PROJECT RECHARGE

- STEAM Curriculum -

2022/2023 Program Funding Provided By:

In Partnership With:

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The University of Nevada, Reno, Envirolution and Washoe County School District

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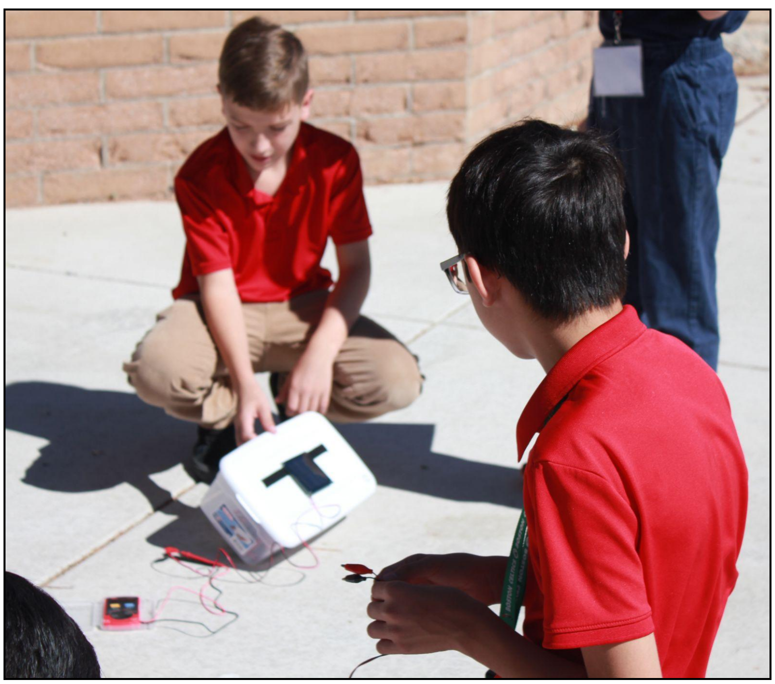
*"The content is very engaging and connects students to the real world. I really like how it gives students a reason to take an active part in the health of the planet." - **PRC Teacher, 2021***

*"I think it was really fun because I never got to turn on a lightbulb using wires and a battery. It made me feel like a scientist." - **Student 2021***



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"Project ReCharge has been able to engage students in things that are happening in the world right now and the level of excitement and intrigue among students on how the world works is a very amazing thing to see."

- Greg Mingo, Principal Grant Sawyer Middle School, 2021

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2022/2023 Recruitment Packet

Project ReCharge Curriculum Map

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Green - NGSS Standards Blue - 21st Century Competencies Red - Common Core Standards Purple - National Art Standards	**Sustainability Introduction Activities** • HS-ESS3-3 • MS-ESS3-3 • 5-ESS3-1 • C-3, KC-3, RW-2, T-2, SC-1

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4. HS Geothermal Energy • HS-PS3-4 • HS-ESS2-3 • HS-PS3-3 • HS-ETS1-1 • HS-ESS3-2 • HS-ETS1-3	**5. Solar Energy** • HS-PS3-3 • MS-ESS3-3 • C-1, KC-2, RW-2, T-3, SC-1 • HS: MP.2	**6. Transportation Introduction** • HS-ESS3-4 • MS-ESS3-3 • C-1, KC-3, RW-3, SC-2 • HS: RST.11-12.8	

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1. Lighting • HS-ESS3-4 • HS-ETS1-3 • MS-ESS3-3 • MS-ETS1-3 • 5-ESS3-1 • 3-5-ETS1-2 • C-1, KC-2, RW-2, SC-2, T-1	**2. Appliances** • HS-ESS3-4 • HS-ETS1-3 • MS-ESS3-3 • MS-ETS1-3 • 5-ESS3-1 • 3-5-ETS1-2 • C-1, KC-1, RW-2, SC-2, T-2

Sustainability Detectives			
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Sustainability Projects	Key
Sustainability Projects • HS-ESS3-4 • HS-ETS1-3 • MS-ESS3-3 • MS-ETS1-1 • 5-ESS3-1 • 3-5-ETS1-2 • KC-4,RW-3, T-3, SR-3, SC-3	Green - NGSS Standards Blue - 21st Century Competencies Red - Common Core Standards Purple - National Art Standards

Project ReCharge Curriculum Overview and Standards

Every Project ReCharge lesson follows the 5E Learning Model using hands-on activities to help students build their own understanding from life experiences, collaboration, critical thinking, problem-solving, and engineering design. Students use what they learn to construct a proposal to decrease energy use at home, their school, or the community – some of which will be funded by Envirolution and implemented in the community. 21st Century and SEL standards are woven through each lesson, and the curriculum supports Next Generation Science Standards for Upper Elementary, Middle, and High School levels. This curriculum is designed to be supplemental to fit the needs of the teacher. Each curriculum is updated annually by licensed teachers and professionals, therefore teachers and administrators know they are using a curriculum that meets the latest education requirements.

21st Century and Social Emotional Learning Standards

21st Century Competencies

1. **Collaboration** → Students are collaborating when they work in pairs or groups to discuss an is-sue, solve a problem, and/or create a product.
2. **Knowledge Construction** → Students are constructing knowledge when they apply critical thinking to go beyond knowledge reproduction by generating ideas and understandings that are new to them.
3. **Real-World Problem Solving and Innovation** → Students use problem solving when they define and develop solutions to problems that are new to them, or complete a task they have not been instructed how to do, or design a complex product that meets a set of requirements.
4. **Use of Technology for Learning** → Students are using technology for learning when they directly complete all or part of an activity using technology, and control the technology themselves.
5. **Self Regulation** → Students are using self-regulation when they engage in long-term activities in which they are required to plan the process of their work and improve it over multiple iterations.
6. **Skilled Communication** → Students use extended communi-cation when they repre-sent a set of connected ideas, not a single, sim-ple thought; students use multimodal com-munication when they use multiple modes or tools to communicate a coherent message.

