IPRO 335: Developing Technology to Transform Education in Haiti

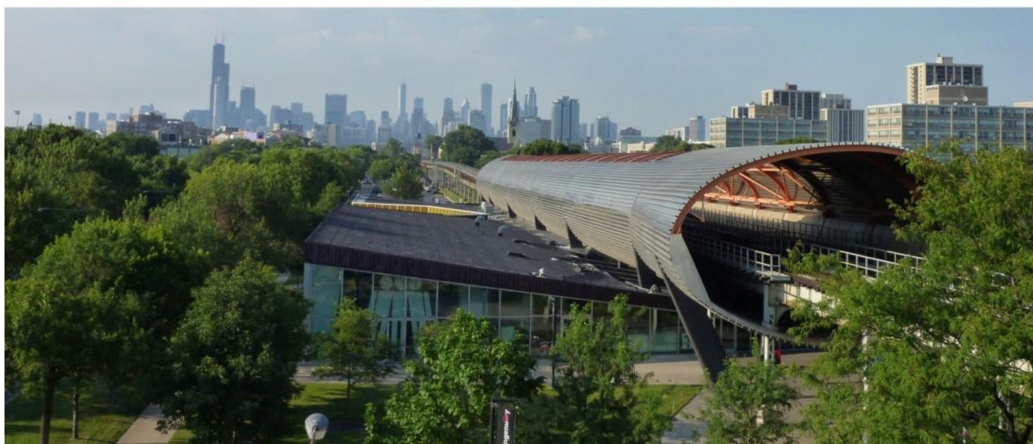

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Table of Contents

I. Executive Summary

A quality education is one of the most effective long term pathways out of poverty and dependence, towards self- sufficiency. In the nation of Haiti, with an illiteracy rate of over 50% a great need for a better quality education is prevalent throughout the nation. Currently, as the poorest country in the western hemisphere, Haiti lacks the proper tools and infrastructure to deliver a better quality education. Furthermore with high unemployment rates, there is a shortage of unmotivated and well trained teachers.

In 2009, the non-profit-organization One Laptop Per Child (OLPC) donated approximately 11,000 XO laptops to Haitian students from grades 2 to 5 in 40 schools located in 4 regions of Haiti. This donation was done in the spirit of their mission “to empower the children of developing countries to learn by providing one connected laptop to every school-age child.”

Unfortunately, most of the schools in Haiti do not have a reliable electrical source to charge the laptops. The sad result is that the laptops cannot be used during class and their educational benefits go unrealized. Across the whole country, only 12.5% of the population has regular access to electricity and only 5% of secondary schools have access. Most of the infrastructure in Haiti is very old and expensive to maintain and operate. Due to this shortage of electricity many households and institutions have to rely on their own diesel generators, or improvised solutions using car batteries and alternators. Fuel for these is very expensive as well as a source of pollution, which makes current energy situation unreliable and unsustainable.

Our team was called upon to provide a low-cost, reliable, and renewable source of energy to primary schools across Haiti. Our goal is to design a solar powered energy solution that is replicable across Haiti and scalable for schools of different sizes. We have chosen solar power as our energy source, because Haiti is well situated with a high solar irradiance across the whole nation where as other sources of power are not as feasible for every part of the country.

With the support of faculty and industry advisers, we are working to improve the conditions of education in Haiti, by helping to support the implementation of the One Laptop Per Child Program. Our team worked with the motivation to enable and empower Haitian children's education through the use of sustainable energy, collaborative technology, and capacity building community driven developmental programs, as well as expanding our practical and professional experience by pursing funding and grants.

This semester, our main focus was the design a solar solution to provide power for the laptops, schools and Internet connectivity, and to design an education component to directly involve the community we are working in . We went on a site-assessment trip in January 2011 and chose two pilot schools in Lascahobas, Haiti to design the solar solution for. We completed specific calculations for each school, wrote a guide on how-to-design-solar solutions, designed lesson plans for the teachers regarding solar and designed a community involvement model. The next step is for us to send a team to Haiti in August 2011 to implement the solar solution and collaborate with the community regarding the community development program. After our implementation trip is completed we will be collaborating with our constituents in Haiti to develop a strategic plan to deploy the community and solar solution in each secondary school across Haiti.

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II. Problem Statement and Objectives

Haiti is the poorest country in the western hemisphere with the lowest per capita income in Central America. More than 65% of the population of 9 million lives below the poverty line and over two-thirds of the labor force are unemployed. Haiti has a literacy rate of about 52% even among those who have attended school for 6 years. Haiti's economy is in drastic need of improvement and one of the best places to start is with the education of its children.

The One Laptop Per Child (OLPC) organization is group of dedicated technologists and educators whose mission is “to create educational opportunities for the world's poorest children by providing each child with a rugged, low-cost, low-power, connected laptop with content and software designed for collaborative, joyful, self-empowered learning.” The laptop they have developed is called the XO, named for the iconic design of child on its case. The laptop delivers on all the goals that the OLPC organization set out to accomplish and has had many successful deployments around the world. However, not every XO deployment has been as successful.

In 2009, Haiti received a donation of approximately 11,000 XO laptops from the OLPC Foundation and the Inter-American Development Bank (IDB). This donation was formed on a handshake agreement between the two foundations and one main issue that donors did not consider in their gift-giving was that 95% of Haiti’s primary schools lack a reliable source of electricity. The few schools that have electricity get it from expensive and polluting diesel generators, or from equally unreliable improvised sources using car batteries and alternators. Haiti lacks a reliable centralized electrical grid and the power plants it does have are very old and expensive to repair. There are currently three large thermal plants and one hydroelectric plant serving the metropolitan area of Port-Au-Prince but only a few smaller thermal and hydroelectric plants in the outer provinces. It should have been clear that however well-intentioned the donation was, the infrastructure simply does not exist so support such an influx of new technologies.

Anticipating this issue the Coordinator of the OLPC program in Haiti, Guy Serge

Pompilus, negotiated to receive fewer laptops than had been previously designated before they were sent to Haiti, and in their place, have funds allocated for teacher training and electrification of the schools. As a result, $5,000 was allocated for each school's electrification efforts. Unfortunately, when the Ministry of Education put out a bid for a local solar company to give an estimate of the cost, the company's estimate was based on powering 30 off-the-shelf normal laptops, and 24-hour electrification for the entire school's potential needs—this estimate did not take into consideration the lower power needs of OLPC's XO laptops, nor the fact that some schools will have 400+ of these laptops to charge on a regular basis. The private-company's estimate came in at $14,000 per school, at which point the Minister of Education canceled plans for solar power, and the electrification process has been put on hold.

It was at this point that Guy Serge, in coordination with the President of Green Wifi, Bruce Baikie, approached Professor Hosman at IIT, about forming an IPRO to address the electrification of Haiti's primary schools to facilitate deployment of the OLPC program.

Our primary goal, then, became to recalibrate the solar powering estimate based on actual needs, take advantage of technological improvements, breakthroughs, and other cost-saving measures, and ultimately reach the $5,000 price point that was the originally budgeted allocation, so that these solutions will be affordable for the schools and the children and teachers will be able to power the laptops they already have, but cannot charge or use. Additionally this solution would have to be adaptable to the unique conditions present at each school. In addition to that, this project has great potential to empower Haiti through community development plans. A primary objective of our team was to develop educational plans that would empower the teachers with information on technology we are bringing to the schools to teach to the children and also develop maintenance sessions to host with the community to ensure their involvement and sense of ownership over the projects.

A secondary goal of ours is to develop a system for collaboration between partners in the US and in Haiti that will allow for us to follow-up on the deployments we work with as well as enable deployments within the country to communicate with each other and share insights on common problems. This would most directly manifest in a partnership with a group of engineering students from one of Haiti's national universities.

A final, ever-present, goal would be to acquire external funding for any of the project needs. Given the economic realities of Haiti we cannot receive extensive financial support from our sponsor and must find means of funding on our own.

From these three primary goals our group arrived at three main objectives for our project:

- Finalize a photovoltaic design in order to charge the XO laptops in two schools in Lascahobas, Haiti.
- Collaborate with locals in order to reproduce this solar design in every secondary school in Haiti.
- Provide an educational component that will transfer knowledge of solar solutions and sustainable energy sources in the two secondary schools of Haiti.

III. Organization and Approach

In order to fulfill the main objectives of our organization, our team was organized into four groups. Last semester, we were able to gain an extensive knowledge and appreciation for solar energy. This semester we are planning to utilize that information to finalize a photovoltaic design for two schools in Lascahobas. This goal was be completed by the Solar sub-group. While working in developing communities, the biggest challenge is promoting a partnership within the community and helping them develop a sense of ownership over the project. The Educational sub-group was primarily be concerned with the educational sustainability and transfer of information to the teachers and students in Lacahobas. We also reached out to a variety of networks and media sources through the Public Relations sub-group raised funds for our projects through the Fundraising sub-group.

In addition to designing a solar system and educational lesson plans for the schools, the educational committee reached out to individuals who have had experience in the developing world to learn more about the ethical implications of our project and how to partner with the in-country communities so they feel a sense of ownership over the project. After the Ethics roundtable discussion, we kept in close contact with the panelists and took their ideas into serious consideration while crafting a community development model to engage all members of the community.

IV. Analysis and Findings

Last semester the design was created to be DC-only, to save costs and avoid misuse of the system. This semester the solar design was created more specifically for the two schools in Lascahobas; St. Gabriel and Ecole Baptiste.

With a simple solar solution in mind, we sized our design according to the amount of laptops and other data collected on the implementation trip (Attached). Given that an XO laptop requires 17 watts for 1.5 hours to fully charge and our target region of Haiti has an average solar irradiance of 5.3 hours we would require 1,750 watts of power from panels and 1,000 amp hours of battery storage. In order to power the 500 laptops at St. Gabriel, 14 solar panels, 15 batteries and 1 charge controller. In order to power the 350 laptops in Ecole Baptiste 10 solar panels and 10 batteries will be utilized paired with 1 charge controller. The battery capacity was designed with an 80% life-cycle The solar panels will be mounted on the roofs of the schools at an 18° angle using a rack mount. The roofs of the schools had enough clearance with no large trees disrupting the solar capturing capabilities of the school to go with a rack type mounting over a pole mount system.

With the finalization of the calculations we were able to contact solar distributors in Haiti in order to obtain cost estimates and finalize our bill of materials (attached). We decided to buy our panels in Haiti in order to promote Haiti's economy and incase of system failure for the near future the major parts of the system are available in Haiti for replacement.

The solar team was also able to create mini-models of the schools we are working in to aid in the visualization of the project to our constituents in the United States.

The educational component team was originally created with the intention to design lesson plans on how solar energy works in order to teach the plans at the school. After doing much more research into how to educate students in the developing world, the lesson plans idea quickly changed from the team taking over the classroom to a partnership with the teachers and administrators of the schools we are working in. Instead the solar team created content regarding how does solar energy work, benefits of clean energy and electricity safety. The content was combined into a teacher guide with suggested lesson plans and activities. The major reason behind us not being the teachers of these ideas is because, being non-Haitian residents we are not fully aware of how the stat quo is in the classroom. Our teaching techniques may seem disruptive and culturally insensitive and the students may not take us seriously. Additionally, this method of our educational component will empower the teachers with a new set of tools that will enable them to feel more confident when teaching about solar energy in the classroom.

The educational team also quickly turned into a community development team. Since this is a project centered largely on a school, it would be very difficult to gain the support of the community and have them feel a sense of ownership over the project itself. Additionally, without the support of the community, the project is at risk of failure through theft and no upkeep of the system. In order to engage the community, we have designed a community development plan. During our implementation trip in August 2011, the first item on the agenda will be to hold community meetings, where we will communicate who we are, why we are here and how this project will impact them. Additionally, we will be asking for their support by helping us install the system in the schools. We will also be stressing the importance of the long-term maintenance of the two schools since these pilot projects are going to be the model for the future expansion of the program.

