	5.3	6.0	6.8	7.4	7.4	7.4	7.2	7.3	7.3	6.8	5.8	5.2	6.6
	Min/Max	4.0/6.2	4.8/7.1	6.0/7.8	6.6/8.0	6.7/7.7	7.0/7.6	6.3/7.6	6.4/7.9	5.8/7.9	5.8/7.3	4.7/6.4	4.4/5.8	6.2/6.9
Latitude +15	Average	5.7	6.2	6.7	6.8	6.5	6.3	6.2	6.6	7.0	6.9	6.2	5.6	6.4
	Min/Max	4.3/6.8	4.9/7.4	5.8/7.8	6.1/7.4	5.8/6.7	6.0/6.4	5.5/6.5	5.8/7.1	5.6/7.7	5.9/7.5	5.0/6.9	4.8/6.4	5.9/6.6
90	Average	5.2	5.1	4.7	3.8	2.8	2.4	2.5	3.3	4.4	5.4	5.4	5.2	4.2
	Min/Max	3.7/6.2	3.9/6.2	4.0/5.4	3.4/4.0	2.6/2.9	2.2/2.5	2.3/2.6	3.0/3.4	3.6/4.8	4.5/5.9	4.3/6.1	4.3/6.0	3.8/4.3

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	4.9	6.2	8.1	10.0	11.1	11.8	11.2	10.5	9.3	7.5	5.5	4.6	8.4
	Min/Max	3.7/5.7	4.6/7.4	7.0/9.6	8.6/11.0	9.9/11.6	10.9/12.4	9.0/12.2	8.5/11.6	7.0/10.4	6.2/8.2	4.4/6.3	3.9/5.2	7.7/8.8
Latitude -15	Average	5.9	7.1	8.8	10.4	11.2	11.7	11.1	10.8	10.0	8.4	6.6	5.6	9.0
	Min/Max	4.4/7.0	5.3/8.6	7.6/10.5	8.9/11.5	10.0/11.7	10.8/12.3	9.0/12.2	8.8/11.9	7.5/11.1	6.9/9.3	5.2/7.4	4.7/6.5	8.2/9.4
Latitude	Average	6.5	7.5	9.0	10.3	10.9	11.2	10.7	10.6	10.1	8.8	7.2	6.3	9.1
	Min/Max	4.8/7.7	5.6/9.1	7.8/10.8	8.8/11.4	9.7/11.4	10.4/11.8	8.7/11.8	8.6/11.7	7.6/11.3	7.3/9.7	5.6/8.1	5.2/7.2	8.3/9.5
Latitude +15	Average	6.8	7.7	8.9	10.0	10.3	10.5	10.1	10.1	9.9	8.9	7.5	6.6	8.9
	Min/Max	4.9/8.1	5.7/9.4	7.7/10.8	8.5/11.0	9.1/10.7	9.7/11.0	8.1/11.1	8.2/11.2	7.4/11.1	7.3/9.9	5.8/8.5	5.5/7.7	8.1/9.4

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	6.9	7.7	9.0	10.4	11.3	12.0	11.4	10.8	10.1	9.0	7.5	6.8	9.4
	Min/Max	5.0/8.2	5.7/9.4	7.8/10.9	8.9/11.5	10.1/11.9	11.1/12.6	9.2/12.5	8.8/12.0	7.6/11.3	7.3/9.9	5.9/8.5	5.6/7.8	8.6/9.9

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	Average	4.5	4.7	5.0	5.7	6.5	7.1	6.6	6.2	5.9	5.5	4.9	4.6	5.6
Horiz Axis	Min/Max	2.9/5.8	3.0/6.2	3.9/6.5	4.4/6.8	5.6/7.0	6.1/7.8	4.6/7.6	4.6/7.2	4.2/6.8	4.1/6.3	3.4/5.9	3.5/5.6	4.8/6.0
1-Axis, N-S	Average	3.7	4.6	6.1	7.7	8.7	9.6	8.8	8.4	7.5	6.0	4.3	3.5	6.6
Horiz Axis	Min/Max	2.4/4.7	2.8/6.2	4.7/8.1	5.8/9.1	7.6/9.5	8.2/10.4	6.0/10.4	6.0/9.9	5.1/9.0	4.3/6.9	2.9/5.2	2.6/4.3	5.6/7.1
1-Axis, N-S	Average	5.1	5.8	6.9	8.0	8.4	8.9	8.4	8.4	8.2	7.2	5.7	5.0	7.2
Tilt=Latitude	Min/Max	3.3/6.5	3.6/7.8	5.3/9.1	6.0/9.4	7.3/9.2	7.7/9.8	5.7/9.8	6.1/9.9	5.6/9.7	5.2/8.3	3.9/6.9	3.7/6.1	6.1/7.7
2-Axis	Average	5.4	5.9	6.9	8.1	8.9	9.7	9.0	8.7	8.2	7.3	6.0	5.4	7.5
	Min/Max	3.5/7.0	3.7/8.0	5.3/9.1	6.1/9.6	7.7/9.7	8.4/10.6	6.1/10.5	6.2/10.2	5.6/9.8	5.3/8.4	4.1/7.2	4.1/6.6	6.3/8.0

Average Climatic Conditions

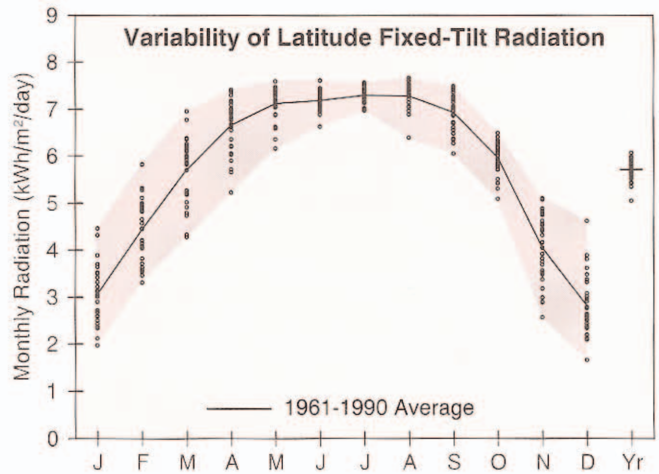
Element	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Year
Temperature (°C)	9.3	12.1	14.6	18.2	23.1	28.2	31.6	30.6	26.5	20.7	13.8	9.2	19.8
Daily Minimum Temp	2.6	5.2	7.8	10.8	15.3	19.7	23.3	22.7	18.7	13.1	6.9	2.6	12.4
Daily Maximum Temp	15.9	18.9	21.4	25.6	30.8	36.6	39.9	38.6	34.3	28.2	20.8	15.8	27.2
Record Minimum Temp	-12.2	-6.7	-2.8	0.6	6.1	9.4	15.0	14.4	9.4	-1.1	-3.9	-12.2	-12.2
Record Maximum Temp	27.8	30.0	32.8	37.2	43.3	46.1	46.7	44.4	42.8	40.6	32.2	26.7	46.7
HDD, Base 18.3°C	281	178	129	67	8	0	0	0	0	22	139	282	1106
CDD, Base 18.3°C	0	0	13	62	154	295	412	381	245	94	4	0	1659
Relative Humidity (%)	47	42	38	32	29	24	24	28	31	33	40	46	35
Wind Speed (m/s)	3.5	4.5	5.9	6.3	6.8	6.4	5.5	4.9	4.7	4.2	4.3	3.8	5.1

Fresno, CA

WBAN NO. 93193

LATITUDE: 36.77° N
LONGITUDE: 119.72° W
ELEVATION: 100 meters
MEAN PRESSURE: 1004 millibars