Social Emotional Learning Connections

1. **Self-Awareness** → Identify one's emotions, maintain an accurate and positive self-concept, recognize individual strengths, experience a sense of self-efficacy
2. **Self-Management** → Regulate emotions, manage stress, monitor and achieve behaviors related to school and life success

3. **Social Awareness** → Exhibit empathy, appreciate diversity, understand social and ethical norms for behavior, recognize family, school, and community supports

4. **Relationship Skills** → Build and maintain relationships with diverse groups & individuals, communicate clearly to express needs and resolve conflict

Project ReCharge Units and NGSS Standards

<table>
<tr><th colspan="2">Sustainability Introduction</th></tr>
<tr><td colspan="2">These activities were designed to introduce students to the idea of sustainability and give students the necessary background knowledge to look at the rest of the curriculum through the lens of sustainability efforts. Students start by exploring how sustainability and their happiness are connected. Students then explore the United Nations Sustainable Development Goals and consider ways they could be more sustainable in their lives. After that, students work together to learn about the different aspects of sustainability - people, planet, profit, and use their knowledge to develop a working definition of sustainability. Lastly students investigate their carbon footprint and use that information to develop a S.M.A.R.T sustainability and student commitment.</td></tr>
<tr><td>1. Happiness and Sustainability → students identify what aspects of their life give them happiness and relate those traits to the UN Sustainable Development Goals.

2. Sustainability BINGO → students get to know their classmates by identifying what sustainability contributions their peers are practicing.

3. Three Spheres of Sustainability → Students will be interpreting the term triple bottom line, and discussing the financial and ethical connections to conservation.

4. Ecological Footprint → Students will calculate their own ecological footprint and discuss areas they could change to help build a more sustainable future while still having balance in the three spheres: society, economy, environment.

5. Product Comparisons → Students work in pairs to research a product and a "greener" alternative and present their findings in a full page advertisement.

6. Sustainability Goals and Commitment → Students investigate the United Nation Sustainable Development Goals and consider which ones mean the most to them. Students then brainstorm sustainability efforts they can practice this year and create a SMART goal and Commitment.</td><td><u>Standards</u>

5-ESS3-1. Obtain and combine information about ways individual communities use science ideas to protect the Earth's resources and environment.

MS-ESS3-3. Apply scientific principles to design a method for monitoring and minimizing a human impact on the environment.

HS-ESS3-3. Create a ~~computational simulation to~~ illustrate the relationships among management of natural resources, the sustainability of human populations, ~~and biodiversity~~.</td></tr>
</table>

Energy and Electricity

This unit is designed to give all students the necessary background knowledge on electricity that they will need in coming Project ReCharge™ units. Students will explore simple circuits, series and parallel configurations, conductors and insulators, and energy changes. This unit also introduces students to our Energy Bike that can power a light board and other various appliances. These activities can be used to fill in existing gaps or to deepen prior knowledge, depending on the needs of your students.

Lessons

1. **Energy and Electricity: Simple Circuits →** students explore the concept of open and closed circuits by making simple circuits with given materials.
2. **Energy and Electricity: Series & Parallel Circuits →** students compare and contrast series and parallel circuits, challenging students to make slightly more complicated circuits that can light multiple bulbs to the same brightness while using only one D-cell.
3. **Energy and Electricity: Conductivity →** students investigate the properties of conductors and insulators by testing different classroom objects. In the end, students will determine the characteristics of electric conductors and electric insulators
4. **Energy and Electricity: Energy Transformations and E-Bike →** students investigate different objects to understand the law of conservation of energy, followed by several hands-on activities involving a bicycle generator to illustrate that motion can generate electricity.

Standards

4-PS3-2. Make observations to provide evidence that energy can be transferred from place to place by ~~sound,~~ light, ~~heat~~, and electric currents.

4-PS3-4. Apply scientific ideas to design, test, and refine a device that converts energy from one form to another

5-PS1-3- Make observations and measurements to identify materials on their properties.

MS-PS3-5. Construct, use, and present arguments to support the claim that when the kinetic energy of an object changes, energy is transferred to or from the object.

HS-PS3-3. ~~Design~~, build, and refine a device that works within given constraints to convert one form of energy into another form of energy.

Resources and Energy

This unit is designed to give all students the necessary background knowledge on electrical generation, global warming, and renewable resources. This unit builds on Energy and Electricity. Students will investigate the importance of electricity, how electricity is generated and distributed to our homes, and the effects of electricity generated from fossil fuels on our environment and community. Lasty, students will consider electrical generation from renewable resources, specifically solar and wind energy.

Lessons

1. **Resources and Energy: Electrical Generation →** this lesson lays the groundwork for how electricity is generated. Students complete a series of stations to investigate the relationship between electricity and magnetism. Lastly, students do a card sort to look at the effectiveness of alternative sources of energy.
2. **Resources and Energy: Climate Change Investigation →** students investigate the effects of greenhouse gasses and climate change by completing a reverse Escape Room. Students solve

Standards

MS-PS2-3. Ask questions about data to determine the factors that affect the strength of electric and magnetic forces.

MS-PS2-5. Conduct an investigation and evaluate the experimental design to provide evidence that fields exist between objects exerting forces on each other even though the objects are not in contact.