The PR committees' main goal was to communicate with similar minded NGO's and external organizations to spread the word about our project and gain additional support. After unsuccessful tries with contacting NGOs via email and follow up calls. We decided to go about a different approach and gained contacts with Engineering For Change and the Chicago Tribune. After the article was written for us on the Engineering for Change website and we were featured in the homeland section in the Chicago Tribune, we were able to find successes with PR from within the United States. We were also able to get a flow of communication with PRODEP, an organization in Haiti with funding to help fulfill the 2010 UN Millenium Development Goals, the Inter-Development Bank (IDB) and the Solar Electric Light Fund (SELF) who specializes in solar energy projects in Haiti.

Fundraising for a $40,000 project was a large task for our fundraising team. Through the course of the semester, the team filled out several grants, organized fundraisers at IIT, recruited the

IIT Greek Community and participated in a Global Giving Challenge. The grant writing, while extremely good experience for the team, ended up mildly successful. The team received a grant from the Millennium Campus Network for $4,000 to be used towards the projects. We are still waiting to hear back from the other grants for their results. The organization of fundraisers was also mildly successful, the most successful one was the Lincoln for Lincoln fundraiser where we wrote letters to all the faculty/staff at IIT asking for donations. After a few unsuccessful small-events we decided to forgo organizing these events since they take a lot of effort with minimal return, and focus Global Giving and writing Grants. In March we applied to join the network of Global Giving, an online fundraising source which features special projects, provides excellent PR and is an effective way to fundraise for NGOs and other non-for-profits. We were accepted into their April Challenge month where we were tasked to raise $4,000 in the month of April. Not only did we meet the challenge but succeeded above and beyond the goal. Additionally, the Greek Community hosted a fundraiser 'Sausage Fest' with all benefits going towards the IPRO.

The biggest most important accomplishment from this semester was the distinct development in our mindsets about how to work in developing communities. We spent a lot of time focusing in the implications of the project in the developing work, taking ethical considerations into mind and trying to minimize any risk associated with the project. Everyone on the project team has become more culturally aware and more effective at communicating and prioritizing the community development component, which is the key aspect of sustainability to the project.

V. Conclusions and Recommendations

Our project team was highly successful this semester with a lot of prolific advancements in all the sub-groups areas. The best way of staying focused on each task and completing items in a timely manner came from our group communication. At the beginning of the semester, we outlined our strengths and weaknesses. That outline was definitely of use when it came to assigning items to do and holding people accountable. Furthermore, items tended to get done more quickly when it was of a particular interest to the student completing the task.

The biggest strength that we have had this semester was having people from the IPRO rejoin us as well as having team members who traveled in January to motivate the rest of the team to accomplish every item we did. Without the energy and support of the entire team none of the items accomplished would have been possible.

A recommendation for future IPROs would be to involved educators who specialize in education in developing countries immediately, their experience and knowledge is invaluable especially when designing capacity-building projects for nations like Haiti.

VI. Appendix

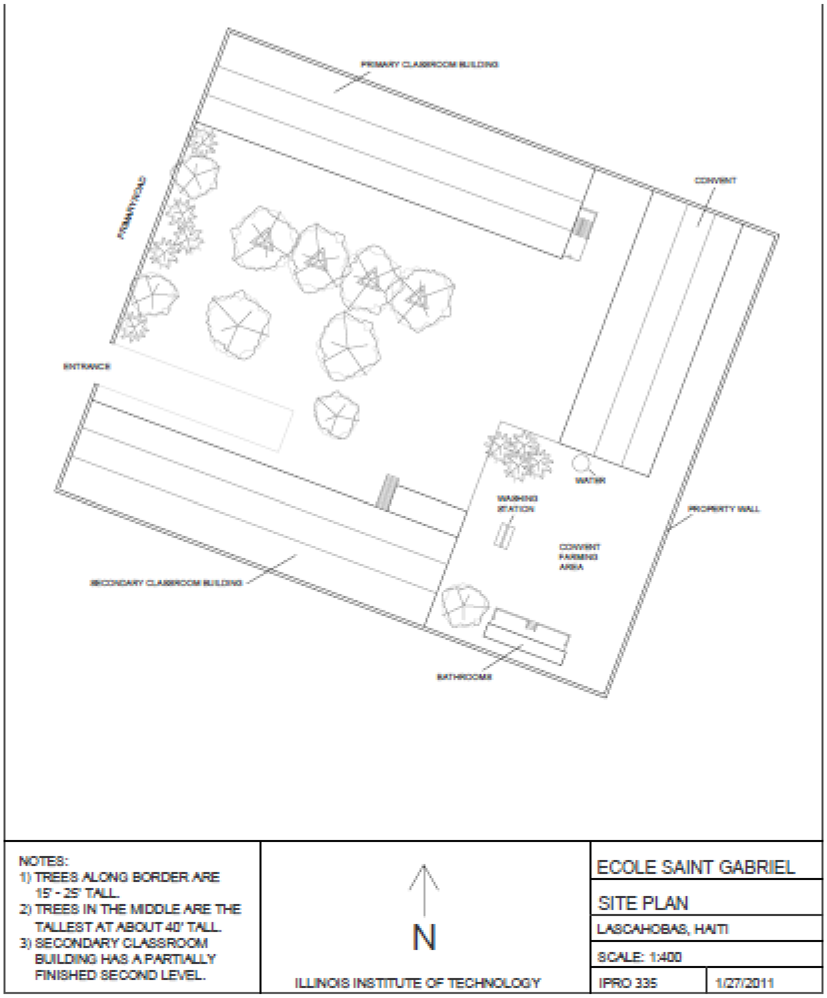
A. Diagrams of St. Gabriel

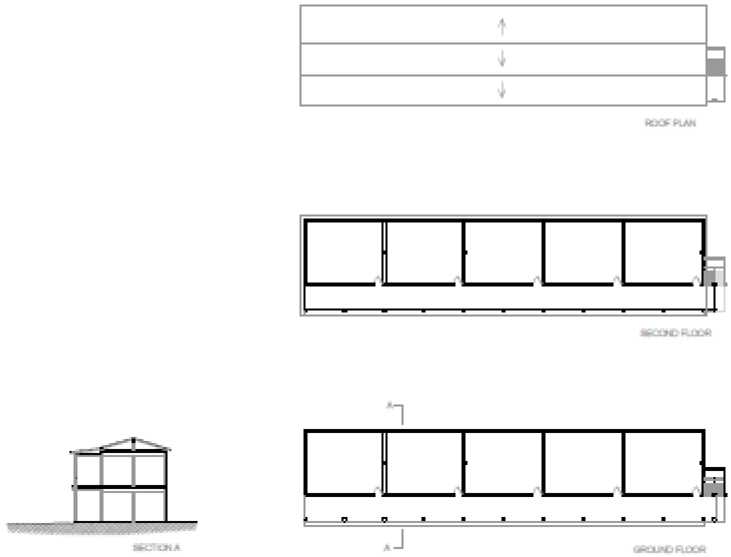
B. Diagrams of Ecole Baptiste

C. Bill of Materials

D. Educational Materials

E. Appendix A: Diagrams of St. Gabriel





NOTES:
1) ANGLE ON UPPER ROOF IS 16.9
2) CONCRETE BLOCK CONSTRUCTION WITH POURED CONCRETE COLUMNS AND TIN ROOF ON WOOD SUPPORTS

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ECOLE SAINT GABRIEL

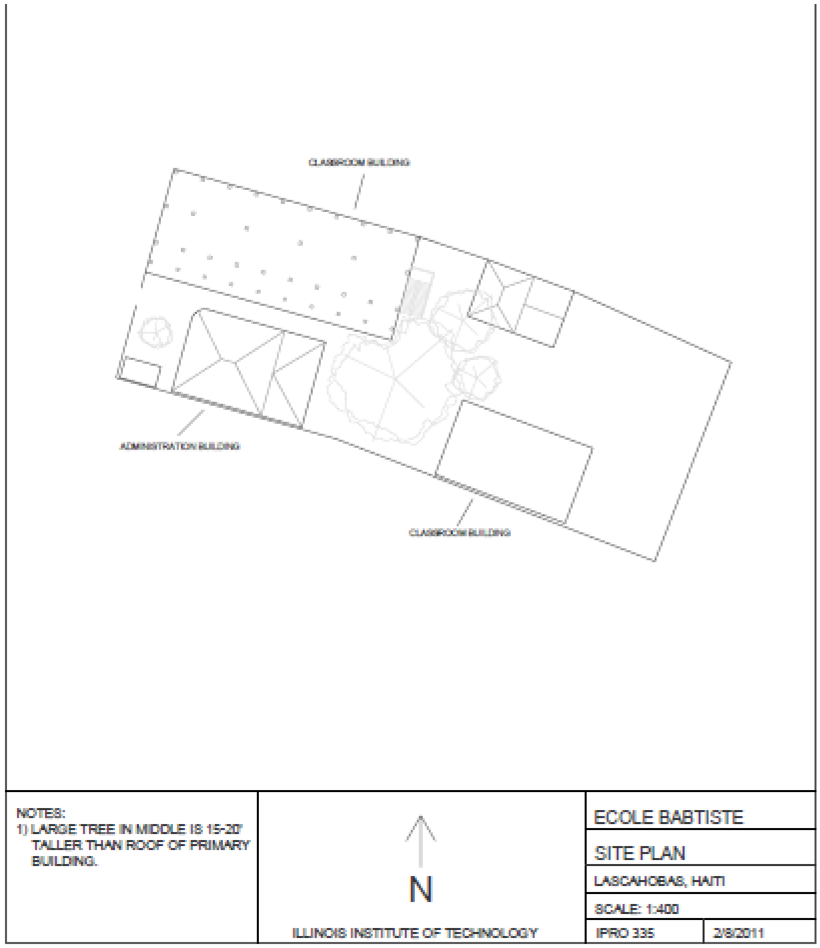
PLANS

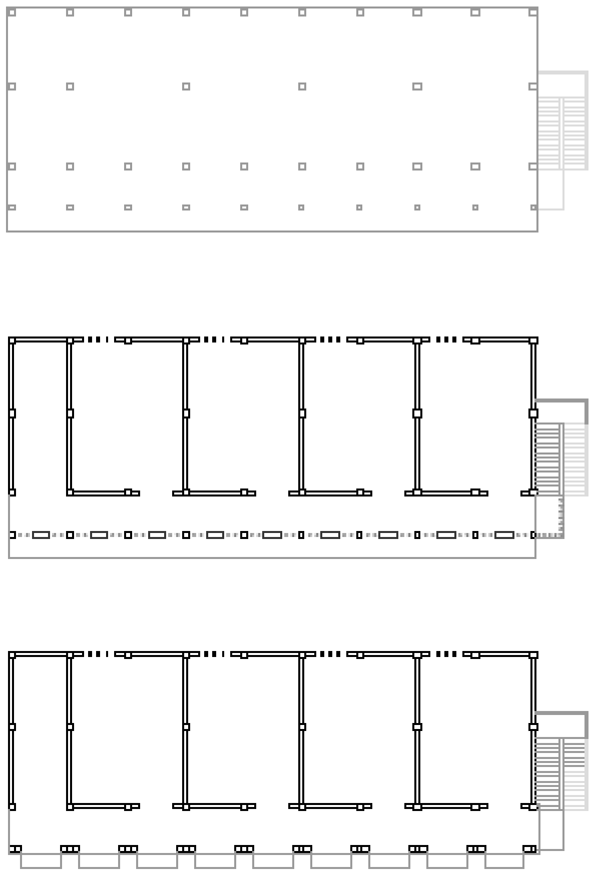
LASCAHOBAS, HAITI

SCALE: 1' = 1/32"

IPRO 335 | 1/27/2011

Appendix B: Diagrams of Ecole Baptiste





NOTES:
1) CONCRETE BLOCK CONSTRUCTION WITH POURED CONCRETE COLUMNS AND ROOF

N

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ECOLE BABTISTE

PLANS

LASCAHOBAS, HAITI

SCALE: 1/16" = 1'0"

IPRO 335 | 1/31/2011

Appendix C: Bill of Materials

Bill of Materials[2]

Ecole St. Gabriel

Item/amount	*Cost*
Solar panels (14)	$4,910
Charge Controller	$546
Batteries (15)	$4,242
Wires, breakers, combiner box	$629
Mounting	$1,000
Shipping, Customs, Duties	$4,606
Total	$15,933

Ecole Baptiste

Item/amount	*Cost*
Solar panels (10)	$3,507
Charge Controller	$546.00
Batteries (10)	$2,828

[2] Bill of Materials cost estimates from local Haitian Solar Services Provider. We are in the process of procuring additional bids.

