**Solar Panel Power Output Activity**

Goal: In this activity, we will determine whether there is a statistically significant difference in the number of watts of power produced on individual solar panels at Bryn Mawr College.

Introduction: Bryn Mawr College has installed two sets of solar panels, configured as shown below. The Ground Mount set has twelve panels and 50 feet away is the Top of Pola set of two panels. One can explore the power output of these panels at various periods of time at the website <https://enlighten.enphaseenergy.com/public/systems/faZD132956> .

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Ground Mount** | | | | | **Top of Pola Mount** | | | | |
| #1 | #2 | #3 | #4 |  |  | #13 |  |  |  |
| #5 | #6 | #7 | #8 |  |  | #14 |  |  |  |
| #9 | #10 | #11 | #12 |  |  |  |  |  |  |

Please go to this site and explore the various interactive features. In particular, notice how on a typical day the solar power starts at 0 watts (before the sun is up) and rises to a peak before gradually returning to 0 watts when the sun goes down. Of course, throughout the day the output may be choppy due to cloud cover or participation. For the same reasons, the power can differ greatly from day to day. The data below shows the watts of power produced at specific times on six days of March 2013. These times were chosen because they were the approximate times of peak power for those days.

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| --- | --- | --- | --- | --- | --- | --- |
|  |  |  |  |  |  |  |
| **Date** | 9-Mar | 10-Mar | 11-Mar | 13-Mar | 14-Mar | 15-Mar |
| **Time** | 14:00 | 14:00 | 14:00 | 11:55 | 11:40 | 11:40 |
|  |  |  |  |  |  |  |
| **#1** | 195 | 206 | 128 | 206 | 203 | 169 |
| **#2** | 197 | 208 | 134 | 208 | 204 | 170 |
| **#3** | 198 | 209 | 134 | 207 | 203 | 169 |
| **#4** | 200 | 211 | 134 | 208 | 205 | 169 |
| **#5** | 196 | 207 | 134 | 206 | 203 | 170 |
| **#6** | 197 | 209 | 133 | 207 | 203 | 169 |
| **#7** | 198 | 211 | 135 | 208 | 205 | 171 |
| **#8** | 198 | 210 | 134 | 206 | 204 | 168 |
| **#9** | 199 | 211 | 135 | 210 | 205 | 172 |
| **#10** | 197 | 209 | 134 | 206 | 203 | 174 |
| **#11** | 196 | 208 | 133 | 205 | 202 | 168 |
| **#12** | 199 | 215 | 136 | 209 | 203 | 171 |
|  |  |  |  |  |  |  |
| **#13** | 196 | 208 | 131 | 215 | 207 | 179 |
| **#14** | 198 | 210 | 133 | 216 | 207 | 180 |

Questions:

1. Calculate the mean power on the six given days for each of the 14 panels.
2. Calculate the mean power for the 72 measurements in the Ground Mount configuration.
3. Calculate the mean power for the 12 measurements in the Top of Pola configuration.
4. Would it be appropriate to use an ANOVA test to determine whether there is a difference in the six means you found in question 1? Why or why not? Assuming the appropriate conditions are met, carry out the ANOVA test and answer the following questions.
   1. Determine the P-value for the ANOVA test.
   2. What conclusion do you reach about the difference in means?
   3. What purpose would this type of test serve in in the design, implantation, and maintenance of these solar panels?
5. What type of test should be used to determine whether there is difference in the mean amounts of solar power in the Ground Mount and Top of Polya (from Questions 2 and 3)?
6. The two solar panels at Top of Pola can be adjusted on site, which may affect the amount of solar power captured. Design an experiment to determine which position of the panels is most effective.

Notes to teacher:

1. The data set given here is fairly small. If the students are shown this page in advance, they can collect their own larger set of data or can augment the one given.
2. In order to use an ANOVA test, the underlying data should be somewhat normal. That will not happen if cloudy days, when little or no solar power is produced, are included. (This is why data from March 12 was not included and is why the times were chosen when power was at its maximum for the day.) Although the ANOVA test is fairly robust, these issues should be discussed.
3. For question 5, students should use a two-sample t-test. As before, a larger data set would allow a more powerful test.
4. Question 6 is not trivial. One possibility would be to collect data at, say, n=20 times for, say, k=5 different positions of the panels at Top of Polya. For each of the five positions, calculate the difference in the mean panel output between the 2\*20=40 readings from theTop of Polya panels and the 12\*20 = 240 Ground Mount panels. One will then have five samples of data, each with 20 differences. One could use an ANOVA test to determine whether the difference in means of those five samples is statistically significant. Of course, one would need to be on site to actually execute this experiment, which leads us to the next point.
5. It will be much more interesting to the students if they can use data from your school or community! Determine whether such data is available and use it instead of what is given here.