MS-ESS3-3. Apply scientific principles to design a method for monitoring and minimizing a human impact on the environment.

MS-ETS1-1. Define the criteria and constraints of a design problem with sufficient precision to ensure a successful solution, taking into account relevant scientific principles and potential impacts on people and the natural environment that may limit possible solutions.

puzzles to determine who should be held responsible for this real-world problem. 3. **Resources and Energy: Wind Power** → students continue exploring how renewable sources can be used to generate electricity, this time through wind power. 4. **Resources and Energy: HS Geothermal Energy** → students investigate how magma moves to analyze geothermal energy as a potential renewable energy source for their area. 5. **Resources and Energy: Solar Power** → students explore how electricity can be generated from sunlight - a process that differs from what they are familiar with up to this point, using electromagnetic induction. 6. **Resources and Energy: Transportation Introduction** → students investigate their own understanding of transportation, explore a simple motor, learn about the history of transportation, and consider the properties needed out of the future of transportation.	HS-PS2-5. Plan and conduct an investigation to provide evidence that an electric current can produce a magnetic field and that a changing magnetic field can produce an electric current. HS-PS3-3. Design, build, and refine a device that works within given constraints to convert one form of energy into another form of energy. HS-PS3-4 Plan and conduct an investigation to provide evidence that the transfer of thermal energy when two components of different temperature are combined within a closed system results in a more uniform energy distribution among the components in the system (second law of thermodynamics) HS-ESS2-3 Develop a model based on evidence of Earth's interior to describe the cycling of matter by thermal convection. HS-ESS3-2. Evaluate competing design solutions for developing, managing, and utilizing energy and mineral resources based on cost-benefit ratios.* HS-ESS3-4. Evaluate ~~or refine~~ a technological solution that reduces impacts of human activities on natural systems.* HS-ETS1-3. Evaluate a solution to a complex real-world problem based on prioritized criteria and trade-offs that account for a range of constraints, including cost, safety, reliability, and aesthetics as well as possible social, cultural, and environmental impacts.

Thermal Systems

Thermal Systems starts by examining the physical properties of different types of insulation materials (Elementary) and the heat transfer properties (Secondary). Students apply this knowledge to a closed system to test for energy efficiency. Lastly, students investigate passive cooling and heating strategies to reduce energy cost and environmental impact.

Lessons	Standards
1. **Thermal Systems: Insulation Properties (5th Grade)**→ students explore the properties of insulation and then apply their knowledge to create a model that reduces heat loss. 2. **Thermal Systems: Building Envelope (Secondary)**→ students explore insulation with the goal of determining how insulation can help reduce energy consumption. 3. **Thermal Systems: Passive Cooling** → students explore how insulation can be used to mitigate the impact of solar energy on a home in order to keep a home cool. Students will determine how to cool a home without the use of an air conditioner. 4. **Thermal Systems: Passive Heating** → students begin to explore the thermal system of heating. Through the use of solar power students will discover how to keep buildings warm without	5-PS1-3. Make observations and measurements to identify materials based on their properties. 5-ESS3-1. Obtain and combine information about ways individual communities use science ideas to protect the Earth's resources and environment. 3-5-ETS1-2. Generate and compare multiple possible solutions to a problem based on how well each is likely to meet the criteria and constraints of the problem. MS-PS3-3. Apply scientific principles to ~~design~~, construct, and test a device that either minimizes or maximizes thermal energy transfer. MS-ETS1-2. Evaluate competing design solutions using a systematic process to determine how well they meet the criteria and constraints of the problem.

consuming energy. Once students understand insulation more in depth, they can begin to make connections between how to heat or cool a home passively, and keep it warm or cool using different insulation methods.	[HS-PS3-4.](#) Plan and conduct an investigation to provide evidence that the transfer of thermal energy when two components of different temperatures are combined within a closed system results in a more uniform energy distribution among the components in the system (second law of thermodynamics). [HS-ESS3-4](#). Evaluate or refine a ~~technological~~ solution that reduces impacts of human activities on natural systems. [HS-ETS1-3](#). Evaluate a solution to a complex real-world problem based on prioritized criteria and trade-offs that account for a range of constraints, including cost, safety, reliability, and aesthetics as well as possible social, cultural, and environmental impacts.

Electrical Systems

This unit is made up of two lessons that develop an understanding of energy use and storage in homes. Students will investigate the electrical energy usage of lighting systems by comparing different light bulb options. Lasty, students will collect data on different common appliances to determine ways to be more sustainable and consider energy efficiency upgrades.

Lessons	**Standards**
1. **Electrical Systems: Lighting** → students explore the differences in cost and energy consumption based on the type of light bulb. 2. **Electrical Systems: Appliances** → students explore the impact of different appliances on the environment, as well as the cost required to run them.	5-ESS3-1. Obtain and combine information about ways individual communities use science ideas to protect the Earth's resources and environment. 3-5-ETS1-2. Generate and compare multiple possible solutions to a problem based on how well each is likely to meet the criteria and constraints of the problem. MS-ESS3-3 Apply scientific principles to design a method for monitoring and minimizing a human impact on the environment.* MS-ETS1-3. Analyze data from tests to determine similarities and differences among several design solutions to identify the best characteristics of each that can be combined into a new solution to better meet the criteria for success. HS-ESS3-4 Evaluate or refine a technological solution that reduces impacts of human activities on natural systems.* HS-ETS1-3 Evaluate a solution to a complex real-world problem based on prioritized criteria and trade-offs that account for a range of

	constraints, including cost, safety, reliability, and aesthetics as well as possible social, cultural, and environmental impacts.