Wires, breakers, combiner box	$629
Mounting	$1,000
Shipping, Customs, Duties	$3,329
Total	$11,839

Travel

Item/amount	*Cost*
Plane Tickets (10)	$5,000
Hotel Room ($80/night, 4 rooms) staying for 14 nights	$4,480
Travel Insurance (package)	$600
Total	$10,080

*Total**: $37,850***

Appendix D: Teacher Guide

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Energy Education and Development

Energy from the Sun

Student Guide

Seven Activities

Grades: K - 4

c: Solar

ENERGY FROM THE SUN

STUDENT GUIDE

This Guide Belongs To:

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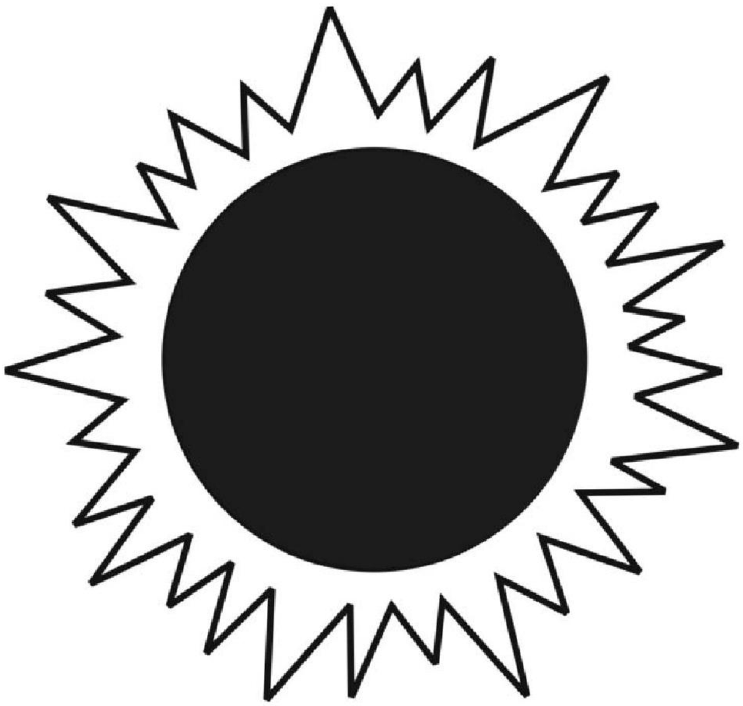
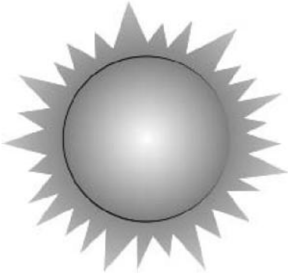


3300 South Federal Street, Chicago, IL 60616, 312 567-3300, www.iitempoweringhaiti.org

Solar Energy

Lesson Plans/Activity	Energy from the Sun Teacher Guide
Grades:	K-4
Subject:	Solar
Summary:	Hands – on explorations to introduce the scientific concepts of solar energy to elementary students. - Introduction to solar energy (K-4) - Solar energy to heat and motion - Cooking with solar energy (K-4) - Turning solar energy into electricity - PV cells on the school
Curriculum:	Science, Math, Social Studies
Plan Time:	**Eight 30 – minute class periods.**
Standards:	○ Activity 1 – Introduction to Solar Energy (60 mns over 2 days) **Objective:** To learn about solar energy by reading by completing worksheets. ○ Activity 2 – Solar energy to heat and motion 2 (30 mns) **Objective:** To learn that warm air rises because it is less dense--there are fewer molecules per given volume than the surrounding air. ○ Activity 3 – Cooking with solar energy (30 mns) **Objective:** To learn that shiny materials reflect solar energy. To learn to cook with a solar oven. - Teacher Information: Photovoltaic (PV) cells. ○ Activity 1 – Turning solar energy into electricity (30 mns) **Objective:** To learn that photovoltaic (PV) cells turn solar energy into electricity. To learn that electricity can produce light and motion. ○ Activity 2 : PV cells on the school (30 mns) **Objective:** To learn about the PV cells in use on the school. - Evaluation Form
Materials:	Handouts; other materials vary by activity; a Student Guide is included.

Solar Energy

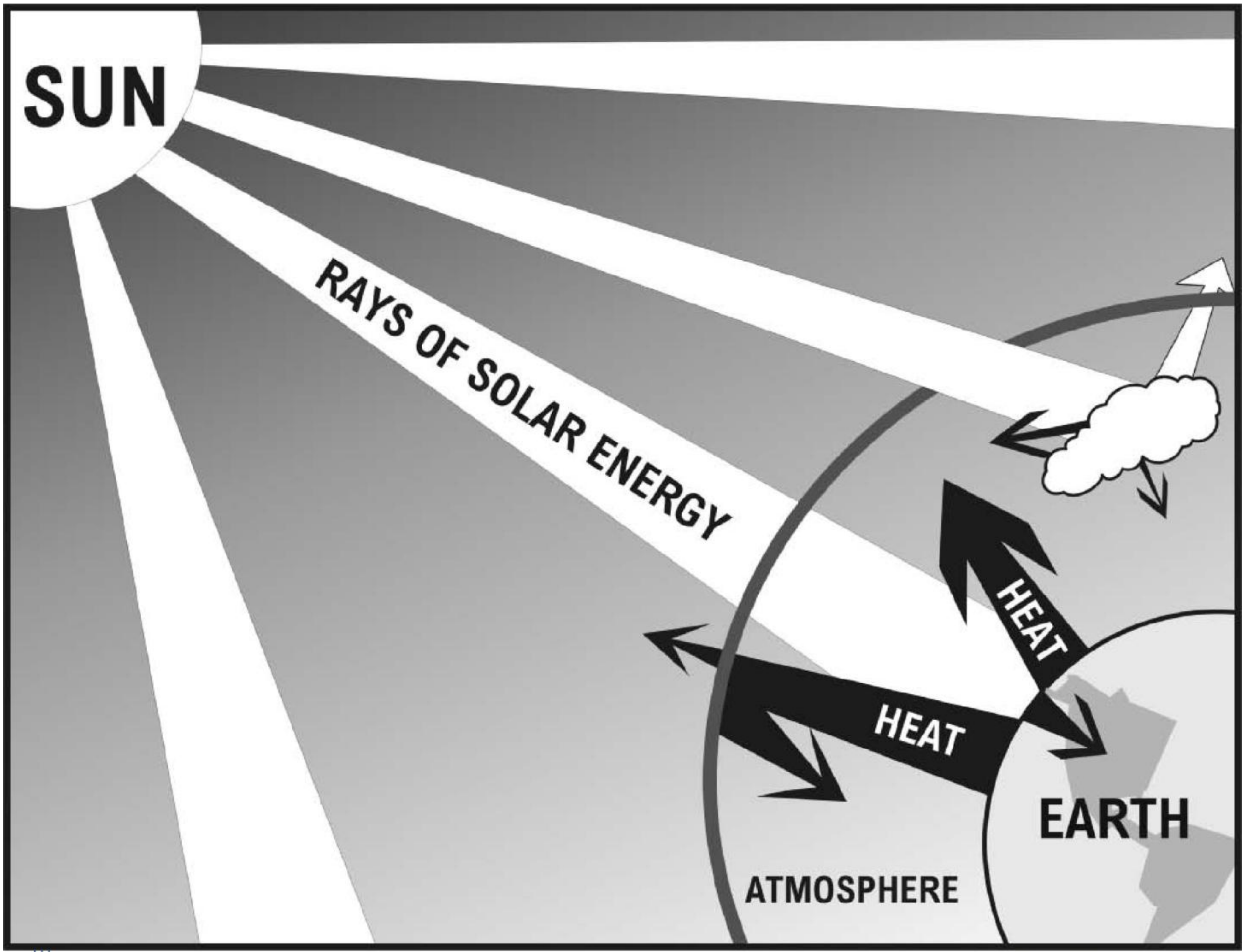


Our earth gets most of its energy from the sun. We call this energy **solar energy**. **Sol** means sun.

Solar energy travels from the sun to the earth in **rays**. Some are light rays that we can see. Some are rays we can't see, like x-rays. Energy in rays is called **radiant energy**.

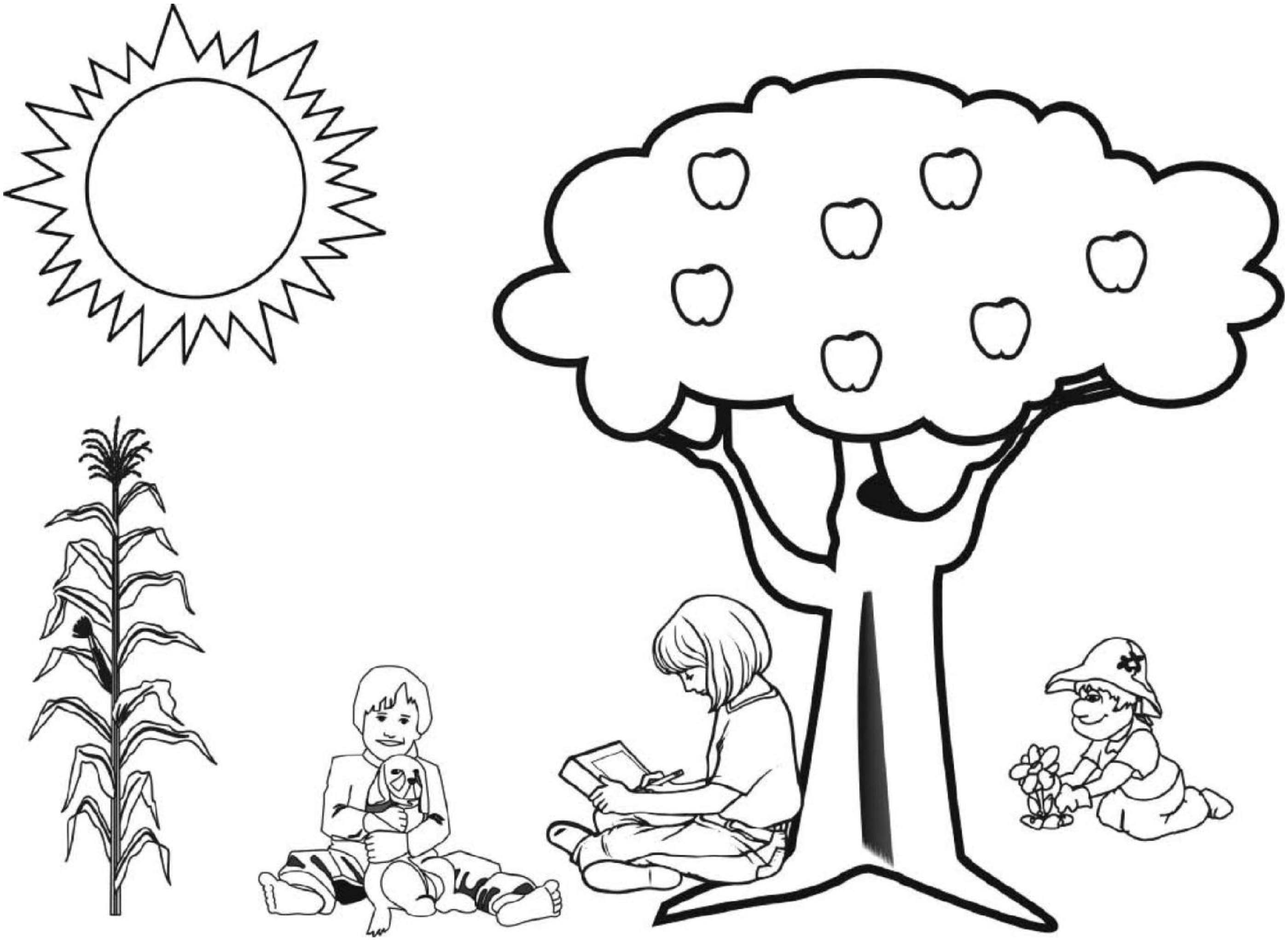
The sun is a giant ball of gas. It sends out huge rays of energy every day. Most of the rays go off into space. Only a small part reaches the earth.