STATION TYPE: Primary



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	2.1	3.2	4.7	6.3	7.5	8.1	8.0	7.2	5.9	4.3	2.7	1.9	5.2
	Min/Max	1.7/2.7	2.5/3.9	3.7/5.5	5.1/7.0	6.6/8.0	7.4/8.7	7.6/8.4	6.3/7.6	5.2/6.3	3.9/4.6	2.0/3.2	1.4/2.6	4.7/5.4
Latitude -15	Average	2.8	4.1	5.5	6.8	7.6	7.8	7.9	7.5	6.8	5.5	3.6	2.5	5.7
	Min/Max	1.9/3.9	3.1/5.3	4.2/6.6	5.4/7.5	6.6/8.1	7.2/8.3	7.5/8.2	6.6/7.9	5.9/7.3	4.8/6.0	2.4/4.5	1.6/3.9	5.1/6.0
Latitude	Average	3.1	4.4	5.7	6.7	7.1	7.2	7.3	7.3	6.9	6.0	4.1	2.8	5.7
	Min/Max	2.0/4.5	3.3/5.8	4.3/6.9	5.2/7.4	6.2/7.6	6.6/7.6	7.0/7.6	6.4/7.7	6.1/7.5	5.1/6.5	2.6/5.1	1.7/4.6	5.1/6.1
Latitude +15	Average	3.2	4.5	5.6	6.2	6.3	6.1	6.3	6.6	6.7	6.1	4.2	3.0	5.4
	Min/Max	2.0/4.8	3.3/6.1	4.1/6.9	4.8/6.9	5.4/6.7	5.7/6.4	6.0/6.5	5.8/6.9	5.8/7.2	5.1/6.6	2.6/5.4	1.7/5.0	4.7/5.8
90	Average	2.8	3.7	4.0	3.6	3.0	2.6	2.7	3.5	4.4	4.8	3.7	2.6	3.4
	Min/Max	1.6/4.3	2.6/5.1	2.9/4.9	2.9/4.0	2.7/3.2	2.5/2.8	2.6/2.9	3.2/3.6	3.8/4.8	3.9/5.3	2.2/4.8	1.4/4.7	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	2.7	4.3	6.4	8.5	10.2	11.0	11.2	10.1	8.3	6.2	3.7	2.4	7.1
	Min/Max	1.8/3.9	3.3/5.7	4.5/8.0	6.5/10.0	8.7/11.3	9.8/12.2	10.1/11.8	8.0/10.9	7.1/9.3	5.0/6.8	2.3/4.7	1.5/3.9	6.0/7.6
Latitude -15	Average	3.2	5.0	7.0	9.0	10.4	10.9	11.2	10.4	9.1	7.1	4.4	2.9	7.5
	Min/Max	2.0/4.8	3.7/6.7	4.9/8.9	6.8/10.5	8.8/11.5	9.8/12.1	10.2/11.8	8.3/11.3	7.7/10.0	5.7/7.8	2.6/5.6	1.6/4.9	6.3/8.1
Latitude	Average	3.4	5.2	7.2	8.9	10.1	10.5	10.8	10.3	9.2	7.4	4.7	3.1	7.6
	Min/Max	2.1/5.2	3.9/7.1	4.9/9.1	6.7/10.5	8.5/11.1	9.3/11.6	9.8/11.4	8.1/11.1	7.8/10.2	6.0/8.2	2.8/6.1	1.7/5.4	6.3/8.2
Latitude +15	Average	3.5	5.3	7.1	8.6	9.5	9.8	10.1	9.8	9.0	7.5	4.9	3.2	7.4
	Min/Max	2.0/5.5	4.0/7.3	4.8/9.0	6.4/10.1	8.0/10.5	8.7/10.9	9.1/10.7	7.7/10.6	7.6/10.0	6.0/8.3	2.8/6.4	1.7/5.8	6.0/8.0

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

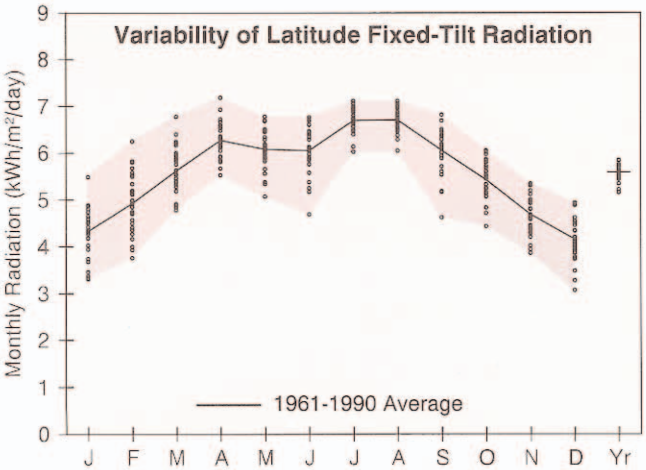
Tracker		Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Year
2-Axis	Average	3.6	5.3	7.2	9.0	10.5	11.2	11.4	10.5	9.2	7.5	4.9	3.3	7.8
	Min/Max	2.1/5.5	4.0/7.3	4.9/9.1	6.8/10.6	8.9/11.6	9.9/12.4	10.3/12.1	8.3/11.4	7.8/10.2	6.0/8.3	2.8/6.4	1.7/5.8	6.5/8.4

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	1.8	2.7	3.6	4.6	5.7	6.4	6.6	5.9	5.1	4.3	2.7	1.7	4.3
	Min/Max	0.5/3.4	1.7/4.4	2.0/5.2	2.7/5.9	4.4/6.8	4.6/7.4	5.7/7.3	4.2/6.7	4.0/5.9	2.9/5.0	1.2/4.0	0.5/3.8	3.2/4.8
1-Axis, N-S Horiz Axis	Average	1.3	2.5	4.1	5.9	7.6	8.4	8.8	7.8	6.3	4.3	2.2	1.2	5.1
	Min/Max	0.4/2.6	1.5/4.1	2.1/6.0	3.6/7.9	5.8/9.0	5.8/10.0	7.2/9.9	5.2/9.0	4.8/7.4	2.8/5.2	0.9/3.3	0.4/2.7	3.7/5.8
1-Axis, N-S Tilt=Latitude	Average	1.9	3.3	4.7	6.2	7.3	7.9	8.4	7.9	6.9	5.4	3.1	1.8	5.4
	Min/Max	0.6/3.7	2.0/5.3	2.5/6.9	3.8/8.2	5.7/8.8	5.4/9.4	6.8/9.4	5.3/9.1	5.3/8.1	3.5/6.3	1.3/4.6	0.5/4.0	3.9/6.2
2-Axis	Average	2.1	3.4	4.8	6.3	7.8	8.6	9.0	8.1	7.0	5.4	3.2	1.9	5.6
	Min/Max	0.6/4.0	2.0/5.4	2.5/6.9	3.8/8.4	6.0/9.3	5.9/10.2	7.3/10.1	5.4/9.4	5.3/8.2	3.5/6.4	1.3/4.8	0.6/4.3	4.1/6.4

Average Climatic Conditions

Element	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Year
Temperature (°C)	7.6	10.7	12.8	16.2	20.6	24.8	27.7	26.8	23.6	18.4	12.0	7.4	17.4
Daily Minimum Temp	3.0	4.7	6.3	8.5	12.1	15.8	18.4	17.7	14.9	10.4	5.8	2.8	10.1
Daily Maximum Temp	12.3	16.5	19.2	23.9	29.0	33.7	37.0	35.9	32.3	26.5	18.2	12.1	24.7
Record Minimum Temp	-7.2	-4.4	-3.3	0.0	2.2	6.7	10.0	9.4	2.8	-2.8	-3.3	-7.8	-7.8
Record Maximum Temp	25.6	26.7	32.2	37.8	41.7	43.3	44.4	43.9	43.9	38.9	31.7	24.4	44.4
HDD, Base 18.3°C	332	214	174	101	19	0	0	0	4	47	190	338	1420
CDD, Base 18.3°C	0	0	4	38	88	196	291	263	163	51	0	0	1093
Relative Humidity (%)	83	77	69	57	47	42	39	45	50	58	74	84	60
Wind Speed (m/s)	2.2	2.5	3.0	3.4	3.8	3.8	3.4	3.1	2.8	2.3	2.1	2.1	2.9



