Quarrybrook
EXPERIENTIAL EDUCATION CENTER

Program Title: **A Solar Harvest**

Audience: 6th-8th grade students

Program Theme: For millions of years plants have harvested the Sun's electromagnetic radiation and transformed it into chemical energy. Humans can also harvest this light energy and convert it into electricity through ever-evolving technologies.

Program Goals: Students will explore the transfer of energy through natural and man-made systems. Students will be introduced to the technology of photovoltaic systems—cells turning sunlight ("photo") into electricity ("voltaic")—through experiments with our solar-powered fountain and hand-held solar cells. We'll see how Quarrybrook runs its utilities on energy harvested from the Sun. Along the trail students will investigate light energy conversion in the plant kingdom, via photosynthesis, and the biomechanical design efficiencies of different plants. We'll discuss how biomimicry is helping us to improve solar cell performance, by designing cells that look and feel more like real leaves. Students will be challenged to design, build, test, and re-design a solar oven, with the goal of improving their design efficiency.

Next Generation Standards:
MS-PS3-3 Apply scientific principles to design, construct, and test a device that either minimizes or maximizes thermal energy transfer.
MS-ETS1-4 Develop a model to generate data for iterative testing and modification of a proposed object, tool, or process such that an optimal design can be achieved.

Objectives:

- **What are the objectives?** Students will understand how plants and man-made photovoltaic cells convert the Sun's radiation into usable energy. Students will know that output is dependent on the availability of sunlight and the angle of exposure. Students will know three to five specific adaptations that help plants to process sunlight as efficiently as possible. Students will experience the practical use of solar energy to perform a task.
- **How will they be measured?** Students will use a solar-powered fountain to measure water flow based on solar panel direction. Students will manipulate the angle of incidence of hand-held solar cells. Students will investigate forest structure and identify plant characteristics that increase exposure to the Sun. Students will design, build, test, and re-design solar ovens.

Program Outline:

NOTE Activity 1 takes place around Quarrybrook's solar-powered fountain. To share the fountain among multiple groups, Activities 1A and 1B are interchangeable and each group will begin their day at one of the two learning stations, visiting the other station at another appropriate point in the lesson.

Activity 1A: SOLAR FOUNTAIN (20 min.) – Students will investigate a photovoltaic (PV) panel and the importance of its position in relation to the angle of the Sun and its location in the sky throughout the day and year. When they use the solar fountain, students will see solar energy transformed into electrical energy by a PV panel. A motor converts the electricity into kinetic energy, which is used to pressurize and spout water up into the air. As the water rises, it loses kinetic energy and gains gravitational potential energy. Eventually the water hits its maximum height and then starts to fall again, as its gravitational potential energy is converted back into kinetic energy. The height of the water corresponds to the amount of sunlight that the PV panel receives. Through an experimental procedure students will use compasses to identify the cardinal directions and then orient the fountain's PV panel toward each direction, measuring and recording the varying flow of water.

Students will need to be divided into smaller sub-teams. Teachers will be helpful in guiding the students through the measurement process and assisting with proper compass use. All activities will be explained and demonstrated by the Quarrybrook instructors first. Teachers are always welcome to add to the discussion and make connections back to the classroom.

Activity 1B: INVESTIGATING SOLAR CELLS (20 min.) – Students will learn how PV cells convert photons into electricity. Student sub-teams will each receive a hand-held solar cell and wire it to a small motor, making a circuit. They will then investigate the change in electrical output, seen through the motion of the motor, when varying the angle of the solar cell relative to the Sun's placement in the sky.

Teachers will be helpful in checking on each sub-team and making sure they are on task and working successfully with the materials.

Activity 2: COOKING WITH THE SUN (50 min.) – Solar ovens use solar energy—light and heat emitted by the Sun—to cook food. They can also be used to purify water or sterilize medical instruments. How does a solar oven work? They are designed to absorb more heat than they release. In a solar oven design challenge, student teams will receive materials in order to construct a pizza-box oven in the most efficient way, with the goal of capturing the maximum solar energy possible, to heat up a small pot of water. To measure the efficiency of their oven design, students will monitor the temperature of the water in two-minute intervals and record its progress on a team datasheet. Then we will leave the ovens to conduct the plant investigation walk and see if we can gain more design information and inspiration from Nature regarding their pizza-box "solar panels." We will return to the ovens at the end of the program, with enough time for students to reassess their designs and make improvements if they choose.

Once the process and goals have been explained, student teams will design and build their own ovens. Teachers will be very important in guiding the teams throughout the construction and testing process and should encourage the students to try different angles and placements for

their ovens. We will also need to make sure they stay on task with taking the temperature of the water every two minutes and recording their data.

Activity 3: NATURE'S POWER PLANTS (30 min.) – We will head into the woods to take a critical look at the best and most efficient solar factories on the planet: PLANTS! Through direct observation, students will collect information on the design and structure of plants and trees, as well as the overall profile of the forest (shrub layer, understory, canopy, etc.). Students will learn about how Nature has structured its "solar factories" to maximize exposure to sunlight in all seasons. As producers, plants fuel the entire food chain via solar radiation and scientists are looking very closely at their design when thinking about new solar cell technologies. Instructors will share news on the latest advances in solar cell design in which scientists at Princeton and MIT are now inventing cells that look and act more like actual leaves, with surface creases and folds that channel light more efficiently than the flat panels we currently see in use. Biomimicry (imitating living things) encourages us to study Nature and use its solutions to solve our challenges. Student sub-teams will identify a particular species of tree, shrub, or herbaceous plant, then investigate it closely to notice the specific adaptations helping that plant to process sunlight as efficiently as possible. If it is a shade plant, what adaptations allow it to survive with minimal sunlight? Students will present their observations to the entire group.

Teachers will be needed to support student sub-teams during their species investigations and offer leading questions to help them start thinking critically about design efficiencies. Teachers will assist them in preparing their group presentations.

Conclusion/Wrap-up:

Activity 4: OVEN RE-DESIGN (15 min.) – Student teams will go back to their ovens where they will have the option of re-designing their panels based on information they have gained through the plant investigation. Extra materials will be available. Students will measure temperature again and see if their water heats up any faster than it did before their design adjustments.

As student sub-teams explore ideas and improvements, encouraging questions from teachers and chaperones are always welcome.