**Engineering Design with AI Assistants**

In the first activity,you have learned the basic science concepts through working with Alice the AI assistant to maximize the energy output for a single rack of solar panels. In this activity, you will optimize the design of a solar farm, which consists of an array of solar panel racks. Two other AI assistants, Bob and Carol, will help you with this task. Bob will help you explore more design options, whereas Carol will help you improve your solution.

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| **Solar Farm Design Specifications** | |
| **Goal:** Design a solar panel array on a given piece of land in the Boston area that generates maximumprofit on September 22. | |
| **Constraints**:   1. The area allotted for the solar farm is limited to 32m × 28m (896m2). 2. The base height of the solar racks is fixed at 3m. 3. Solar panels are placed in landscape orientation on a rack. 4. A polycrystalline solar panel with the following custom properties is used:   Size: 0.99m × 1.65m, solar cell efficiency: 15%, inverter efficiency of 95% | |
| **Three Parameters:** | Adjust the following design parameters to meet the criteria. |
|  | The **tilt angle** of a solar panel is the angle between its surface and the surface of the ground. In Energy3D, the tilt angle must be between -90° (facing south) and 90° (facing north). |
|  | The **solar panel rows per rack** refers to the number of individual solar panels in any column of a solar rack. The number of rows can range from one to six. |
|  | The **inter-row spacing** is the distance between adjacent racks from center to center. |

When engineers solve a problem or search for a solution, they usually go through many iterations. Central to this iterative process is the divergent-convergent thinking loop.

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| **Design Thinking: The Divergent-Convergent Loop** |
| **Divergent thinking** is a process of generating a variety of different potential solutions to a specific problem. |
| **Convergent thinking** is a process of selecting one or more solutions to refine and optimize until they meet the design specs. |
| **Iteration at different levels:** Design is a complex nonlinear process, where iterations can happen at different levels. For example, at a high level, you can go over multiple designs. At a low level, you can tweak a design parameter several times. |

**Part I: Explore Design Options**

Remember that the goal is to design a solar farm that generates maximum profit on September 22.You will explore the problem thoroughly and come up with several possible solutions. Apply what you have learned from the previous activity about the science of solar energy to think about new ideas and test them. After producing three different designs of your own, you will review five other designs generated by your new AI assistant Bob. He is an exploratory designer who is good at divergent thinking. Examining his designs will help you see more about the solution space. Based on your evaluation of his designs, you will then select three most promising designs from all the candidates created by you or Bob for Part II of this activity.

To accomplish Part I, read the following instruction carefully.

**A. Design by yourself**

1. **Open the file.** Double-click on “solar-farm-initial.ng3” in the desktop folder named after the ID you were assigned. Once the file opens in Energy3D, you should see an existing solar panel array. The date should be already set to September 22 and the location to Boston, MA. The default solar panel array should have zero tilt angle, three rows of solar panels per rack, and four meters of inter-row spacing.
2. **Investigate the solar radiation on the solar panel array.** Use the Energy3D tools that you are already familiar with (e.g. the heliodon, the shadow tool, and the sunbeam) to examine the orientation of the solar panels in relation to the Sun and its effect on the total amount of solar energy received by the solar panels in the array.
3. **Adjust the tilt angle, solar panel rows per rack, and inter-row spacing.** Click the *Let me try* button in the *Sheet 1* of the *Instruction & Documentation* area. If the button is not shown on the right-hand side of Energy3D, click on the green ground in the view window to bring it back. Once you click the button, enter values that you think would be the best for the tilt angle, the solar panel rows per rack, and the inter-row spacing. Then press *OK*.
4. **Analyze the daily yield (output).** Click the *Calculate* button in the *Instruction & Documentation* area. A new window should open. Click the *Run* button in the window to calculate the daily output. When completed, a graph showing the hourly outputs will appear along with the total daily output. Examine the graph to see if the results make sense. Record the total daily output in Table 1 on your excel answer sheet’s tab 1 (provided separately).
5. **Calculate the total profit.** Locate the *Total Number* field for solar panels above the *Instruction & Documentation* section on the right-hand side of Energy3D. Enter in the total daily output and number of panels into Table 1. The profit of your design will be calculated automatically.
6. **Document the results.** Write down the values of the design parameters you have set in Table 1 on the answer sheet.
7. **Create more designs.** Now that you have done your first design, can you think of a different design? Repeat steps 2 – 6 to create two more different designs. The designs should follow the scientific principles you have learned so far and be as different as possible. Make sure to document all of your design solutions in Table 1.