Long Beach, CA

WBAN NO. 23129

LATITUDE: 33.82° N
LONGITUDE: 118.15° W
ELEVATION: 17 meters
MEAN PRESSURE: 1014 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	2.8	3.6	4.7	6.0	6.4	6.7	7.3	6.7	5.4	4.2	3.1	2.6	5.0
	Min/Max	2.3/3.3	2.9/4.3	4.1/5.6	5.3/6.8	5.4/7.2	5.2/7.5	6.5/7.7	6.1/7.1	4.3/5.9	3.6/4.6	2.8/3.5	2.1/2.9	4.6/5.2
Latitude -15	Average	3.8	4.5	5.4	6.4	6.4	6.5	7.2	6.9	6.0	5.0	4.1	3.6	5.5
	Min/Max	3.0/4.7	3.5/5.6	4.6/6.5	5.6/7.3	5.4/7.2	5.1/7.3	6.5/7.7	6.3/7.3	4.6/6.7	4.2/5.6	3.5/4.7	2.7/4.2	5.1/5.7
Latitude	Average	4.3	4.9	5.6	6.3	6.1	6.0	6.7	6.7	6.1	5.4	4.7	4.2	5.6
	Min/Max	3.3/5.5	3.8/6.3	4.8/6.8	5.5/7.2	5.1/6.8	4.7/6.8	6.0/7.1	6.1/7.1	4.6/6.8	4.4/6.1	3.9/5.3	3.1/4.9	5.2/5.9
Latitude +15	Average	4.6	5.1	5.5	5.8	5.4	5.2	5.8	6.1	5.8	5.5	5.0	4.5	5.4
	Min/Max	3.5/5.9	3.8/6.5	4.7/6.7	5.1/6.7	4.5/6.0	4.1/5.8	5.3/6.2	5.5/6.5	4.4/6.6	4.4/6.2	4.0/5.7	3.2/5.4	4.9/5.6
90	Average	4.1	4.1	3.8	3.2	2.5	2.2	2.4	3.0	3.7	4.2	4.3	4.1	3.4
	Min/Max	3.0/5.3	3.0/5.3	3.2/4.6	2.9/3.6	2.2/2.7	2.0/2.3	2.3/2.5	2.8/3.2	2.8/4.2	3.3/4.7	3.4/4.9	2.8/4.9	3.2/3.7

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	3.9	4.9	6.3	7.9	8.1	8.4	9.3	8.7	7.1	5.7	4.4	3.7	6.5
	Min/Max	3.0/5.0	3.8/6.3	5.3/7.9	6.7/9.4	6.5/9.4	6.1/9.8	8.0/10.2	7.8/9.3	5.2/8.0	4.6/6.4	3.6/5.0	2.7/4.4	6.0/6.9
Latitude -15	Average	4.7	5.6	6.8	8.2	8.1	8.3	9.3	8.9	7.6	6.3	5.1	4.4	6.9
	Min/Max	3.5/6.0	4.2/7.3	5.7/8.6	7.0/9.8	6.5/9.4	6.0/9.7	8.0/10.2	7.9/9.6	5.5/8.6	5.1/7.2	4.1/5.9	3.2/5.3	6.3/7.3
Latitude	Average	5.1	5.9	7.0	8.1	7.9	7.9	8.9	8.8	7.6	6.6	5.6	4.9	7.0
	Min/Max	3.7/6.6	4.4/7.8	5.8/8.8	6.9/9.8	6.3/9.1	5.7/9.3	7.7/9.8	7.8/9.4	5.5/8.7	5.3/7.6	4.4/6.5	3.4/5.9	6.4/7.4
Latitude +15	Average	5.3	6.0	6.9	7.8	7.4	7.4	8.3	8.3	7.5	6.7	5.8	5.1	6.9
	Min/Max	3.9/7.0	4.5/8.0	5.7/8.7	6.6/9.4	5.9/8.6	5.3/8.7	7.2/9.1	7.4/8.9	5.3/8.5	5.3/7.6	4.6/6.8	3.6/6.3	6.2/7.3

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	5.4	6.0	7.0	8.2	8.2	8.4	9.4	8.9	7.7	6.7	5.8	5.2	7.3
	Min/Max	3.9/7.1	4.5/8.0	5.8/8.8	7.0/9.8	6.6/9.5	6.1/9.9	8.1/10.3	8.0/9.6	5.5/8.7	5.3/7.6	4.6/6.8	3.6/6.4	6.6/7.7

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	Average	3.2	3.3	3.5	4.1	4.0	4.2	5.2	4.8	4.0	3.7	3.5	3.2	3.9
Horiz Axis	Min/Max	2.0/4.6	2.1/4.9	2.6/5.1	3.2/5.5	2.7/5.1	2.0/5.4	4.1/5.9	3.9/5.5	2.2/4.8	2.6/4.5	2.5/4.3	1.8/4.2	3.3/4.3
1-Axis, N-S	Average	2.6	3.2	4.1	5.3	5.2	5.4	6.6	6.2	4.8	3.8	2.9	2.4	4.4
Horiz Axis	Min/Max	1.6/3.7	1.9/4.7	3.0/6.0	4.0/7.1	3.5/6.6	2.7/7.0	5.1/7.6	5.1/7.0	2.7/5.8	2.8/4.7	2.1/3.7	1.4/3.2	3.7/4.7
1-Axis, N-S	Average	3.5	4.0	4.6	5.4	5.0	5.0	6.2	6.2	5.3	4.6	3.9	3.4	4.8
Tilt=Latitude	Min/Max	2.2/5.1	2.4/5.9	3.4/6.7	4.1/7.4	3.3/6.3	2.5/6.6	4.8/7.2	5.1/7.0	2.9/6.3	3.3/5.6	2.8/4.9	2.0/4.5	4.1/5.2
2-Axis	Average	3.8	4.1	4.6	5.5	5.3	5.5	6.7	6.4	5.3	4.6	4.1	3.7	5.0
	Min/Max	2.3/5.4	2.5/6.1	3.4/6.7	4.2/7.5	3.5/6.7	2.7/7.1	5.2/7.7	5.2/7.2	2.9/6.3	3.3/5.7	2.9/5.2	2.1/4.8	4.2/5.4

Average Climatic Conditions

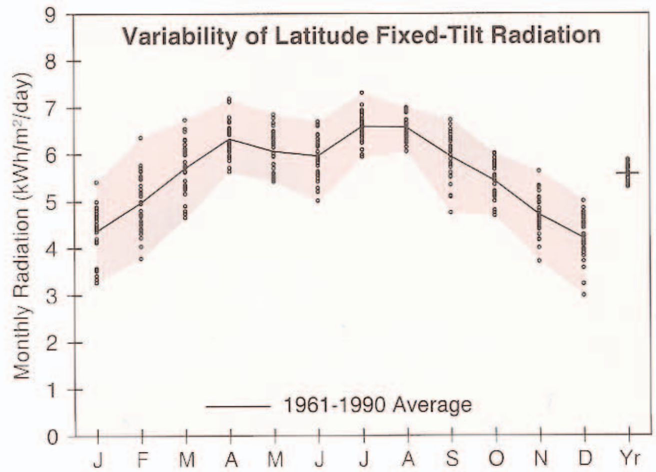
Element	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Year
Temperature (°C)	13.3	14.1	14.7	16.5	18.2	20.3	22.8	23.6	22.4	20.1	16.3	13.3	17.9
Daily Minimum Temp	7.2	8.3	9.4	11.0	13.5	15.4	17.4	18.2	17.1	14.3	10.2	7.2	12.4
Daily Maximum Temp	19.3	19.8	20.0	21.9	22.9	25.0	28.2	28.9	27.8	25.8	22.3	19.4	23.4
Record Minimum Temp	-3.9	0.6	0.6	3.3	4.4	8.3	10.6	11.1	10.0	3.9	1.1	-2.2	-3.9
Record Maximum Temp	32.8	32.8	36.7	40.6	39.4	42.8	41.7	40.6	43.3	43.9	38.3	33.3	43.9
HDD, Base 18.3°C	158	123	119	74	38	22	0	0	8	13	81	158	794
CDD, Base 18.3°C	0	3	7	19	35	80	142	164	132	67	19	0	667
Relative Humidity (%)	64	67	67	66	68	70	69	69	70	68	66	65	67
Wind Speed (m/s)	2.5	2.8	3.1	3.3	3.3	3.1	3.0	3.0	2.8	2.5	2.5	2.3	2.9

Los Angeles, CA

WBAN NO. 23174

LATITUDE: 33.93° N
LONGITUDE: 118.40° W
ELEVATION: 32 meters
MEAN PRESSURE: 1012 millibars