When the rays reach the earth, some bounce off clouds back into space--the rays are **reflected**. The earth **absorbs** most of the solar energy and turns it into **heat**. This heat warms the earth and the air around it--the **atmosphere**. Without the sun, we couldn't live on the earth-it would be too cold.



WE USE SOLAR ENERGY TO SEE AND GROW THINGS

We use solar energy in many ways. During the day, we use sunlight to see what we are doing and where we are going.



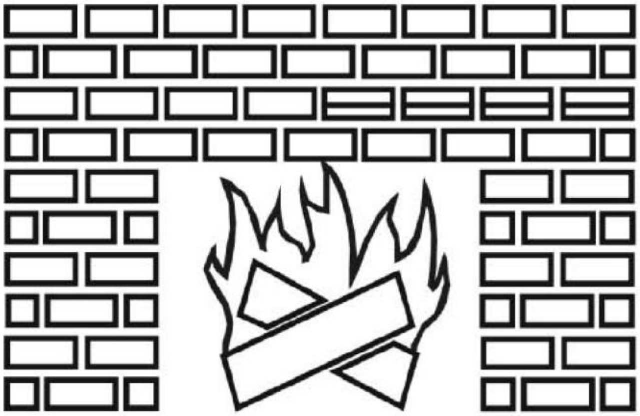
Plants use the light from the sun to grow. Plants **absorb** (take in) the solar energy and use it to grow. The plants keep some of the solar energy in their roots, fruits, and leaves. They store it as **chemical energy**.

The energy stored in plants feeds every living thing on the earth. When we eat plants and food made from plants, we store the energy in our bodies. We use the energy to grow and move. We use it to pump our blood, think, see, hear, taste, smell and feel. We use energy for everything we do.

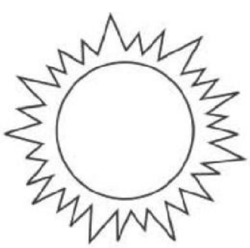
The energy in the meat that we eat also comes from plants. Animals eat plants to grow. They store the plants' energy in their bodies.

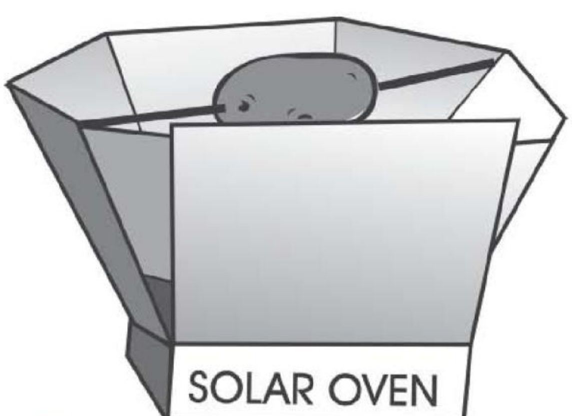
WE CAN USE ENERGY FROM THE SUN FOR HEAT

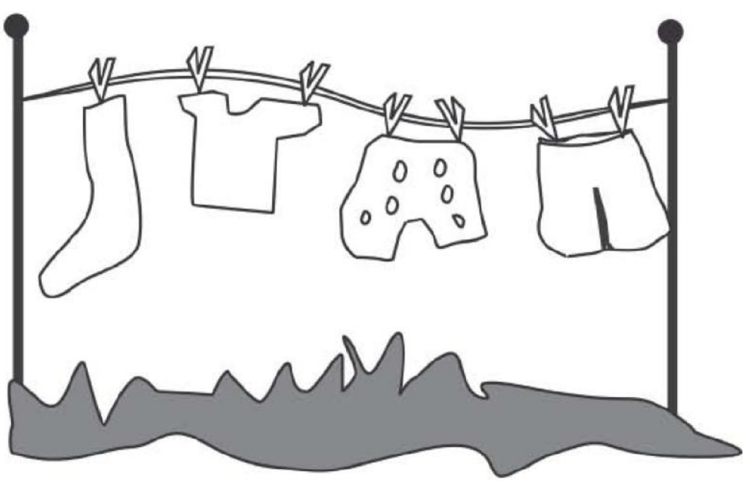
We also use the energy stored in plants to make heat. We burn wood in campfires and fireplaces. Early humans burned wood to provide light, cook food, scare away wild animals, and keep warm.



Solar energy turns into heat when it hits objects. That's why we feel warmer in the sun than in the shade. The light from the sun turns into heat when it hits our clothes or our skin. We use the sun's energy to cook food and dry our clothes.



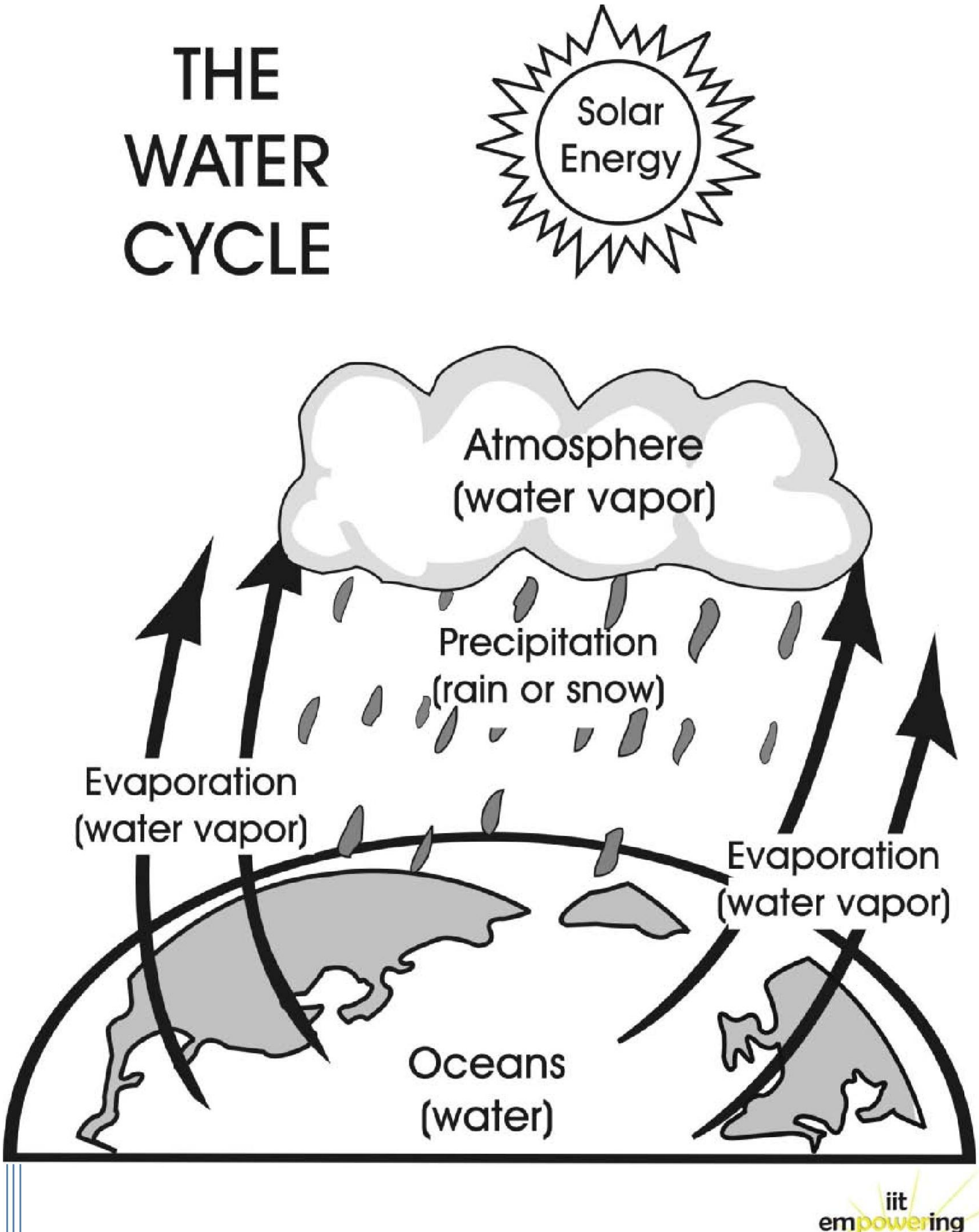




THE SUN'S ENERGY IS IN MANY THINGS

Solar energy powers the **water cycle**. The water cycle is how water moves from clouds to the Earth and back again. The sun heats water on the earth. The water **evaporates**-it turns into **water vapor** and rises into the air to form clouds. The water falls from the clouds as **precipitation**--rain, sleet, hail or snow.