<table>
<tr><th colspan="2">Sustainability Detectives</th></tr>
<tr><td colspan="2">This unit introduces the students to tools to analyze the home and school energy use and how data collected can be used to identify potential energy saving projects at their school. Students should have covered the content found in previous units.</td></tr>
<tr><td><u>Lessons</u></td><td><u>Standards</u></td></tr>
<tr><td>
1. Sustainability Detectives: Analyzing Home Energy Bills → introduces students into information that can be found on their own residential energy bills and analyzes sample bills to find trends and interesting conclusions.

2. Sustainability Detectives: Exploring Data → students will begin to analyze data and evaluate its validity by reviewing the concept of outliers. Students will learn to identify outliers and decide when they are important and when they should be disregarded.

3. Sustainability Detectives: School Energy Trends → introduces students to school energy bills and the concept of demand charges. Students will analyze their own schools energy bills to identify seasonal trends and the impact demand charges have on the school energy bill. Students also compare school data to look for ways to improve energy efficiency. Two different lesson plans are available, one lesson utilizes a PowerED McKinstry Dashboard, while the second lesson is designed for areas that do not have access to an energy dashboard.

4. Sustainability Detectives: Energy Auditors → introduces the students to the energy audit process by having student groups collect data at their school on lighting, HVAC systems and occupant engagement or human behavior observations. Data collected during this lesson will be used in Student Sustainability Proposals.
</td><td>
5-ESS3-1. Obtain and combine information about ways individual communities use science ideas to protect the Earth's resources and environment.

3-5-ETS1-2. Generate and compare multiple possible solutions to a problem based on how well each is likely to meet the criteria and constraints of the problem.
<hr>
MS-ESS3-3 Apply scientific principles to design a method for monitoring and minimizing a human impact on the environment.*

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.
<hr>
HS-ESS3-4. Evaluate or refine a technological solution that reduces impacts of human activities on natural systems.*

HS-ETS1-3. Evaluate a solution to a complex real-world problem based on prioritized criteria and trade-offs that account for a range of constraints, including cost, safety, reliability, and aesthetics as well as possible social, cultural, and environmental impacts.
</td></tr>
</table>

Sustainability Year-End Projects

Students will team up to come up with energy and sustainability conservation measure recommendations for saving energy and money which they will present to school administrators.

Lessons	Standards
1. **Public Service Announcement (PSA)** → Students create a PSA around a sustainability topic of their choosing to persuade their peers or community to take action. 2. **Green School or Energy Star Certification** → Students collect and analyze data to be submitted to the appropriate company for certification. 3. **Home Sustainability Proposals** → Students use a simplified grant proposal format and student collected data to create a Sustainability Proposal. This proposal can be submitted for potential funding and implementation at the Year-End-Event. 4. **School or Business Sustainability Proposals**→ Students collect real-world data from their school or selected business to assess sustainability issues in the building. Students use a grant proposal format to provide recommendations for improvement. This proposal can be submitted for potential funding and implementation at the Year-End-Event. 5. **Civic Engagement** → students choose a sustainability topic that they are passionate about and are empowered to make a change in their community through action or legislation.	**5-ESS3-1.** Obtain and combine information about ways individual communities use science ideas to protect the Earth's resources and environment. **3-5-ETS1-2.** Generate and compare multiple possible solutions to a problem based on how well each is likely to meet the criteria and constraints of the problem. --- **MS-ESS3-3** Apply scientific principles to design a method for monitoring and minimizing a human impact on the environment.* **MS-ETS1-1.** Analyze data from tests to determine similarities and differences among several design solutions to identify the best characteristics of each that can be combined into a new solution to better meet the criteria for success --- **HS-ESS3-4.** Evaluate or refine a technological solution that reduces impacts of human activities on natural systems.* **HS-ETS1-3**. Evaluate a solution to a complex real-world problem based on prioritized criteria and trade-offs that account for a range of constraints, including cost, safety, reliability, and aesthetics as well as possible social, cultural, and environmental impacts.

Appendix A: Project ReCharge Example Lesson

<table>
<tr><th colspan="3">Thermal Systems (Secondary)</th></tr>
<tr><td colspan="3">Lesson 2: Passive Cooling</td></tr>
<tr><td colspan="3">Adapted from: Envirolution, Project ReCharge 2009</td></tr>
<tr><td>Grade Level: 6th to 12th</td><td>Time: 180 min</td><td>Last Updated: 01/2022</td></tr>
</table>

NGSS High School Standards:

HS-ESS3-4. Evaluate or refine a ~~technological~~ solution that reduces impacts of human activities on natural systems.

HS-ETS1-3. Evaluate a solution to a complex real-world problem based on prioritized criteria and trade-offs that account for a range of constraints, including cost, safety, reliability, and aesthetics as well as possible social, cultural, and environmental impacts.

NGSS High School Connections:

Science & Engineering Practice	Disciplinary Core Idea	Crosscutting Concept
HS-ESS3-4. Constructing Explanations and Designing Solutions: Design or refine a solution to a complex real-world problem, based on scientific knowledge, ~~student-generated sources of evidence~~, prioritized criteria, and trade off considerations. **HS-ETS1-3. Constructing Explanations and Designing Solutions**: Evaluate a solution to a complex real world problem, based on scientific knowledge, ~~student-generated sources of evidence~~, prioritized criteria, and trade off considerations.	**ESS3.C: Human Impacts on Earth Systems** Scientists and engineers can make major contributions by developing technologies that produce less pollution and waste and that preclude ecosystem degradation. **ETS1.B: Developing Possible Solutions** When evaluating solutions, it is important to take into account a range of constraints, including cost, safety, reliability, and aesthetics, and to consider social, cultural, and environmental impacts. (secondary)	**HS-ESS3-4. Stability and Change:** Feedback (negative or positive) can stabilize or destabilize a system. **Suggested:** **Scale, Proportion, and Quantity:** Using the concept of orders of magnitude allows one to understand how a model at one scale relates to a model at another scale.