STATION TYPE: Primary



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	2.8	3.6	4.8	6.1	6.4	6.6	7.1	6.5	5.3	4.2	3.2	2.6	4.9
	Min/Max	2.3/3.3	3.0/4.4	4.0/5.6	5.5/6.8	5.7/7.2	5.6/7.7	6.4/8.0	6.1/7.0	4.4/5.8	3.8/4.5	2.7/3.6	2.1/3.0	4.7/5.1
Latitude -15	Average	3.8	4.5	5.5	6.4	6.4	6.4	7.1	6.8	5.9	5.0	4.2	3.6	5.5
	Min/Max	2.9/4.6	3.6/5.7	4.5/6.4	5.8/7.3	5.7/7.3	5.4/7.3	6.3/7.9	6.3/7.2	4.7/6.6	4.4/5.6	3.4/4.9	2.7/4.3	5.2/5.7
Latitude	Average	4.4	5.0	5.7	6.3	6.1	6.0	6.6	6.6	6.0	5.4	4.7	4.2	5.6
	Min/Max	3.3/5.4	3.8/6.4	4.7/6.7	5.6/7.2	5.4/6.8	5.0/6.7	5.9/7.3	6.1/7.0	4.8/6.7	4.7/6.0	3.7/5.6	3.0/5.0	5.3/5.9
Latitude +15	Average	4.7	5.1	5.6	5.9	5.4	5.2	5.8	6.0	5.7	5.5	5.0	4.5	5.4
	Min/Max	3.4/5.9	3.8/6.6	4.5/6.6	5.2/6.7	4.8/6.1	4.4/5.8	5.2/6.3	5.5/6.4	4.5/6.5	4.7/6.1	3.9/6.0	3.1/5.4	5.1/5.7
90	Average	4.1	4.1	3.8	3.3	2.5	2.2	2.4	3.0	3.6	4.2	4.3	4.1	3.5
	Min/Max	2.9/5.2	3.0/5.4	3.1/4.5	2.9/3.6	2.3/2.7	2.1/2.3	2.3/2.5	2.8/3.2	2.9/4.1	3.5/4.7	3.2/5.2	2.7/5.0	3.3/3.7

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	3.9	5.0	6.4	7.9	8.0	8.1	9.0	8.3	6.9	5.6	4.4	3.7	6.4
	Min/Max	3.0/4.9	3.7/6.4	5.1/7.8	6.9/9.3	6.7/9.4	6.6/9.7	7.6/10.8	7.6/9.3	5.3/8.0	4.8/6.3	3.4/5.3	2.6/4.3	6.1/6.8
Latitude -15	Average	4.7	5.6	6.9	8.2	8.0	8.0	9.0	8.6	7.3	6.3	5.2	4.4	6.9
	Min/Max	3.5/5.9	4.1/7.4	5.4/8.5	7.1/9.7	6.8/9.4	6.5/9.6	7.6/10.8	7.8/9.5	5.6/8.5	5.4/7.0	3.9/6.3	3.0/5.3	6.5/7.3
Latitude	Average	5.1	6.0	7.1	8.2	7.8	7.7	8.7	8.4	7.4	6.6	5.6	4.9	7.0
	Min/Max	3.7/6.5	4.3/7.9	5.5/8.7	7.0/9.6	6.5/9.2	6.3/9.3	7.3/10.4	7.7/9.3	5.6/8.6	5.6/7.4	4.2/6.9	3.3/5.9	6.5/7.4
Latitude +15	Average	5.4	6.1	7.0	7.8	7.3	7.1	8.1	8.0	7.2	6.6	5.8	5.2	6.8
	Min/Max	3.8/6.8	4.3/8.1	5.4/8.6	6.7/9.3	6.1/8.6	5.8/8.6	6.8/9.8	7.3/8.9	5.4/8.4	5.6/7.5	4.4/7.2	3.4/6.3	6.4/7.3

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

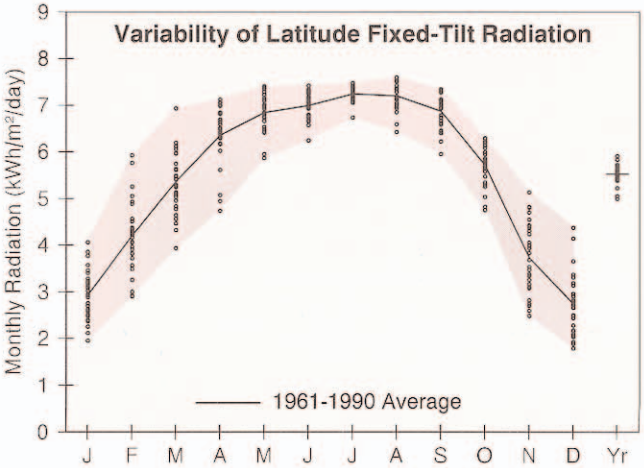
Tracker		Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Year
2-Axis	Average	5.4	6.1	7.1	8.3	8.1	8.2	9.1	8.6	7.4	6.7	5.8	5.3	7.2
	Min/Max	3.9/6.9	4.4/8.1	5.6/8.7	7.1/9.7	6.8/9.6	6.7/9.9	7.7/11.0	7.9/9.5	5.7/8.6	5.6/7.5	4.4/7.2	3.5/6.4	6.7/7.7

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	3.2	3.4	3.6	4.1	3.9	3.9	4.8	4.5	3.8	3.6	3.5	3.2	3.8
	Min/Max	2.0/4.5	1.9/5.0	2.4/4.9	3.3/5.4	3.0/5.1	2.4/5.3	3.7/6.1	4.0/5.3	2.2/4.8	2.8/4.4	2.3/4.7	1.8/4.1	3.4/4.2
1-Axis, N-S Horiz Axis	Average	2.6	3.2	4.1	5.3	5.0	5.0	6.1	5.7	4.6	3.7	2.9	2.4	4.2
	Min/Max	1.6/3.6	1.8/4.8	2.8/5.8	4.2/7.0	3.7/6.6	3.2/6.9	4.6/8.0	4.9/6.8	2.7/5.8	2.9/4.5	1.9/4.0	1.3/3.1	3.8/4.7
1-Axis, N-S Tilt=Latitude	Average	3.6	4.1	4.7	5.5	4.8	4.6	5.8	5.7	5.0	4.5	3.9	3.5	4.6
	Min/Max	2.2/4.9	2.3/6.1	3.2/6.6	4.3/7.2	3.5/6.3	3.0/6.5	4.3/7.6	4.9/6.8	2.9/6.3	3.5/5.4	2.6/5.3	1.8/4.4	4.1/5.1
2-Axis	Average	3.8	4.2	4.7	5.5	5.1	5.0	6.2	5.9	5.0	4.6	4.1	3.8	4.8
	Min/Max	2.3/5.3	2.3/6.2	3.2/6.6	4.4/7.3	3.7/6.7	3.2/7.0	4.7/8.1	5.1/7.0	2.9/6.3	3.5/5.5	2.8/5.6	2.0/4.7	4.3/5.3

Average Climatic Conditions

Element	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Year
Temperature (°C)	13.8	14.2	14.4	15.6	17.1	18.7	20.6	21.4	21.1	19.3	16.4	13.8	17.2
Daily Minimum Temp	8.8	9.6	10.3	11.6	13.5	15.3	17.1	17.9	17.3	15.1	11.6	8.8	13.1
Daily Maximum Temp	18.7	18.8	18.6	19.7	20.6	22.2	24.1	24.8	24.8	23.6	21.3	18.8	21.3
Record Minimum Temp	-5.0	0.0	1.1	3.9	6.1	8.9	9.4	10.6	8.3	5.0	1.1	0.0	-5.0
Record Maximum Temp	31.1	33.3	35.0	38.9	36.1	40.0	36.1	36.7	43.3	41.1	38.3	34.4	43.3
HDD, Base 18.3°C	143	119	124	88	53	30	5	3	12	18	71	143	810
CDD, Base 18.3°C	0	4	4	6	14	42	76	98	94	49	14	4	404
Relative Humidity (%)	63	68	71	71	74	76	77	77	74	71	65	63	71
Wind Speed (m/s)	3.1	3.4	3.8	4.0	3.9	3.8	3.7	3.7	3.5	3.3	3.2	3.0	3.5