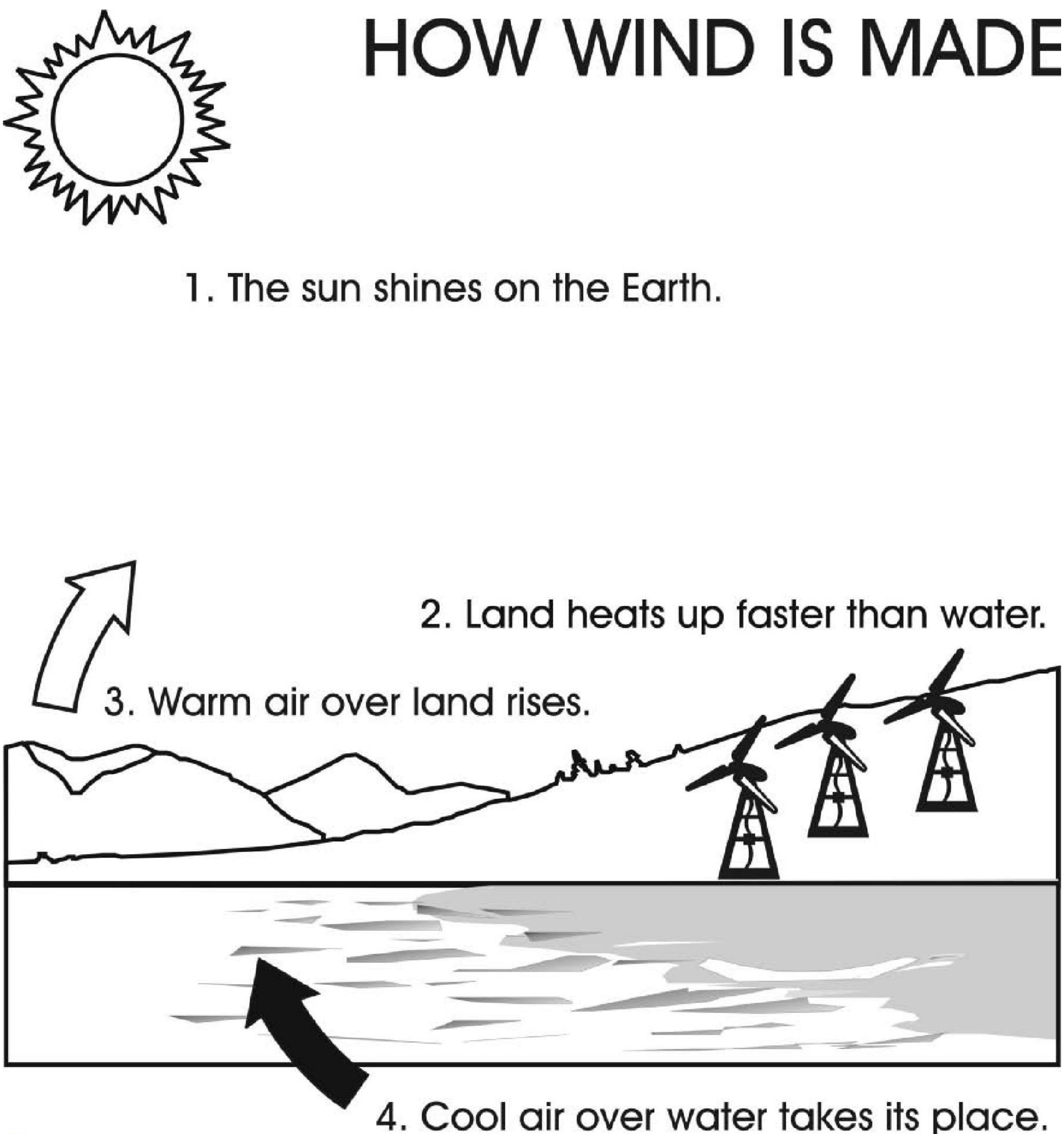
When water falls on high ground, **gravity** pulls it to lower ground. There is energy in the moving water. We can capture that energy with dams and use it to make **electricity**.



THE SUN MAKES THE WIND

Solar energy makes the winds that blow over the earth. The sun shines down on the land and water. The land heats up faster than the water. The air over the land gets warm. The warm air rises. The cooler air over the water moves in where the warm air was. This moving air is wind.

Windmills can capture the wind's energy. The windmills turn the energy in moving air into **electricity**. The wind pushes against the blades of the windmill and they begin to spin. A **generator** inside the windmill changes the motion into electricity.

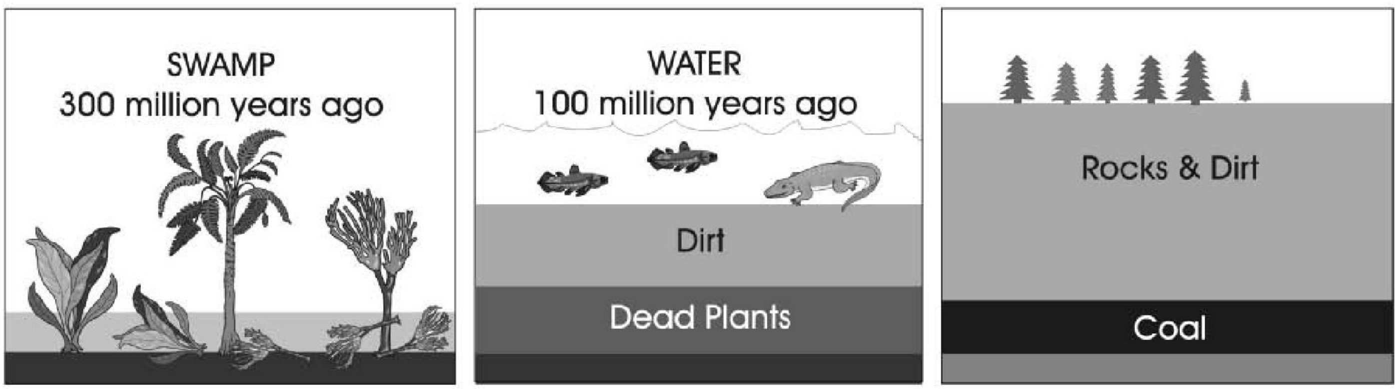


FOSSIL FUELS CONTAIN ENERGY FROM THE SUN

Coal, oil, and natural gas are called **fossil fuels**, because they were made from prehistoric plants and animals. The energy in them came from the sun.

We use the energy in fossil fuels to cook our food, warm our homes, run our cars, and make electricity. Most of the energy we use today comes from fossil fuels.

HOW COAL WAS FORMED

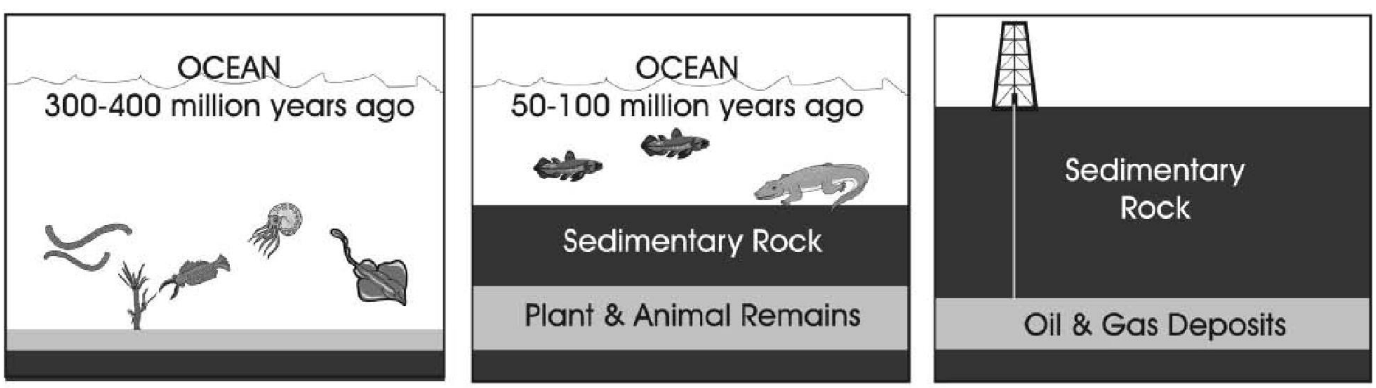


Before the dinosaurs, many giant plants died in swamps.

Over millions of years, the plants were buried under water and dirt.

Heat and pressure turned the dead plants into coal.

HOW OIL & NATURAL GAS WERE FORMED



Tiny sea plants and animals died and were buried on the ocean floor. Over time, they were covered by layers of sedimentary rock.

Over millions of years, the remains were buried deeper and deeper. The heat and pressure turned them into oil and gas.

Today, we drill down through layers of sedimentary rock to reach the rocks that contain oil and gas.

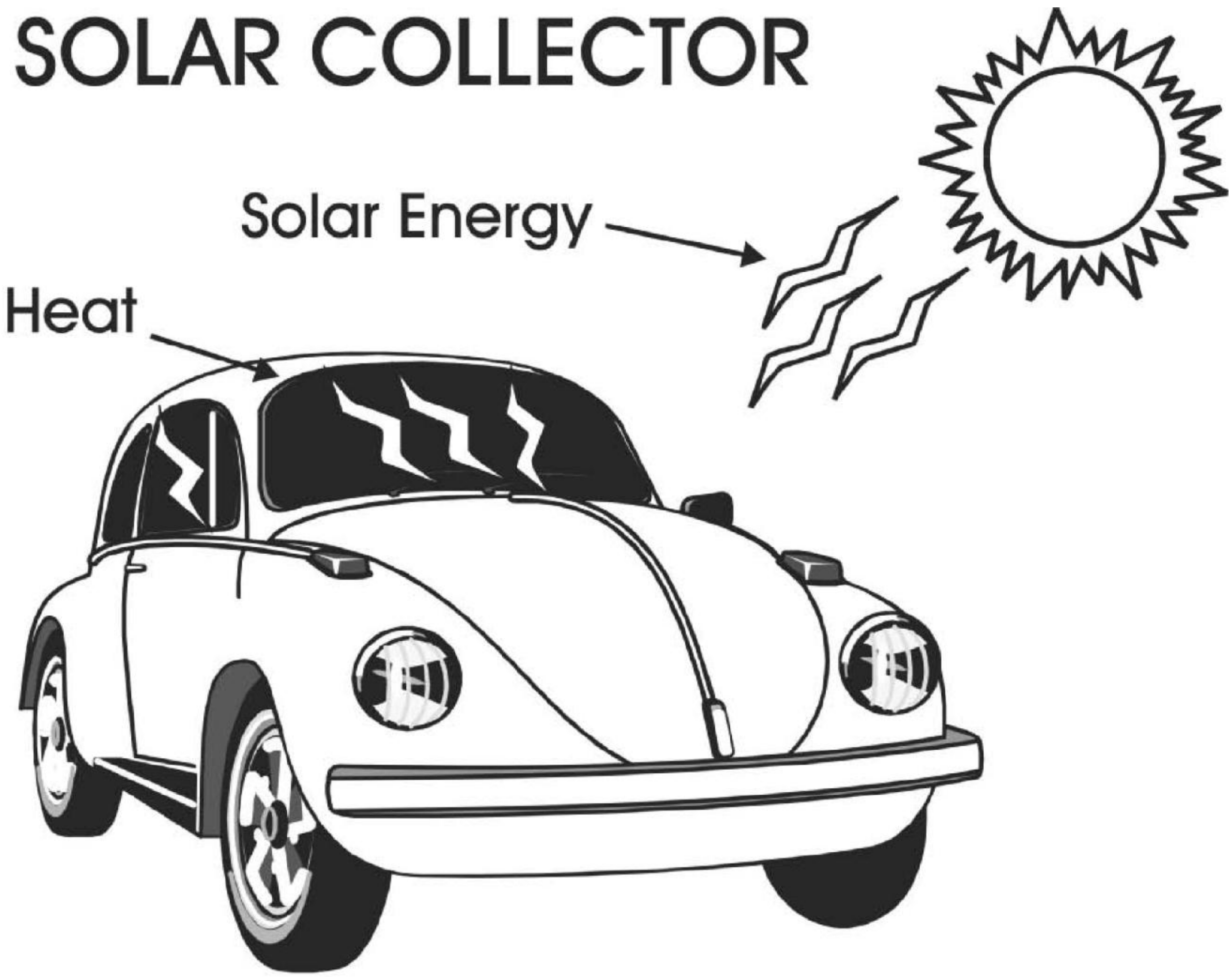
SOLAR ENERGY IS RENEWABLE

Solar energy is free and clean. Solar energy is **renewable**. We will never run out of it. The sun will keep making energy for millions of years.

Why don't we use the sun for all our energy needs? We don't know how to yet. The hard part is capturing the energy. Only a little bit reaches any one place. On a cloudy day, most of the solar energy never reaches the ground at all.

WAYS WE CAPTURE SOLAR ENERGY

Lots of people put **solar collectors** on their roofs. Solar collectors capture the energy from the sun and turn it into heat. People heat their houses and their water using the solar energy. A closed car on a sunny day is a solar collector.