Connections to Engineering, Technology, and Applications of Science

Influence of Science, Engineering, and Technology on Society and the Natural World:

HS-ESS3-4. Engineers continuously modify these technological systems by applying scientific knowledge and engineering design practices to increase benefits while decreasing costs and risks.

HS-ETS1-3. New technologies can have deep impacts on society and the environment, including some that were not anticipated. Analysis of costs and benefits is a critical aspect of decisions about technology.

Common Core State Standards Connections:

ELA/Literacy: not applicable
Mathematics:
- **HS-ESS3-4. MP.2** Reason abstractly and quantitatively.
- **HS-ETS1-3. MP.4** Model with mathematics.

NGSS Middle School Standards:

MS-PS3-3. Apply scientific principles to design, construct, and test a device that either minimizes or maximizes thermal energy transfer.

MS-ETS1-2. Evaluate competing design solutions using a systematic process to determine how well they meet the criteria and constraints of the problem.

NGSS Middle School Connections:

Science & Engineering Practice	Disciplinary Core Idea	Crosscutting Concept
MS-PS3-3. Constructing Explanations and Designing Solutions: Apply scientific ideas, principles, and/or evidence to construct, revise and/or use an explanation for real world phenomena, examples, or events. **MS-ETS1-2. Engaging in Argument from Evidence:** Evaluate competing design solutions based on jointly developed and agreed-upon design criteria. **Suggested:** **Analyzing and Interpreting Data:** Analyze data to define an optimal operational range for a proposed object, tool, process or system that best meets criteria for success.	**PS3.A: Definitions of Energy** Temperature is a measure of the average kinetic energy of particles of matter. The relationship between the temperature and the total energy of a system depends on the types, states, and amounts of matter present. **PS3.B: Conservation of Energy and Energy Transfer** Energy is spontaneously transferred out of hotter regions or objects and into colder ones. **ETS1.B: Developing Possible Solutions** There are systematic processes for evaluating solutions with respect to how well they meet the criteria and constraints of a problem.	**MS-PS3-3. Energy and Matter:** The transfer of energy can be tracked as energy flows through a designed or natural system. **Suggested:** **Scale, Proportion, and Quantity:** ~~Time, space, and~~ energy phenomena can be observed at various scales using models to study systems that are too large or too small.

Common Core State Standards Connections:

ELA/Literacy:
- **MS-PS3-3. RST.6-8.3** Follow precisely a multistep procedure when carrying out experiments, taking measurements, or performing technical tasks.

Mathematics: none

21st Century Competencies:	SEL Standards and Connections:
C-3. Students make substantive decisions together. **KC-3.** Students are required to apply their knowledge in a new context. **RW-3.** The activity requires innovation - the creation of a product, method, or idea new to the student.	**Self-Awareness**: Students are encouraged to make connections to the different ways they use passive cooling strategies in their lives (i.e. fans / sun hats to keep their bodies cool, trees for shade and comfort, blinds over their windows, etc.). **Self-Management**: Students are expected to demonstrate these skills in order to work effectively with their teams throughout the investigation activities. **Social Awareness and Relationship Skills**: As students are working in their collaborative teams, they will have natural opportunities to engage in and practice these skills. Students will need to consider why the reduction of energy is so important considering factors like societal trends and demands, population growth,

SC-2. Students must provide supporting evidence OR communicate to a particular audience.	and limited natural resources. **Responsible Decision-Making**: Students will build an awareness and understanding of how passive cooling strategies can be used to help lower energy costs and reduce the impact of our human footprint. Finally, the students will need to apply these problem solving skills in order to make positive contributions to their group's collaborative efforts during the investigations. They will also be asked to reflect on what changes, if any, they would make to their designs if they had the opportunity to repeat the experiment.

Helpful Teaching Tools:

Lesson Objectives

- The student will conduct an experiment to demonstrate how insulation can help reduce energy consumption and regulate temperature.
- The student will explain how to keep a building cool without air conditioning.
- The student will determine the difference between passive cooling and other cooling strategies.
- Students will be able to explain how passive cooling strategies can help consumers save money as well as reduce the impact of the human footprint on our planet.

Essential Questions

1. How can houses be kept cool without using energy for air conditioning?
2. How do energy analysts balance appropriate cooling strategies with ones that are the most cost effective and energy efficient?
3. How can passive cooling strategies help consumers save money as well as reduce the impact of the human footprint on our planet?

Key Concepts and Vocabulary

- Passive cooling, active cooling, evapotranspiration, refrigerant, albedo, consumer, human footprint

Differentiation

- **Language Adaptation:** Have students describe differences in houses from their previous homes and cultures compared to Nevada. Focus on how differences in climate are reflected in the style of dwellings.
- **Level Up:** Have students research how different countries and cultures use passive cooling strategies in their homes and communities OR create some kind of advertisement or infographic that promotes the use of passive cooling strategies in an effort to be more eco-friendly.

Management Strategy

- Organize the class into teams of 2-3 students. Make sure there are enough work spaces with electrical outlets for each group.

Teacher Background Knowledge

Solar Energy

Solar energy is the most abundant energy resource on Earth - **173,000 terawatts of solar energy strike the Earth continuously!** That is more than 10,000 times the world's total energy use.