Sacramento, CA

WBAN NO. 23232

LATITUDE: 38.52° N
LONGITUDE: 121.50° W
ELEVATION: 8 meters
MEAN PRESSURE: 1015 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	1.9	3.0	4.3	5.9	7.2	7.9	7.9	7.0	5.7	4.0	2.4	1.7	4.9
	Min/Max	1.6/2.4	2.3/3.8	3.4/5.4	4.6/6.6	6.2/7.8	7.0/8.4	7.4/8.2	6.3/7.4	5.1/6.1	3.5/4.3	1.9/3.0	1.4/2.3	4.6/5.1
Latitude -15	Average	2.6	3.9	5.2	6.5	7.3	7.6	7.8	7.5	6.7	5.3	3.3	2.4	5.5
	Min/Max	1.9/3.6	2.8/5.3	3.9/6.6	4.9/7.2	6.2/7.9	6.8/8.1	7.3/8.1	6.7/7.9	5.9/7.2	4.4/5.8	2.3/4.5	1.7/3.7	5.1/5.8
Latitude	Average	2.9	4.2	5.4	6.3	6.8	7.0	7.2	7.2	6.9	5.7	3.7	2.7	5.5
	Min/Max	2.0/4.1	2.9/5.9	3.9/6.9	4.7/7.1	5.9/7.4	6.2/7.4	6.7/7.5	6.4/7.6	5.9/7.3	4.8/6.3	2.5/5.1	1.8/4.4	5.0/5.9
Latitude +15	Average	3.1	4.3	5.2	5.9	6.0	6.0	6.3	6.5	6.6	5.8	3.9	2.9	5.2
	Min/Max	2.0/4.3	2.9/6.2	3.8/6.8	4.4/6.6	5.2/6.5	5.4/6.3	5.8/6.4	5.8/6.9	5.7/7.1	4.8/6.4	2.5/5.4	1.8/4.7	4.7/5.6
90	Average	2.7	3.6	3.8	3.6	3.0	2.7	2.9	3.6	4.5	4.6	3.4	2.6	3.4
	Min/Max	1.6/3.9	2.3/5.2	2.8/5.0	2.7/4.0	2.7/3.2	2.5/2.8	2.8/2.9	3.3/3.7	3.9/4.8	3.8/5.2	2.1/4.9	1.5/4.4	3.0/3.8

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	2.5	4.0	5.9	8.1	9.9	10.8	11.1	10.0	8.3	5.8	3.3	2.2	6.8
	Min/Max	1.7/3.4	2.7/5.7	4.1/7.9	5.7/9.3	8.2/11.1	9.2/11.9	10.1/11.7	8.8/10.8	6.8/9.0	4.8/6.5	2.2/4.5	1.5/3.5	6.2/7.2
Latitude -15	Average	3.0	4.7	6.6	8.6	10.1	10.8	11.2	10.4	9.1	6.8	4.0	2.8	7.3
	Min/Max	2.0/4.3	3.0/6.8	4.5/8.9	5.9/9.8	8.3/11.3	9.2/11.9	10.2/11.8	9.1/11.2	7.5/9.9	5.6/7.6	2.6/5.6	1.8/4.6	6.5/7.8
Latitude	Average	3.3	4.9	6.7	8.5	9.8	10.3	10.8	10.2	9.2	7.1	4.3	3.0	7.4
	Min/Max	2.0/4.7	3.2/7.3	4.6/9.1	5.9/9.8	8.0/10.9	8.8/11.4	9.8/11.3	8.9/11.1	7.5/10.0	5.8/7.9	2.7/6.1	1.9/5.1	6.5/7.9
Latitude +15	Average	3.4	5.0	6.6	8.2	9.2	9.7	10.1	9.8	9.0	7.2	4.5	3.2	7.2
	Min/Max	2.1/4.9	3.2/7.4	4.5/9.0	5.6/9.4	7.6/10.3	8.2/10.6	9.2/10.6	8.5/10.6	7.4/9.8	5.8/8.0	2.7/6.4	1.9/5.4	6.3/7.7

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	3.4	5.0	6.7	8.6	10.2	11.0	11.4	10.4	9.2	7.2	4.5	3.2	7.6
	Min/Max	2.1/5.0	3.2/7.4	4.6/9.1	6.0/9.9	8.4/11.4	9.4/12.2	10.4/12.0	9.1/11.3	7.6/10.0	5.8/8.1	2.8/6.4	1.9/5.5	6.7/8.1

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	Average	1.8	2.6	3.4	4.3	5.5	6.2	6.6	5.8	5.2	4.1	2.5	1.7	4.1
Horiz Axis	Min/Max	0.7/3.0	1.2/4.6	1.8/5.3	2.1/5.4	4.0/6.5	4.9/7.3	5.6/7.1	4.7/6.6	3.8/5.8	3.2/4.8	1.1/4.1	0.6/3.6	3.4/4.6
1-Axis, N-S	Average	1.3	2.4	3.8	5.6	7.3	8.3	8.8	7.7	6.3	4.1	2.0	1.2	4.9
Horiz Axis	Min/Max	0.5/2.2	1.0/4.2	2.0/6.1	2.8/7.0	5.3/8.7	6.4/9.8	7.4/9.6	6.3/8.8	4.4/7.2	3.1/4.9	0.9/3.2	0.4/2.5	4.1/5.3
1-Axis, N-S	Average	1.9	3.1	4.4	5.9	7.1	7.8	8.4	7.9	7.1	5.2	2.8	1.8	5.3
Tilt=Latitude	Min/Max	0.8/3.2	1.4/5.5	2.3/7.1	2.9/7.4	5.2/8.5	6.0/9.2	7.1/9.1	6.4/8.9	5.0/8.0	3.9/6.1	1.3/4.6	0.7/3.8	4.4/5.8
2-Axis	Average	2.1	3.2	4.4	6.0	7.5	8.4	9.0	8.1	7.1	5.3	2.9	1.9	5.5
	Min/Max	0.8/3.5	1.4/5.7	2.3/7.1	3.0/7.5	5.5/9.0	6.5/10.0	7.6/9.8	6.6/9.2	5.0/8.0	4.0/6.2	1.3/4.8	0.7/4.1	4.5/6.1

Average Climatic Conditions

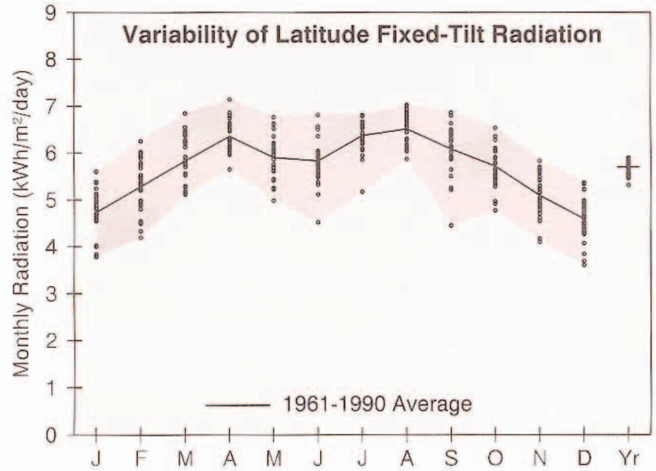
Element	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Year
Temperature (°C)	7.3	10.4	12.0	14.6	18.5	22.0	24.3	23.9	21.9	17.9	11.8	7.4	16.0
Daily Minimum Temp	3.2	5.2	6.2	7.5	10.2	12.9	14.5	14.4	13.2	10.2	6.3	3.2	8.9
Daily Maximum Temp	11.5	15.6	17.8	21.7	26.8	31.0	34.0	33.4	30.7	25.5	17.3	11.5	23.1
Record Minimum Temp	-5.0	-5.0	-3.3	0.0	2.2	5.0	8.9	9.4	6.1	2.2	-3.3	-7.8	-7.8
Record Maximum Temp	21.1	24.4	31.1	33.9	40.6	46.1	45.6	42.8	42.2	38.3	30.6	22.2	46.1
HDD, Base 18.3°C	341	222	198	128	44	7	0	0	9	43	195	339	1527
CDD, Base 18.3°C	0	0	0	16	49	117	184	174	117	29	0	0	687
Relative Humidity (%)	83	77	72	64	59	55	53	56	57	63	76	83	66
Wind Speed (m/s)	2.5	3.1	3.5	3.6	3.9	4.0	3.8	3.6	3.1	2.5	2.5	2.5	3.2