On a sunny day, a closed car is a solar collector.
Solar energy passes through the glass,
hits the inside of the car and changes into heat.
The heat gets trapped inside.

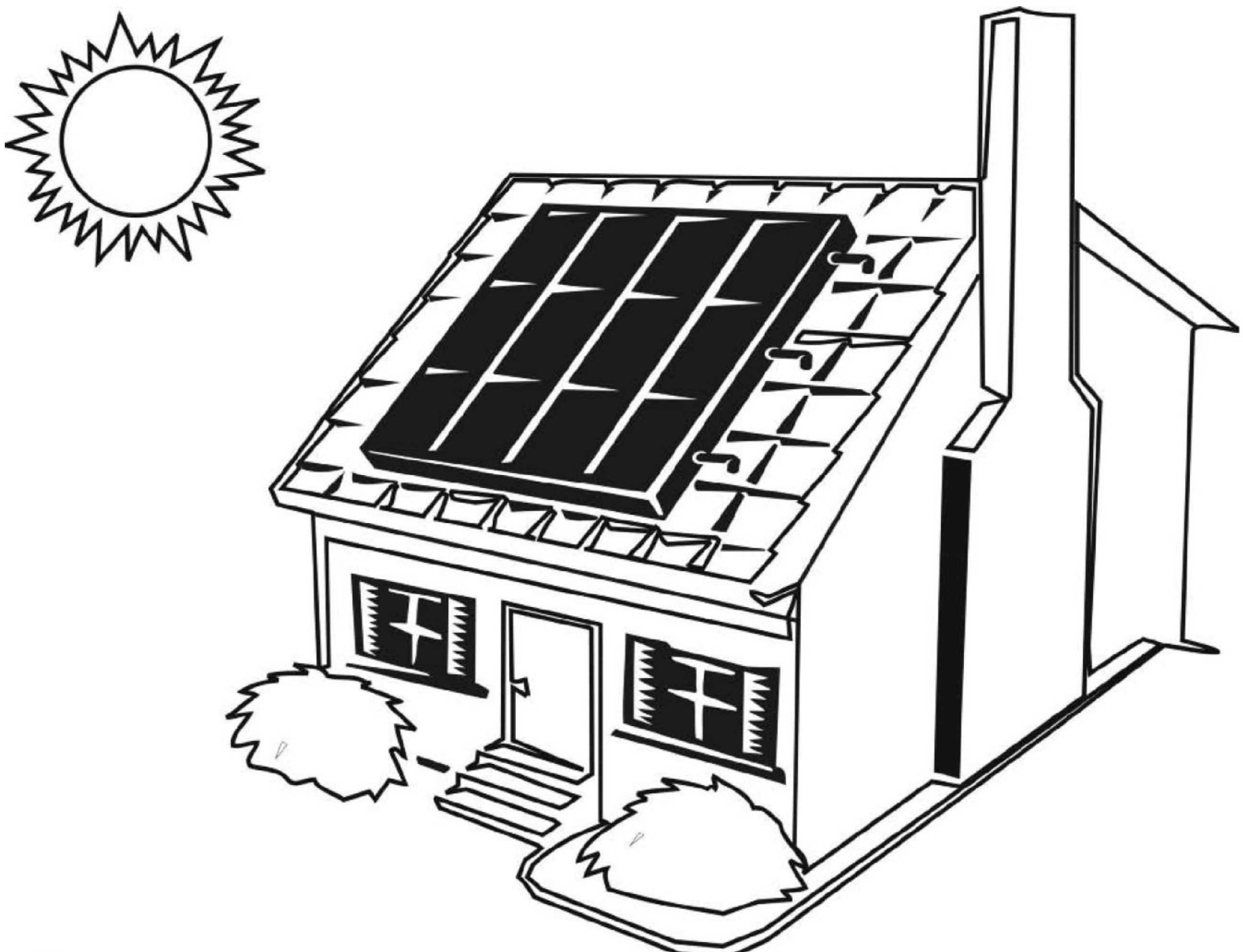
SOLAR ENERGY CAN MAKE ELECTRICITY

Photovoltaic (PV) cells turn the sun's energy into electricity. **Photo** means light and **volt** is a measure of electricity. PV cells are made of two pieces of **silicon**, the main ingredient in sand. Each piece of silicon has a different **chemical** added. When **radiant energy** hits the PV cell, the layers of silicon work together to change the radiant energy into electricity.

Some toys and calculators use small PV cells instead of batteries. Big PV cells can make enough electricity for a house. They are expensive, but good for houses far away from power lines.

Some schools are adding PV cells to their roofs. The electricity helps lower the amount of money schools must pay for energy. The students learn about the PV cells on their school buildings.

Today, solar energy provides only a tiny bit of the electricity we use. In the future, it could be a major source of energy. Scientists are looking for new ways to capture and use solar energy.



SOLAR ENERGY

Fill in the blanks with the words in the box at the bottom of the page. Use each word only once.

1. Solar comes from the word ________________, which means sun.
2. The word _________________ means light.
3. ________________ is a measure of electricity.
4. _________________________ is energy that travels in rays.
5. Plants ____________________ , or take in, radiant energy.
6. White and shiny objects ____________________ radiant energy.
7. A _________________________ takes in solar energy and turns it into heat.
8. Solar energy is called a __________________ energy source, because it will always be there.
9. A ________________________ cell turns light into electricity.
10. Plants take in solar energy and store it in their leaves and roots as ____________________________.

reflect	absorb	chemical energy	photo	volt	sol
renewable	photovoltaic	solar collector	radiant energy		

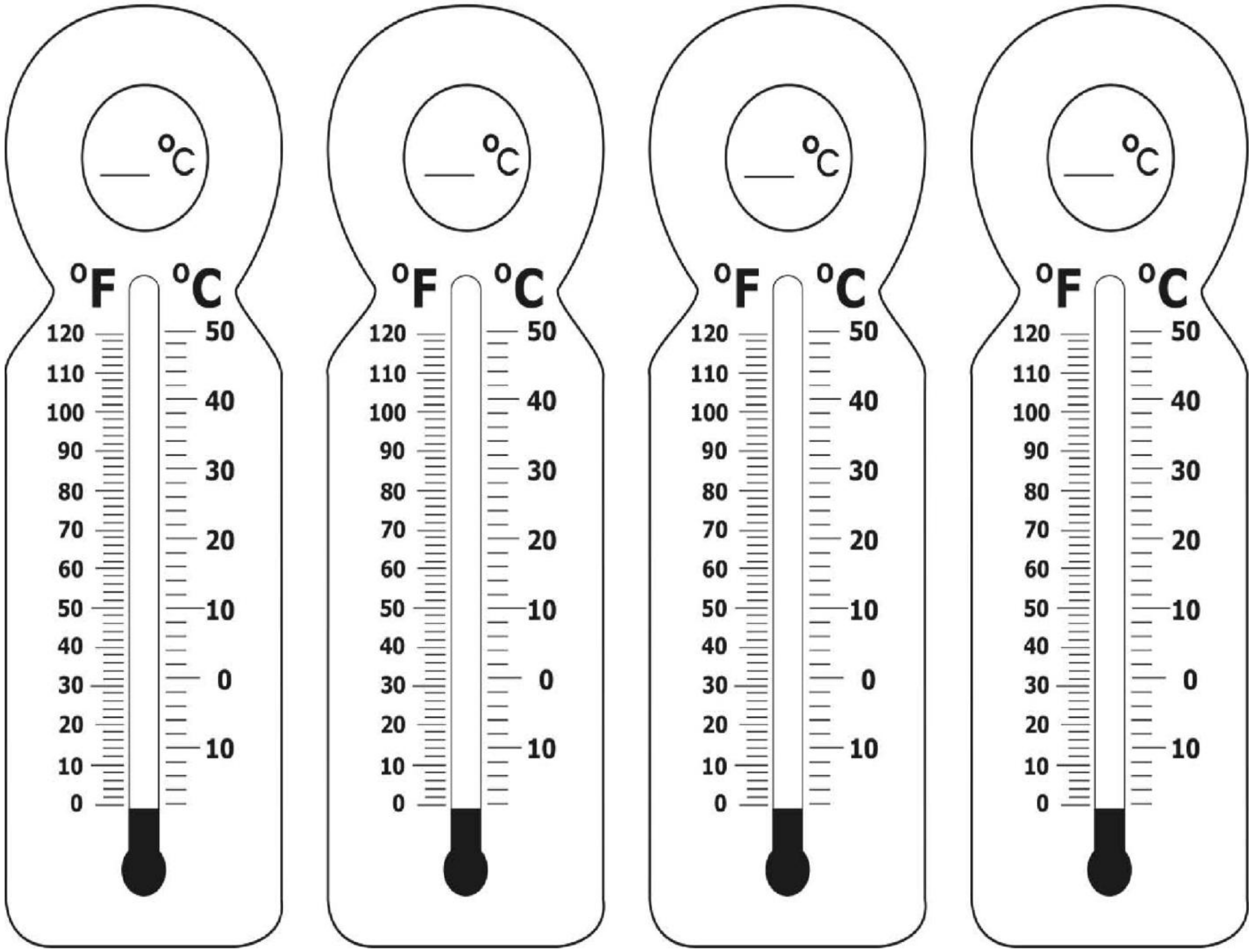
WATER & WIND

Fill in the blanks with the words in the box at the bottom of the page. Use each word only once.

1. Water as a gas is called ____________________________.
2. Rain and snow are called __________________________.
3. The air around the earth is the ___________________________.
4. When water turns into a gas, it _________________________.
5. The air over _________________ heats up faster than air over water.
6. A __________________ is a machine that captures the energy in moving air.
7. Warm air ___________________ into the atmosphere.
8. Moving air is called _____________________.
9. ________________ moves water from high to low ground.
10. Windmills and dams turn the energy in moving air and moving water into ________________________.

evaporates	rises	water vapor	precipitation	gravity
windmill	electricity	land	atmosphere	wind