Passive Solar Design:

Passive solar design utilizes a building's site, climate, and materials to minimize energy use. A well-designed passive solar home first reduces heating and cooling loads through energy-efficiency strategies and then meets those reduced loads in whole or part with solar energy. Because of the small heating loads of modern homes, it is imperative to avoid oversizing south-facing glass and ensure that south-facing glass is properly shaded to prevent overheating and increased cooling loads in the spring and fall. Before you add solar features to your new home design or existing house, remember that energy efficiency is the most cost-effective strategy for reducing heating and cooling bills. Choose building professionals experienced in energy-efficient house design and construction and work with them to optimize your home's energy efficiency. If you're remodeling an existing home, the first step is to have a **home energy audit** to prioritize the most cost-effective energy improvements.

If you're planning a new **passive solar home**, a portion of the south side of your house must have an unobstructed "view" of the sun. Consider possible future uses of the land to the south of your site - small trees become large trees, and a future multi-story building can block your home's access to the sun. In some areas where zoning isn't protected in your region, look for a lot that is deep from north to south and place the house on the north end of the lot.

In simple terms, a passive solar home collects heat as the sun shines through south-facing windows and retains it in materials that store heat, known as **thermal mass**. The share of the home's heating load that passive solar design can meet is called the **passive solar fraction** and depends on the area of glazing and the amount of thermal mass. The ideal ratio of thermal mass to glazing varies by climate. Well-designed passive solar homes also provide daylight all year and comfort during the cooling season through the use of nighttime ventilation. To be successful, a passive solar home design must include some basic elements that work together: properly oriented windows, for example. Typically, windows or other devices that collect solar energy should face within 30 degrees of true south and should not be shaded during the heating season by other buildings or trees from 9 a.m. to 3 p.m. each day. During the spring, fall, and cooling season, the windows should be shaded to avoid overheating. **Text adapted from**: *https://www.energy.gov/energysaver/passive-solar-home-design*.

Thermal mass in a passive solar home the material(commonly concrete, brick, stone, and tile) absorbs heat from sunlight during the heating season and absorbs heat from warm air in the house during the cooling season. Other thermal mass materials such as water and phase change products are more efficient at storing heat, but masonry has the advantage of doing double duty as a structural and/or finish material. In well-insulated homes in moderate climates, the thermal mass inherent in home furnishings and drywall may be sufficient, eliminating the need for additional thermal storage materials.

Albedo is a measurement of how well an object reflects sunlight; a higher albedo indicates a higher reflectivity. In well-insulated homes in moderate climates, the thermal mass inherent in home furnishings and drywall may be sufficient, eliminating the need for additional thermal storage materials. Solar heat is transferred from where it is collected and stored to different areas of the house by conduction, convection, and radiation. In some homes, small fans and blowers help to distribute heat.

Solar heat is transferred from where it is collected and stored to different areas of the house by **conduction, convection, and radiation**. In some homes, small fans and blowers help to distribute heat. **Conduction** occurs when heat moves between two objects that are in direct contact with each other, such as when a sun-heated floor warms your bare feet. **Convection** is heat transfer through a fluid such as air or water, and passive solar homes often use convection to move air from warmer areas, a sunspace, for example, into the rest of the house. **Radiation** is what you feel when you stand next to a wood stove or a sunny window and feel its warmth on your skin. Darker colors absorb more heat than lighter colors and are a better choice for thermal mass in passive solar homes.

Although conceptually simple, a successful passive solar home requires that a number of details and variables come into balance. An experienced designer can use a computer model to simulate the details of a passive solar home in different configurations until the design fits the site and the owner's budget, aesthetic preferences, and performance requirements. Some of the elements the designer will consider: *insulation and air sealing, window location, glazing type and window shading, thermal mass location and type, and auxiliary heating and cooling systems*. The designer will apply these elements using passive solar design techniques that include *direct gain, indirect gain, and isolated gain*.

In a **direct gain** design, sunlight enters the house through south-facing windows and strikes masonry floors and/or walls, which absorb and store the solar heat. As the room cools during the night, the thermal mass releases heat into the house. Some builders and homeowners use water-filled containers located inside the living space to absorb and store solar heat. Although water stores twice as much heat as masonry materials per cubic foot of volume, water thermal storage requires carefully designed structural support. An advantage of water thermal storage is that it can be installed in an existing home if the structure can support the weight.

An **indirect-gain** passive solar home has its thermal storage between the south-facing windows and the living spaces. The most common indirect-gain approach is a **Trombe wall**. The wall consists of an 8-inch to 16-inch thick masonry wall on the south side of a house. A single or double layer of glass mounted about one inch or less in front of the dark-colored wall absorbs solar heat, which is stored in the wall's mass. The heat migrates through the wall and radiates into the living space. Heat travels through a masonry wall at an average rate of one inch per hour, so the heat absorbed on the outside of an 8-inch thick concrete wall at noon will enter the interior living space around 8 p.m.

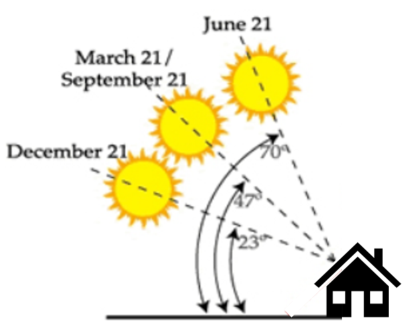
The **isolated-gain** passive solar home design is the most common and is a sunspace that can be closed off from the house with doors, windows, and other operable openings. Also known as a sunroom, solar room, solarium, a sunspace can be included in a new home design or added to an existing home. Sunspaces serve three main functions: 1) they provide auxiliary heat, 2) a sunny space to grow plants, and 3) a pleasant living area. The design considerations for these three functions are very different, and accommodating all three functions requires compromises.