San Diego, CA

WBAN NO. 23188

LATITUDE: 32.73° N
LONGITUDE: 117.17° W
ELEVATION: 9 meters
MEAN PRESSURE: 1014 millibars

STATION TYPE: Primary



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	3.1	3.9	4.9	6.1	6.3	6.5	6.9	6.5	5.4	4.4	3.4	2.9	5.0
	Min/Max	2.6/3.5	3.3/4.4	4.4/5.7	5.5/6.8	5.3/7.2	5.0/7.6	5.6/7.4	5.9/7.0	4.2/6.0	3.8/4.9	3.0/3.7	2.4/3.2	4.7/5.2
Latitude -15	Average	4.1	4.8	5.6	6.4	6.3	6.3	6.8	6.7	6.0	5.3	4.5	3.9	5.6
	Min/Max	3.3/4.8	3.9/5.6	4.9/6.5	5.8/7.2	5.3/7.2	4.9/7.4	5.5/7.3	6.1/7.3	4.5/6.7	4.5/6.0	3.7/5.0	3.2/4.5	5.2/5.7
Latitude	Average	4.7	5.3	5.8	6.3	5.9	5.8	6.4	6.5	6.1	5.7	5.1	4.6	5.7
	Min/Max	3.8/5.6	4.2/6.3	5.1/6.8	5.7/7.1	5.0/6.8	4.5/6.8	5.2/6.8	5.9/7.0	4.4/6.9	4.8/6.5	4.1/5.8	3.6/5.4	5.3/5.9
Latitude +15	Average	5.1	5.5	5.7	5.9	5.2	5.1	5.6	5.9	5.8	5.8	5.4	5.0	5.5
	Min/Max	4.0/6.1	4.3/6.5	5.0/6.8	5.3/6.7	4.5/6.0	4.0/5.8	4.6/5.9	5.4/6.4	4.2/6.6	4.8/6.7	4.3/6.2	3.8/5.9	5.1/5.7
90	Average	4.5	4.3	3.9	3.2	2.4	2.1	2.2	2.9	3.6	4.4	4.6	4.5	3.5
	Min/Max	3.4/5.4	3.3/5.3	3.3/4.5	2.9/3.5	2.2/2.5	1.9/2.1	2.0/2.3	2.7/3.0	2.7/4.0	3.5/5.0	3.6/5.4	3.4/5.4	3.3/3.7

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	4.4	5.4	6.7	8.0	7.7	7.8	8.8	8.4	7.2	6.1	4.9	4.2	6.6
	Min/Max	3.5/5.3	4.1/6.6	5.7/8.1	6.8/9.2	6.1/9.4	5.5/9.9	6.6/9.7	7.3/9.4	4.9/8.3	5.0/7.0	3.9/5.8	3.3/4.9	6.1/6.9
Latitude -15	Average	5.2	6.1	7.2	8.3	7.7	7.8	8.7	8.6	7.6	6.7	5.7	5.0	7.1
	Min/Max	4.1/6.3	4.6/7.4	6.1/8.7	7.1/9.6	6.1/9.4	5.4/9.8	6.6/9.7	7.4/9.6	5.2/8.8	5.5/7.8	4.4/6.7	3.8/5.9	6.4/7.3
Latitude	Average	5.7	6.5	7.4	8.2	7.5	7.4	8.4	8.4	7.7	7.1	6.2	5.5	7.2
	Min/Max	4.4/6.9	4.8/7.9	6.2/9.0	7.0/9.6	5.9/9.1	5.2/9.3	6.3/9.3	7.3/9.4	5.2/8.9	5.7/8.3	4.8/7.3	4.2/6.5	6.5/7.4
Latitude +15	Average	6.0	6.6	7.3	7.9	7.0	6.9	7.8	8.0	7.5	7.1	6.5	5.8	7.0
	Min/Max	4.6/7.3	4.9/8.1	6.1/8.9	6.7/9.2	5.5/8.6	4.8/8.6	5.9/8.7	6.9/8.9	5.0/8.7	5.7/8.4	4.9/7.6	4.4/6.9	6.4/7.3

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

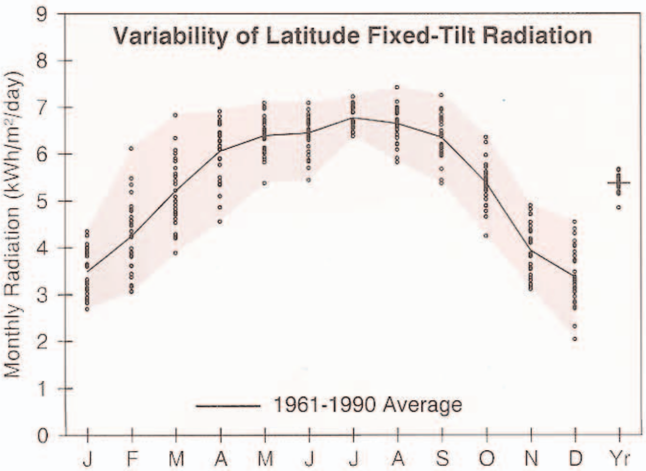
Tracker		Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Year
2-Axis	Average	6.0	6.6	7.4	8.3	7.8	7.9	8.9	8.6	7.7	7.2	6.5	5.9	7.4
	Min/Max	4.6/7.3	4.9/8.1	6.2/9.0	7.1/9.6	6.2/9.5	5.5/10.0	6.7/9.8	7.4/9.6	5.2/8.9	5.8/8.4	5.0/7.7	4.4/7.1	6.8/7.7

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	Average	3.8	3.8	3.9	4.3	3.9	4.0	4.9	4.8	4.2	4.1	4.0	3.8	4.1
Horiz Axis	Min/Max	2.4/4.9	2.5/5.1	2.9/5.3	3.4/5.5	2.5/5.2	1.8/5.7	2.9/5.8	3.8/5.6	1.9/5.2	3.0/5.2	2.7/5.2	2.5/4.8	3.6/4.5
1-Axis, N-S	Average	3.1	3.8	4.6	5.6	4.9	5.0	6.2	6.1	5.1	4.4	3.6	3.0	4.6
Horiz Axis	Min/Max	2.0/4.1	2.3/5.1	3.4/6.3	4.3/7.1	3.1/6.8	2.3/7.3	3.6/7.4	4.7/7.2	2.3/6.3	3.2/5.5	2.4/4.6	2.0/3.8	3.9/5.0
1-Axis, N-S	Average	4.2	4.7	5.1	5.7	4.7	4.7	5.8	6.1	5.5	5.2	4.6	4.1	5.0
Tilt=Latitude	Min/Max	2.7/5.4	2.9/6.2	3.8/7.0	4.4/7.3	3.0/6.5	2.1/6.8	3.4/7.0	4.7/7.2	2.5/6.8	3.8/6.5	3.1/6.0	2.7/5.2	4.3/5.4
2-Axis	Average	4.5	4.8	5.1	5.8	5.0	5.1	6.2	6.3	5.5	5.3	4.9	4.5	5.3
	Min/Max	2.9/5.8	3.0/6.4	3.8/7.1	4.5/7.4	3.2/6.9	2.3/7.3	3.7/7.5	4.9/7.4	2.5/6.9	3.8/6.6	3.3/6.3	3.0/5.7	4.5/5.7

Average Climatic Conditions

Element	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Year
Temperature (°C)	14.1	14.8	15.3	16.7	17.8	19.3	21.7	22.6	21.9	19.8	16.7	14.1	17.9
Daily Minimum Temp	9.4	10.4	11.6	13.1	15.1	16.6	18.7	19.6	18.7	16.1	12.2	9.3	14.2
Daily Maximum Temp	18.8	19.2	19.1	20.2	20.6	22.0	24.6	25.4	25.1	23.7	21.1	18.9	21.6
Record Minimum Temp	-1.7	2.2	3.9	5.0	8.9	10.6	12.8	13.9	10.6	6.1	3.3	1.1	-1.7
Record Maximum Temp	31.1	31.1	33.9	36.7	35.6	38.3	35.0	36.7	43.9	41.7	36.1	31.1	43.9
HDD, Base 18.3°C	136	105	98	63	41	28	7	0	11	13	61	135	698
CDD, Base 18.3°C	5	6	5	13	25	58	111	133	117	59	11	4	547
Relative Humidity (%)	63	66	67	67	71	74	75	74	73	69	66	64	69
Wind Speed (m/s)	2.7	3.0	3.5	3.7	3.7	3.6	3.5	3.5	3.4	3.1	2.8	2.6	3.3