**B. Ask Bob for new ideas**

You may have already realized that design tasks are often open-ended and there is often no single correct solution. Divergent thinking for generating several different possible solutions is therefore important before you or your client nails down the final design. But how do you come up with different solutions? Usually, you can talk to a teammate who may be able to approach the problem from a different perspective that you have overlooked and inspire you with a different idea to solve the problem that you have not thought about. You can now also consult with your AI assistant, Bob. Follow the steps below to interact with Bob.

1. **Open the default file.** Double-click on “solar-farm-initial.ng3” to open it (if you accidentally overwrote it in the previous steps, ask your teacher for the original file).
2. **Ask Bob.** Click the *Ask Bob* button in the *Sheet 1* of the *Instruction & Documentation* area.
3. **Document Bob’s design.** After Bob finishes, he will report his solution side by side with the initial design in a window. Write down the final inter-row spacing, tilt angle, solar panel rows per rack, and the daily profit in Table 2 on the answer sheet.
4. **Let Bob create more designs.** Reopen the default file “solar-farm-initial.ng3” and go through steps 1-3 to get four more designs from Bob.
5. **Compare your and Bob’s designs.** Use Table 3 to take a closer look into Bob’s designs and evaluate the similarities and differences between yours and his.

**C. Select three designs**

After reviewing all the eight designs from you and Bob, which ones do you prefer to carry on to the next step? Pick three out of the eight designs and record these designs in Table 4 on the answer sheet. Answer the questions to complete Part I.

**Part II: Reach the Final Solution**

In Part I, you have explored the solution space and selected different designs with the help of Bob. It is now time to iteratively improve your designs and converge to a final solution. Begin with a design from the three designs you have chosen at the end of Part I and think about how to optimize it. If you’re unsure about what to do, ask your new AI assistant Carol, a contemplative designer, for help. When she evaluates your design, she will test a large number of revisions before giving you her suggestion. Carefully review Carol’s recommendation and try to improve your design based upon what you have learned from her.

The improvements you make can be quantitatively measured by the sum of increased profit due to your work. To be fair, Carol will get her credit, too. Compare the profit increases you and Carol are responsible for and think about how you can out-earn Carol before you and Carol reach the final solution.

Follow the instructions below to begin:

**A. Improve your design**

1. **Select one design.** Pick one of the three chosen designs from Part I and activate it by inputting its three parameters at the layout manager (Click the *Let me optimize* button in the *Sheet 2* of the *Instruction & Documentation* area). Review your design.
2. **Improve the design.** Click the *Let me optimize* button again and enter values that you think would be the best for the tilt angle, the solar panel rows per rack, and the inter-row spacing and press *OK*. Then click the *Calculate* button to calculate the daily profit and record the result in Table 5 in the answer sheet’s tab 2. The daily profit will be calculated automatically.
3. **Try multiple times.** It’s never easy to find a way to improve. Try different combinations of design parameters and test them. Don’t forget to use the knowledge you have learned thus far and the tools you have used before (e.g., the heliodon, the shadow tool, and the sunbeam) to support your reasoning and analysis. Document your iterative process in Table 5 of the answer sheet to keep track of what you have tried.
4. **Calculate the profit you made.** Congratulations on finding a better design! You may now check how much more money you have earned as a result of your hard work at the end of Table 5.

**B. Ask Carol for help**

1. **Submit the current best design to Carol.** Check which is the current best design on the top of Table 6. Click the *Let me optimize* button and input its parameters.
2. **Let Carol assist you.** Click the *Ask Carol* button in *Sheet 2* of the *Instruction & Documentation* area.
3. **Document Carol’s advice.** Carol will generate a new solution based on your current best design and will show the results side by side. Write down the final inter-row spacing, tilt angle, solar panel rows per rack and the daily profit in Table 6 on the answer sheet.
4. **Check the profit Carol made.** The profit Carol earned from her improvement is shown at the end of Table 6. A comparison between yours and Carol’s earnings is presented as a graph.

**C. Another chance for you**

1. **Improve Carol’s work.** You now have a chance to outdo Carol. Click the *Let me optimize* button to set your parameters and then click the *Calculate* button to calculate the daily profit and record the result in Table 7. Feel free to try as many times as needed until you find a more profitable solution.
2. **Repeat steps B and C for at least three rounds.** This should give you more opportunities to work with Carol and learn from her.

**D. Summarize the design improvement**

1. Table 11 lists the profit increasement you and Carol made in Part II. Review the numbers and answer the questions to complete Part II. Inform your teacher that you have accomplished the task.