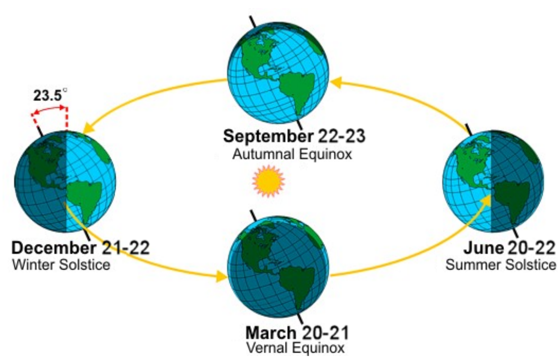
Experienced passive solar home designers plan for summer comfort and winter heating. In most climates, an overhang or other devices, such as awnings, shutters, and trellises, will be necessary to block summer solar heat gain. Landscaping can also help keep your passive solar home comfortable during the cooling season.

***Text adapted from**: Department of Energy website.*

Summer Solstice

The summer solstice occurs when the earth's tilt toward the sun is at a maximum. Therefore, on the day of the summer solstice, the sun appears at its highest elevation with a noontime position that changes very little for several days before and after the summer solstice. In fact, the word solstice comes from Latin *solstitium* or *sol* (the sun) + -*stit-, -stes* (standing). The summer solstice occurs when the sun is directly over the Tropic of Cancer, which is located at 23.5° latitude North and runs through Mexico, the Bahamas, Egypt, Saudi Arabia, India, and southern China. For every place north of the Tropic of Cancer, the sun is at its highest point in the sky, and this is the longest day of the year.





***Source**: https://www.weather.gov/abq/clifeatures_summersolstice*

Student:
- *Life Experience* – Students have experienced the radiant heat from the sun in a greenhouse and felt the warmth of their feet as they walk on a floor warmed by the sun near a south facing window. They have also felt the coolness of shaded places and spots in more direct contact with the cool Earth like a basement.

Materials List: Thermal Systems: Lesson 2 - Passive Cooling

For each group:
- 1 Light fixture
- 1 Heat lamp
- 1 Timer or stopwatch*
- Scissors, glue, and tape*
- 1 Thermometer*
- 1 Protractor and string (to be used as a guide)*
- House Template
- Graph paper with Cardinal Direction

*Supplied by the teacher

For the Class:
- Cotton balls
- White, brown, and green construction paper*
- Aluminum foil
- Awning Cutouts
- Various articles of clothing and props for engagement activity. (white and black clothes that are both thick and thin, wide hat or umbrella, reflective jacket etc)*

Handouts:
- Passive Cooling: Lab Information - print two pages, double-sided (class set)
- Passive Cooling: Keep It Cool - print two pages, double-sided (student handout)
- Cooling: Keeping It Cool - printed building material
- Passive Cooling and Sustainability - print three pages, double-sided
- Clean Energy Analyst: Cooling - print two pages, double-sided

Supplemental Resources:
- Video #1: Earth Ships
- Video #2: Passive Cooling House
- Article for students to read (5th-8th grade):Article about Albedo for students
- Articles for teacher background to guide class discussions:
  - Academic Kids: Albedo
  - Energy Education: Albedo
- Article: Albedo and Climate Change
- Article: Energy Smart: Wall Insulation

Teacher Note: Students save their houses for the next lesson!

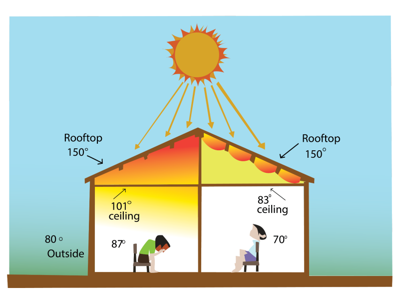
Before Class:
- For the experiment, it is suggested for students to build a second model house to act as an experimental control. You may decide to make one before class to serve as this control instead of having each group make another.
- Bring clothing and prop items from home to assist with Engagement activity.

Safety Procedures:
- The heat lamp is extremely hot and will burn you if touched.
- If heat lamps are placed too close to paper houses, they can smoke: about 1 foot away recommended!
- Remind students to be careful not to drop the breakable thermometers.

Additional Resources: See Teacher Portal for more resources

INSTRUCTIONAL SEQUENCE

Phenomenon: *House Picture* **TIME**: *(10 min)*	**Materials or Notes**
1. Introduce the phenomena to students and solicit questions regarding it: • What do you observe in this picture? • What do you think may have caused this? • What observable evidence led you to think this? • NOTE: Student questions should revolve around how this is possible.	**Materials for Class:** phenomenon photo