San Francisco, CA

WBAN NO. 23234

LATITUDE: 37.62° N
LONGITUDE: 122.38° W
ELEVATION: 5 meters
MEAN PRESSURE: 1017 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	2.2	3.0	4.2	5.7	6.7	7.2	7.3	6.5	5.4	3.9	2.5	2.0	4.7
	Min/Max	1.8/2.5	2.3/3.9	3.3/5.3	4.4/6.4	5.7/7.4	6.1/7.9	6.9/7.9	5.7/7.3	4.7/6.0	3.2/4.4	2.1/2.9	1.4/2.4	4.4/4.9
Latitude -15	Average	3.1	3.9	5.0	6.2	6.8	7.0	7.3	6.9	6.2	5.0	3.5	2.9	5.3
	Min/Max	2.4/3.8	2.9/5.5	3.8/6.5	4.7/7.0	5.7/7.5	5.9/7.7	6.9/7.8	6.0/7.7	5.3/7.1	4.0/5.8	2.8/4.3	1.9/3.9	4.9/5.6
Latitude	Average	3.5	4.2	5.2	6.1	6.4	6.5	6.8	6.7	6.4	5.4	3.9	3.4	5.4
	Min/Max	2.7/4.3	3.1/6.1	3.9/6.8	4.6/6.9	5.4/7.1	5.4/7.1	6.4/7.2	5.8/7.4	5.4/7.3	4.3/6.4	3.1/4.9	2.0/4.6	4.9/5.7
Latitude +15	Average	3.7	4.4	5.1	5.6	5.7	5.6	5.9	6.1	6.1	5.5	4.1	3.6	5.1
	Min/Max	2.8/4.7	3.1/6.4	3.8/6.8	4.2/6.4	4.8/6.3	4.7/6.1	5.6/6.3	5.3/6.7	5.2/7.0	4.3/6.5	3.2/5.2	2.1/5.0	4.6/5.5
90	Average	3.3	3.6	3.7	3.4	2.8	2.5	2.7	3.3	4.1	4.3	3.6	3.3	3.4
	Min/Max	2.5/4.2	2.4/5.4	2.7/4.9	2.6/3.8	2.5/3.0	2.3/2.6	2.6/2.8	3.0/3.6	3.5/4.7	3.4/5.2	2.8/4.6	1.9/4.7	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	3.0	4.1	5.7	7.6	8.8	9.3	9.7	8.7	7.4	5.5	3.5	2.8	6.3
	Min/Max	2.3/3.7	2.8/6.0	4.1/7.7	5.6/8.9	7.0/10.1	7.5/10.8	9.0/10.7	7.4/10.2	6.2/8.8	4.3/6.5	2.8/4.4	1.7/3.8	5.7/6.7
Latitude -15	Average	3.7	4.7	6.3	8.0	8.9	9.2	9.7	9.0	8.1	6.3	4.3	3.5	6.8
	Min/Max	2.8/4.6	3.3/7.1	4.5/8.6	5.8/9.4	7.1/10.3	7.4/10.7	9.0/10.8	7.7/10.6	6.7/9.6	4.8/7.6	3.3/5.4	2.0/4.8	6.1/7.2
Latitude	Average	4.0	5.0	6.5	8.0	8.7	8.9	9.4	8.8	8.2	6.6	4.6	3.9	6.9
	Min/Max	3.0/5.1	3.4/7.6	4.6/8.9	5.7/9.4	6.8/10.0	7.1/10.3	8.7/10.4	7.5/10.4	6.8/9.7	5.1/8.0	3.5/5.9	2.2/5.4	6.1/7.3
Latitude +15	Average	4.2	5.1	6.4	7.7	8.1	8.2	8.7	8.4	8.0	6.7	4.8	4.1	6.7
	Min/Max	3.1/5.4	3.4/7.8	4.5/8.8	5.5/9.0	6.4/9.4	6.6/9.6	8.1/9.7	7.1/9.9	6.6/9.5	5.1/8.1	3.6/6.1	2.3/5.7	5.9/7.1

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	5.1	6.5	8.1	9.0	9.4	9.9	9.0	8.2	6.7	4.8	4.1	7.1
	Min/Max	3.1/5.4	3.4/7.8	4.6/8.9	5.8/9.5	7.2/10.4	7.6/11.0	9.2/11.0	7.7/10.6	6.8/9.7	5.1/8.1	3.7/6.2	2.3/5.8	6.3/7.5

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	Average	2.5	2.8	3.3	4.0	4.7	5.1	5.5	4.9	4.6	3.9	2.8	2.5	3.9
Horiz Axis	Min/Max	1.6/3.5	1.5/4.9	1.9/5.2	2.4/5.2	3.3/5.7	3.6/6.3	4.9/6.4	3.7/6.1	3.3/5.6	2.6/5.0	1.8/3.9	1.1/3.9	3.2/4.2
1-Axis, N-S	Average	1.9	2.5	3.8	5.2	6.1	6.5	7.1	6.3	5.4	3.9	2.3	1.8	4.4
Horiz Axis	Min/Max	1.2/2.6	1.3/4.6	2.1/6.0	3.1/6.7	4.2/7.5	4.6/8.3	6.2/8.3	4.7/8.0	4.0/6.8	2.5/5.0	1.5/3.2	0.8/2.8	3.7/4.7
1-Axis, N-S	Average	2.7	3.3	4.4	5.4	5.9	6.1	6.8	6.4	6.0	4.8	3.2	2.7	4.8
Tilt=Latitude	Min/Max	1.8/3.8	1.7/6.0	2.5/6.9	3.2/7.0	4.1/7.3	4.3/7.7	5.9/7.9	4.8/8.1	4.4/7.6	3.2/6.3	2.0/4.4	1.2/4.2	4.0/5.3
2-Axis	Average	2.9	3.4	4.4	5.5	6.3	6.7	7.3	6.6	6.1	4.9	3.3	2.9	5.0
	Min/Max	1.9/4.0	1.7/6.1	2.5/6.9	3.3/7.1	4.3/7.7	4.7/8.4	6.4/8.5	5.0/8.3	4.4/7.6	3.2/6.3	2.2/4.7	1.3/4.5	4.2/5.5

Average Climatic Conditions

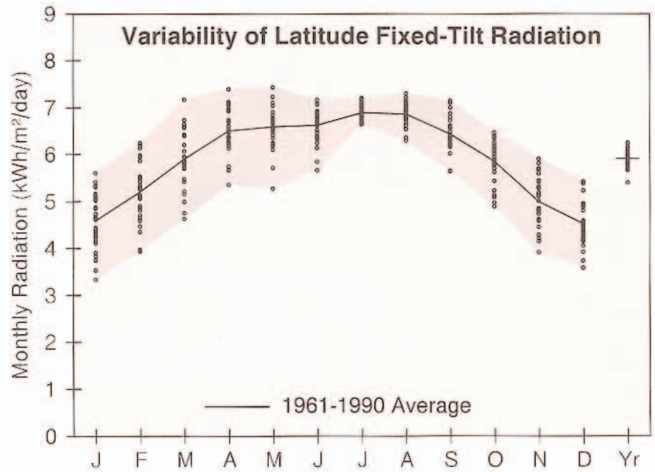
Element	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Year
Temperature (°C)	9.3	11.2	11.8	13.1	14.5	16.4	17.1	17.6	18.1	16.1	12.7	9.7	13.9
Daily Minimum Temp	5.4	7.2	7.7	8.4	9.8	11.4	12.2	12.8	12.9	11.0	8.4	5.9	9.4
Daily Maximum Temp	13.1	15.2	16.0	17.7	19.2	21.3	22.0	22.4	23.1	21.2	16.9	13.4	18.4
Record Minimum Temp	-4.4	-3.9	-1.1	-0.6	2.2	5.0	6.1	5.6	3.3	1.1	-3.9	-6.7	-6.7
Record Maximum Temp	22.2	25.6	29.4	33.3	36.1	41.1	40.6	36.7	39.4	37.2	29.4	23.9	41.1
HDD, Base 18.3°C	281	199	202	159	121	67	51	38	44	75	170	269	1676
CDD, Base 18.3°C	0	0	0	3	0	9	12	16	36	6	0	0	81
Relative Humidity (%)	78	76	73	71	71	72	73	74	72	72	75	77	74
Wind Speed (m/s)	3.3	4.0	4.8	5.5	6.2	6.2	6.2	5.7	5.0	4.3	3.7	3.5	4.9