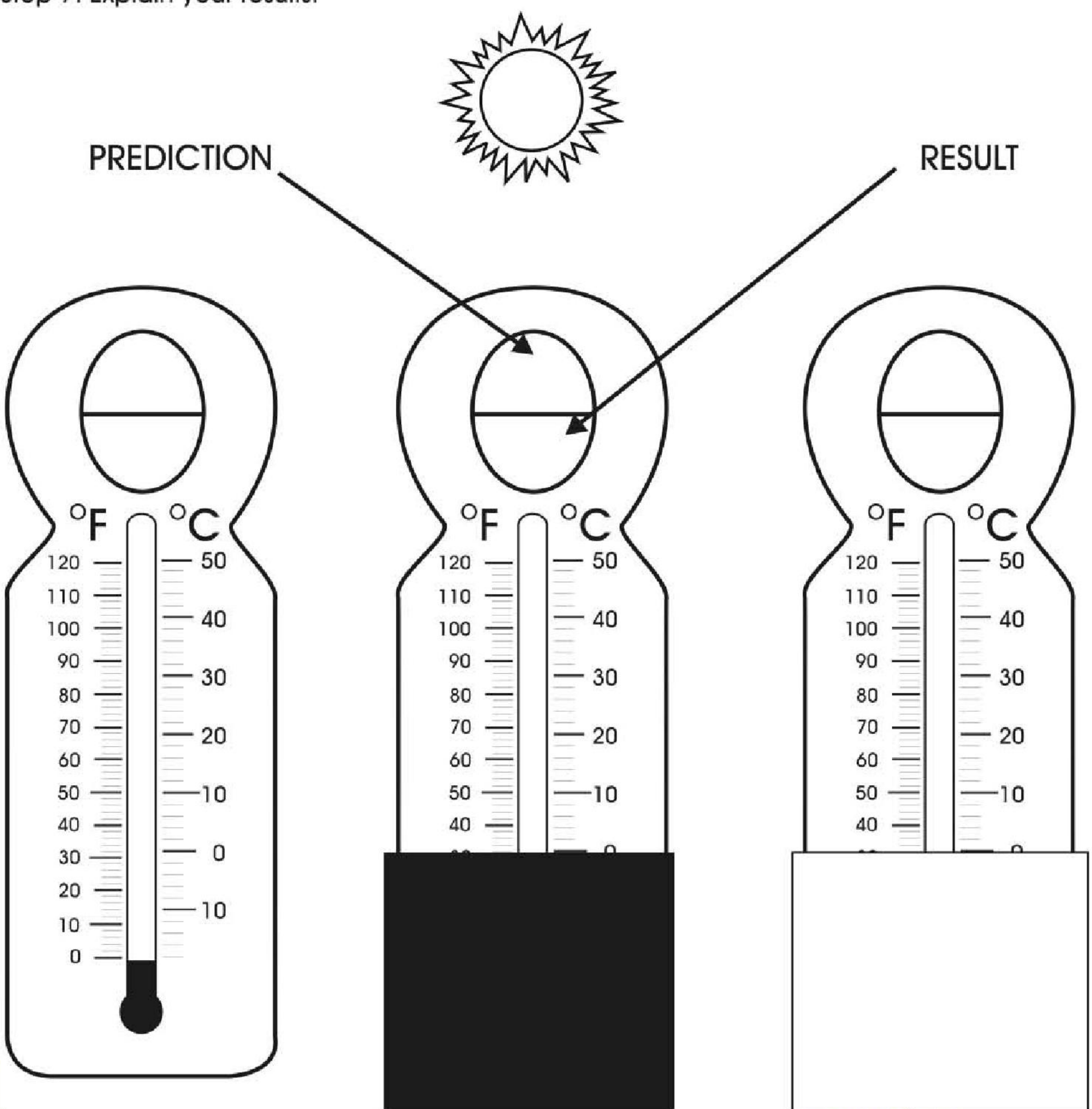
Freezing Water 32°F | Body Temperature 98-99°F | Warm Summer Day 80°F | Very Cold Winter Day 10°F



SOLAR TO HEAT

When radiant energy hits objects, some of the energy is reflected and some is absorbed and changed into heat. Some colors absorb more radiant energy than others.

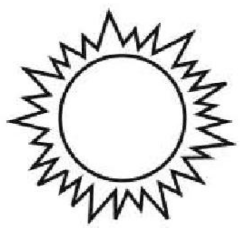
Step 1: Put three thermometers in a sunny place.
Step 2: Cover the bulb of one with black paper. Cover the bulb of one with white paper.
Step 3: Predict which thermometer will get hottest. Number them 1-3, with 1 as the hottest.
Step 4: Observe the thermometer for three minutes.
Step 5: Record your results by coloring the tubes of the thermometers.
Step 6: Look at the results and number the thermometers 1-3 with 1 as the hottest.
Step 7: Explain your results.

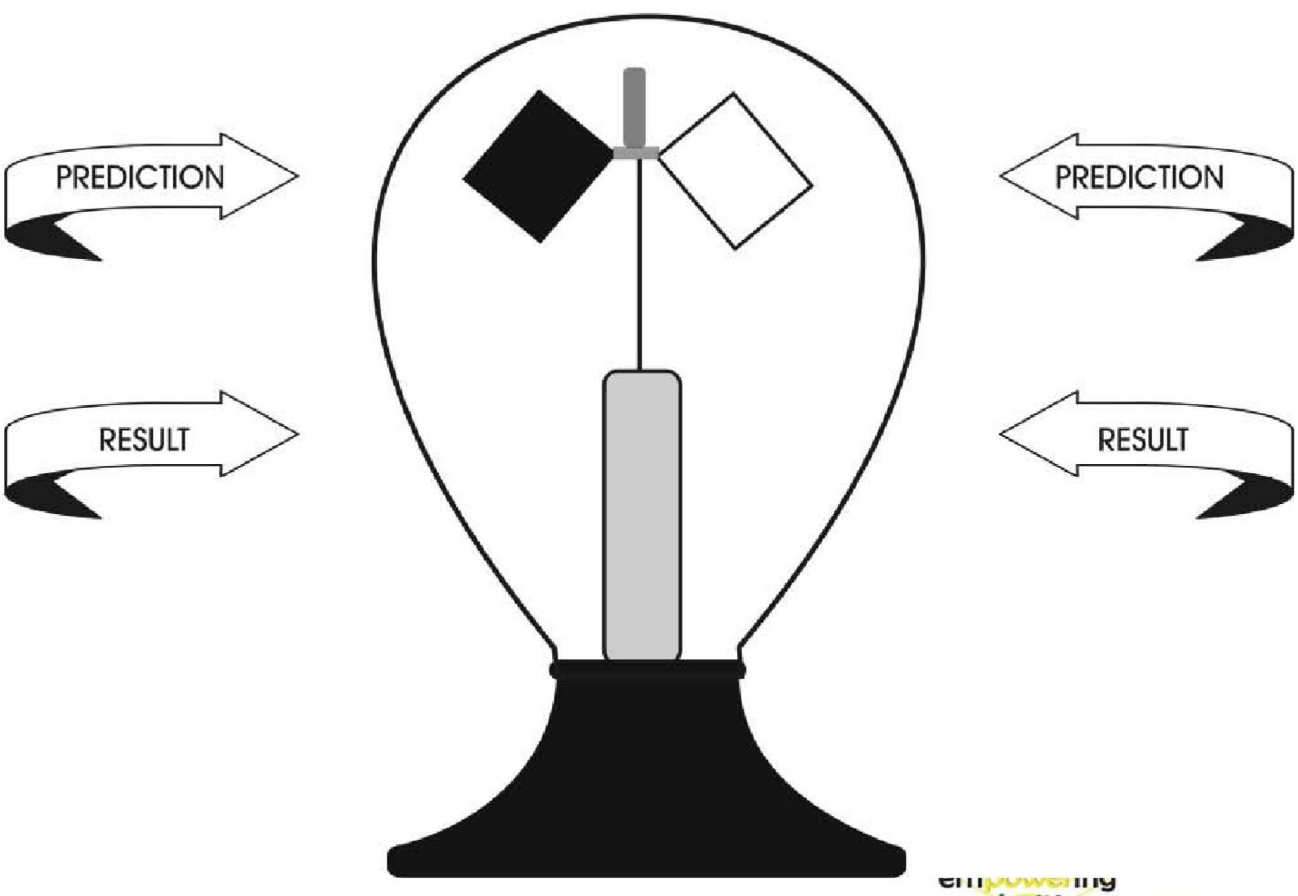


RADIOMETER

A radiometer has four vanes. One side of each vane is white; the other side is black. When radiant energy hits the vanes of the radiometer, they begin to spin. One side of the vanes gets hotter than the other. The air near the hotter side of the vanes gets hotter and pushes against the vanes. The radiometer changes radiant energy to heat, then to motion.

Step 1: Predict which way you think the radiometer vanes will spin. Color the PREDICTION ARROW that shows the direction you think the vanes will spin.
Step 2: Put the radiometer in bright sunlight or under an overhead projector.
Step 3: Observe the radiometer.
Step 4: Record your results. Color the RESULT ARROW that shows the direction the vanes are spinning.
Step 5: Explain your results.

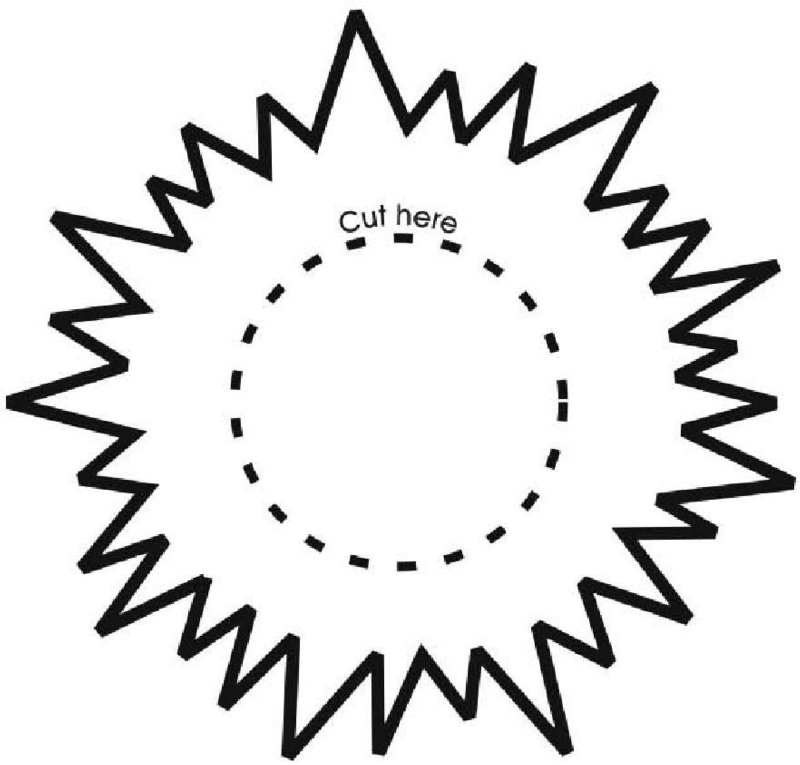




SUN PAPER

Radiant energy can cause chemical changes when it hits objects. Some changes are fast and some are slow. Radiant energy will slowly change the color of construction paper. It will quickly change the color of NaturePrint® Paper. The colors change because the radiant energy makes a chemical change in the paper.

Step 1: Using white paper, cut out two drawings of the sun like in the picture below.
Step 2: Place one drawing on a piece of red construction paper, tape one edge of the drawing to the paper, and put it in the sun.
Step 3: Place the other drawing on a piece of NaturePrint® paper and put it in the sun for two minutes. Remove the drawing and soak the NaturePrint® paper in water for one minute away from the sun. Dry flat. Hang on the wall as a decoration.
Step 4: Observe the red construction paper every hour for four hours. How long does it take for the color to begin to change?
Step 5: Explain your results.



SOLAR BALLOON

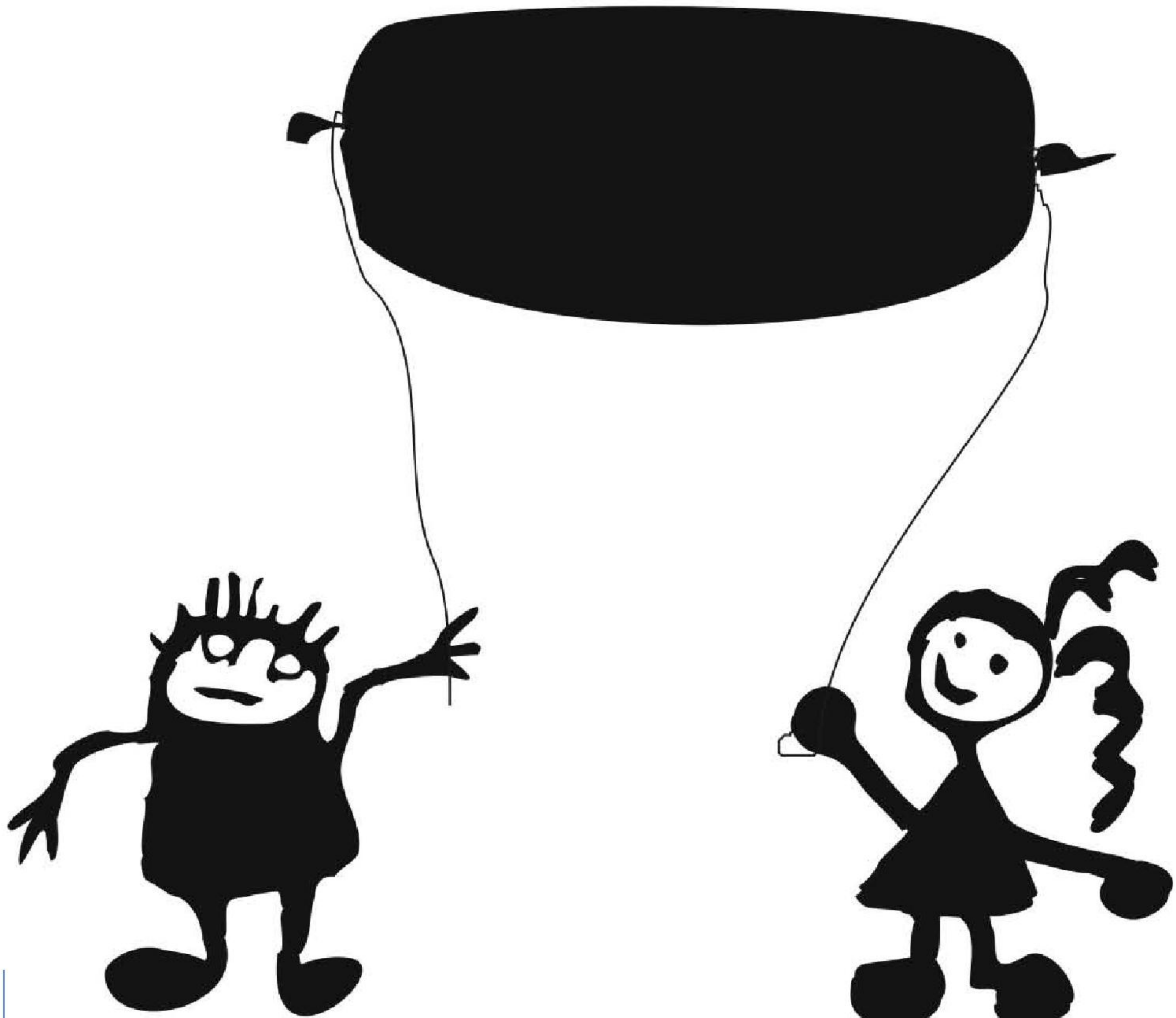
Radiant energy often turns into heat when it hits objects. Black objects absorb more radiant energy than white objects. When air gets hotter, it rises. A solar balloon works because the black plastic absorbs radiant energy and turns it into heat. The air inside gets hotter.

Step 1: On a very sunny day, take the solar balloon outside and tie one end closed with a piece of plastic string. Open the other end and walk into the wind until it fills with air. When the balloon is filled with air, tie off the other end with string.

Step 2: Tie long pieces of string to both ends. Have two people hold the ends of the string and place the balloon in the sun.

Step 3: Observe the balloon as the air inside becomes hotter.

Step 4: Explain your observations.



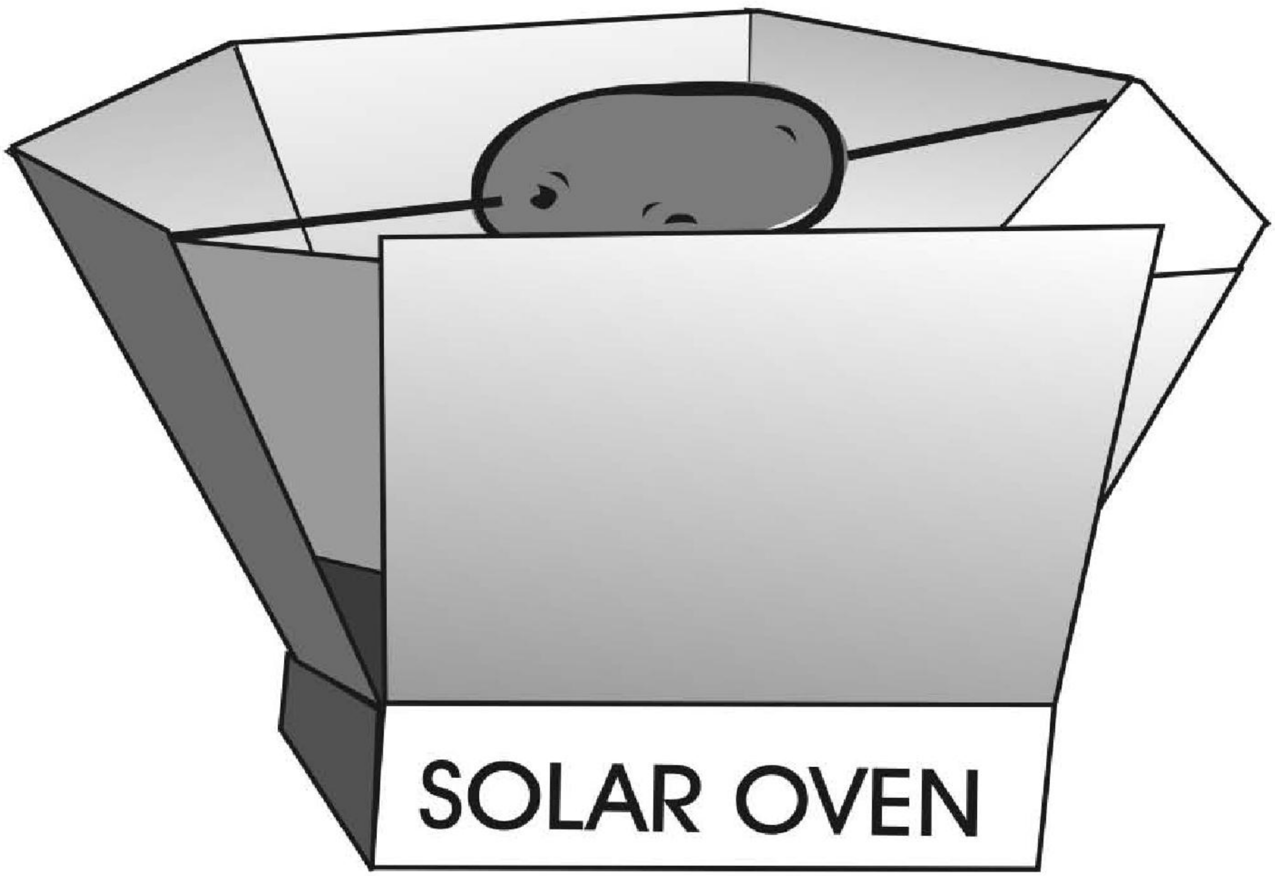
SOLAR OVEN

A solar oven has shiny foil on its inside walls that reflect radiant energy into the middle of the oven. The bottom of the oven is dark to absorb energy. When the radiant energy hits food in the oven, it changes into heat. A solar oven gets hot enough to cook foods, even in the winter. You can cover the solar oven with clear plastic wrap to hold in the heat.

Step 1: On a very sunny day, take the solar oven outside and put it in a sunny place.
Step 2: Place food in the oven.
Step 3: Observe how long it takes to cook the food.

Hints for cooking with a solar oven:

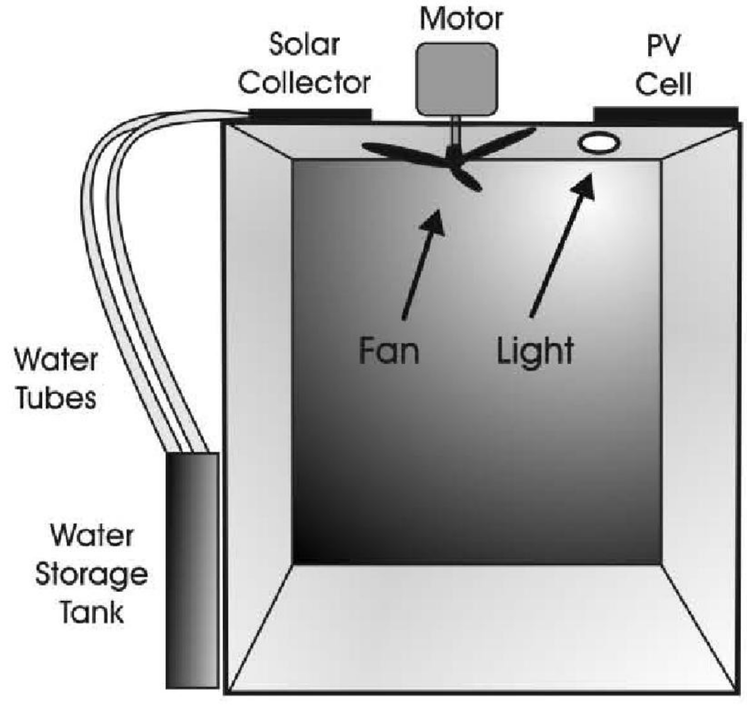
1. Use black metal pans and dark brown glass dishes.
2. Don't add water when cooking vegetables. Use a pan with a lid and they will cook in their own juices.
3. To bake potatoes, rub with oil and put in a dark pot with a lid.
4. Bake bread in dark glass dishes with lids.
5. Use packaged chocolate chip cookie dough on a dark pan.
6. Food won't burn in a solar oven. It might lose too much water if you cook it too long.



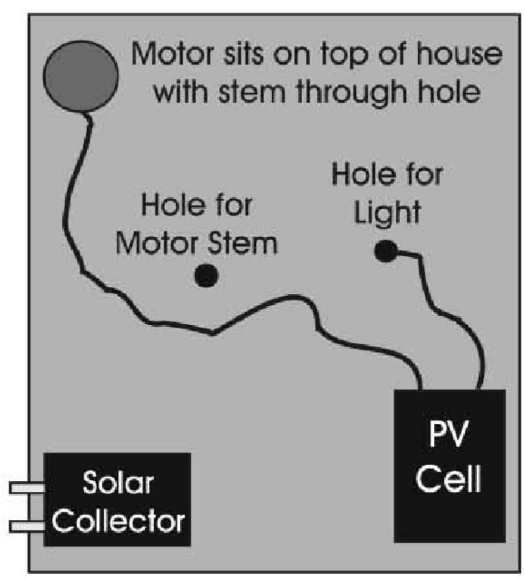
SOLAR HOUSE

A photovoltaic (PV) cell changes radiant energy into electricity. Electricity can run a motor to make motion and make light. A solar collector absorbs radiant energy and turns it into heat. A solar collector can heat water. A water storage tank painted black can store hot water and keep it hot by absorbing radiant energy.

Step 1: Use a cardboard box to make a house with big windows and a door in the front.
Step 2: Use clear transparency film to cover the windows.
Step 3: Use black construction paper to make a round water storage tank. Attach it to the side of the house with tape.
Step 4: Make two holes in the top of the box like in the drawing. Each hole should be about one centimeter (1 cm) in diameter.
Step 5: Place the solar collector on top of the house as shown in the drawing. Put the tubing from the solar collector into the water storage tank.
Step 6: Place the PV cell on top of the house. Insert the light through the hole as shown in the diagram.
Put the stem of the motor through the hole for the motor stem.
Step 7: Put a tiny bit of clay into the hole of the fan and push it onto the stem of the motor that is sticking through the ceiling.
Step 8: On a sunny day, place the house in the sun with the front facing south.
Step 9: Observe the light shine and the fan turn as the PV cell turns radiant energy from the sun into electricity. The solar collector shows how a real solar house could heat and store water. It doesn't really work.



Front View of House



Top View of House