Santa Maria, CA

WBAN NO. 23273

LATITUDE: 34.90° N
LONGITUDE: 120.45° W
ELEVATION: 72 meters
MEAN PRESSURE: 1008 millibars

STATION TYPE: Primary



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	2.8	3.7	4.9	6.2	7.0	7.4	7.5	6.8	5.6	4.4	3.2	2.7	5.2
	Min/Max	2.3/3.3	3.0/4.2	4.0/5.8	5.3/6.9	5.6/7.9	6.3/8.0	7.1/7.9	6.3/7.2	5.0/6.1	3.8/4.7	2.7/3.6	2.3/3.0	4.8/5.4
Latitude -15	Average	4.0	4.7	5.7	6.6	7.0	7.2	7.4	7.1	6.3	5.4	4.4	3.9	5.8
	Min/Max	3.0/4.8	3.7/5.6	4.5/6.8	5.5/7.5	5.6/7.9	6.2/7.8	7.1/7.8	6.5/7.5	5.6/7.0	4.6/5.9	3.5/5.1	3.1/4.6	5.3/6.1
Latitude	Average	4.6	5.2	5.9	6.5	6.6	6.6	6.9	6.9	6.4	5.8	5.0	4.5	5.9
	Min/Max	3.3/5.6	3.9/6.2	4.6/7.2	5.3/7.4	5.3/7.4	5.7/7.2	6.6/7.2	6.3/7.3	5.6/7.1	4.9/6.5	3.9/5.9	3.6/5.4	5.4/6.2
Latitude +15	Average	4.9	5.4	5.8	6.0	5.8	5.7	6.0	6.2	6.2	6.0	5.3	4.9	5.7
	Min/Max	3.5/6.1	4.0/6.5	4.5/7.1	4.9/6.9	4.7/6.5	4.9/6.1	5.8/6.2	5.7/6.6	5.4/6.9	4.9/6.6	4.1/6.3	3.8/5.9	5.2/6.0
90	Average	4.4	4.4	4.0	3.4	2.7	2.3	2.5	3.2	3.9	4.6	4.6	4.5	3.7
	Min/Max	3.0/5.5	3.2/5.4	3.1/4.9	2.8/3.8	2.4/2.9	2.2/2.4	2.4/2.6	3.0/3.3	3.5/4.4	3.7/5.1	3.5/5.6	3.5/5.5	3.3/4.0

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	4.2	5.2	6.7	8.3	9.0	9.4	9.6	8.8	7.5	6.1	4.7	4.0	7.0
	Min/Max	3.0/5.1	3.8/6.3	5.1/8.4	6.7/9.7	6.8/10.6	7.7/10.8	8.8/10.6	7.9/9.6	6.3/8.7	5.0/7.0	3.7/5.7	3.2/4.8	6.3/7.4
Latitude -15	Average	5.0	6.0	7.3	8.7	9.1	9.4	9.6	9.1	8.1	6.9	5.6	4.9	7.5
	Min/Max	3.5/6.2	4.3/7.3	5.5/9.2	6.9/10.2	6.9/10.8	7.6/10.7	8.8/10.6	8.1/9.9	6.7/9.4	5.6/7.9	4.3/6.7	3.8/5.9	6.7/7.9
Latitude	Average	5.5	6.4	7.5	8.6	8.8	9.0	9.2	8.9	8.2	7.3	6.0	5.4	7.6
	Min/Max	3.8/6.8	4.5/7.8	5.6/9.5	6.8/10.1	6.7/10.4	7.3/10.2	8.5/10.2	8.0/9.7	6.8/9.5	5.9/8.3	4.6/7.3	4.2/6.6	6.8/8.1
Latitude +15	Average	5.7	6.5	7.4	8.3	8.3	8.3	8.6	8.5	8.0	7.3	6.3	5.7	7.4
	Min/Max	4.0/7.2	4.5/8.0	5.5/9.4	6.4/9.8	6.3/9.8	6.8/9.5	7.9/9.5	7.6/9.2	6.6/9.3	5.9/8.4	4.7/7.7	4.4/7.0	6.6/7.9

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	5.8	6.5	7.5	8.7	9.2	9.6	9.7	9.1	8.2	7.4	6.3	5.8	7.8
	Min/Max	4.0/7.3	4.6/8.0	5.6/9.5	6.9/10.2	6.9/10.9	7.8/10.9	8.9/10.8	8.1/9.9	6.8/9.5	5.9/8.4	4.8/7.7	4.4/7.2	7.0/8.4

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	Average	3.6	3.8	4.0	4.5	4.9	5.3	5.6	5.2	4.6	4.3	3.9	3.7	4.5
Horiz Axis	Min/Max	2.1/4.9	2.1/5.0	2.3/5.7	3.0/5.7	2.9/6.2	3.6/6.4	4.6/6.4	4.1/5.9	3.2/5.6	3.2/5.2	2.6/5.2	2.6/5.0	3.6/5.0
1-Axis, N-S	Average	2.9	3.6	4.6	5.9	6.4	6.8	7.1	6.5	5.5	4.5	3.4	2.8	5.0
Horiz Axis	Min/Max	1.6/3.9	2.0/4.8	2.7/6.7	4.0/7.5	3.8/8.2	4.5/8.3	5.7/8.3	5.0/7.5	3.7/7.0	3.3/5.5	2.2/4.5	2.0/3.8	4.1/5.5
1-Axis, N-S	Average	4.0	4.6	5.3	6.1	6.2	6.3	6.7	6.6	6.0	5.4	4.5	4.0	5.5
Tilt=Latitude	Min/Max	2.3/5.4	2.5/6.1	3.0/7.6	4.1/7.8	3.7/7.9	4.2/7.8	5.4/7.8	5.1/7.5	4.0/7.6	4.0/6.6	3.0/6.0	2.8/5.4	4.4/6.1
2-Axis	Average	4.3	4.7	5.3	6.2	6.5	6.9	7.2	6.8	6.1	5.5	4.8	4.4	5.7
	Min/Max	2.5/5.8	2.6/6.3	3.0/7.7	4.1/7.9	3.9/8.4	4.6/8.4	5.8/8.4	5.2/7.7	4.0/7.6	4.1/6.7	3.1/6.3	3.1/5.8	4.6/6.4

Average Climatic Conditions

Element	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Year
Temperature (°C)	10.6	11.4	11.6	12.7	13.9	15.9	17.3	17.8	17.6	16.1	13.1	10.6	14.1
Daily Minimum Temp	3.5	4.7	5.2	5.8	8.0	10.2	11.6	12.2	11.3	8.9	5.7	3.2	7.5
Daily Maximum Temp	17.7	18.2	17.9	19.4	19.9	21.7	22.9	23.4	23.8	23.3	20.4	17.9	20.6
Record Minimum Temp	-6.7	-5.6	-4.4	-0.6	-0.6	2.2	6.1	6.1	2.2	-3.3	-3.9	-6.7	-6.7
Record Maximum Temp	30.0	30.6	35.0	39.4	37.8	38.9	40.0	39.4	39.4	42.2	33.9	32.2	42.2
HDD, Base 18.3°C	239	193	210	173	138	77	53	40	56	79	161	239	1658
CDD, Base 18.3°C	0	0	0	3	0	5	21	23	32	11	0	0	94
Relative Humidity (%)	70	73	76	75	76	76	77	78	78	73	71	70	75
Wind Speed (m/s)	2.8	3.2	3.7	3.8	4.0	3.7	3.2	3.0	2.8	2.8	3.0	2.8	3.2