Engagement: *How to keep cool?* **TIME**: *(10 min)*	
1. Set the context for the activity by asking students: *How do we keep our bodies cool on a hot day?* 2. Have ready a variety of clothing articles and props to demonstrate ways to stay cool. (White thin clothing, hat or umbrella to block the sun, black clothing items (both thick and thin articles. 3. Ask a few students to pick items they would wear or use on a hot day. 4. Ask students why they chose those items (white clothes, hat, umbrella) and not the others (black or thick items) 5. Record answers on the board. 6. This may help students identify low-energy passive cooling strategies that work just as well for buildings as they do people.	**Materials for class**: Various clothes / props to demonstrate ways to stay cool
Explore: *Passive Cooling* **TIME**: *(80 min)*	**Materials or Notes**
Before Activity: Passive Cooling 1. Distribute *Passive Cooling: Lab Information* to each student and read through the introduction and prepare sections as a class. 2. **Teacher Note**: The *Passive Cooling: Lab Information* handout indicates that students need to build a second model house to act as an experimental control. You may choose to have each group create their own control house, have one group create one for the entire class, or create one yourself. a. To save time it is recommended that the teacher builds and tests the control. **Safety Procedures:** • The heat lamp is extremely hot and will burn you if touched. • If heat lamps are placed too close to paper houses, they can smoke: about 1 foot away is recommended! • Remind students to be careful not to drop the breakable thermometers. **Procedures**: Passive Cooling 1. **Propose the first challenge to the class**: *How can I make a model house that demonstrates strategies to stay cool without using energy* 2. **Review experimental design**, including: a. How to identify the independent, dependent, and controlled variables. b. How to ensure an experiment is fair and valid. 2. Review the budget guidelines and the "Design Specifications" rules on the *Passive Cooling: Lab Information* handout. 3. Distribute *Passive Cooling: Keep it Cool!* to each student and read through the introduction and prepare sections as a class.	**Handout**: Passive Cooling: Lab Information **Teacher Note:** Houses will be used in the next lesson **Safety Procedures** **Materials per group**: Model houses, graph paper compass, building materials, thermometers, light setups, protractor, ruler

4. Students decide on the materials they would like to purchase, and double-check their budgets and distribute necessary materials. 1. Give students a time constraint to complete their house and have them install their home improvements. a. The set up for the experiment should simulate the 70° inclination of the sun during summer solstice. b. Light fixtures should be at a 70° angle in reference to the base of their models, and at a distance of 1 foot away from the house. Students can refer to the diagram illustrating proper set up located at the bottom of the "Design Specifications" section. 2. Distribute thermometers and give students 15-20 minutes to test their houses. Glass thermometers should be inserted through the back of the house so the measurements are reading the internal temperature. There is a circle on the back of the house that indicates where the thermometer is placed. 3. Take an initial temperature and a final temperature at the end of the time limit. 4. While groups are working, monitor student progress, and probe students with questions about their design: a. *What is your favorite element of your design and why?* b. *If you had time and/or budget to redesign again, what changes would you make?* 5. Ask these questions as a way to make sure students have understood the content of the lesson so far. Use the discussion to further explain and clear up any student misconceptions. a. Post the temperature of the "Control" house for the class to compare their data. b. Write class data on the board. *Which groups kept their houses the coolest?* c. *What design features, if any, did they have in common? See suggested table below.* d. *Would any groups change their design in retrospect?* e. *What would they do differently and why?* f. *Have students noticed any passive cooling strategies in place at their own homes?* g. *Does the school noticeably use any passive cooling strategies?* h. *Which passive cooling strategies are the cheapest? Which are the easiest to implement?* 6. Suggested table for class data	**Handout**: Passive Cooling: Keeping it Cool! **HS/MS SEP**: Constructing Explanations and Designing Solutions. **HS CCC:** Stability and Change **HS/MS CCC:** Scale, Proportion and Quantity **MS CCC**: Energy and Matter

Group	Initial temp °C	Final temp °C	Temp change °C	Building Materials
Control				none
Group 1 (ect.)				

Explain: **TIME**: *(15 min)*	**Materials or Notes**
New Vocabulary 1. Introduce the formal vocabulary definitions during this phase of the lesson. ○ Define **albedo** and explain its connection to the investigation. *[Albedo is a measurement of how well an object reflects sunlight; higher albedo indicates higher reflectivity. Objects with a higher albedo absorb less solar energy. so they remain cooler than objects with a lower albedo.]*	**Links:** Academic Kids: Albedo Energy Education: Albedo

○ Discus how albedo influences what building materials are used in different climates, see links for information: Academic Kids: Albedo or Energy Education: Albedo ○ Discussion regarding Albedo and Climate Change: Albedo and Climate Change **Passive Cooling** 1. **Ask students to write or discuss possible explanations for the initial diagram (phenomena).** 2. Continue the discussion to further explain and clear up any student misconceptions. ○ *Which groups kept their houses the coolest? What design features, if any, did they have in common?* ○ *Would any groups change their design in retrospect? What would they do differently?* ○ *Have students noticed any passive cooling strategies in place at their own homes?* ○ *Does the school noticeably use any passive cooling strategies?* ○ *Which passive cooling strategies are the cheapest? Which are the easiest to implement?* ○ *How can we describe what happened to the heat energy inside/outside the house?* ○ *In what direction did the heat energy move?* **Explanation of Phenomenon**: 1. Refer back to the phenomenon photo - based on the activity, ask students to evaluate the picture again to describe what is happening. ○ Students should be able to describe how the roof insulation is absorbing the sun's heat on the right side of the house, whereas heat is transmitted to the left side of the house. ○ Good Article: Should You Get Black or White Roofing?	Albedo and Climate Change **HS/MS SEP**: Constructing Explanations and Designing Solutions. **MS SEP:** Analyzing and Interpreting Data **MS SEP:** Engaging in Argument from Evidence **HS CCC:** Stability and Change **HS/MS CCC:** Scale, Proportion and Quantity **MS CCC**: Energy and Matter **Article**: Should You Get Black or White Roofing?
Elaborate: *Video and RUCM* **TIME**: *(45 min)*	**Materials or Notes**
1. Distribute Passive Cooling and Sustainability. Read through the article, as a class, individually, or in student groups. Discuss the questions at the end. 2. Ask the class: *Which design features on their house had a relatively high albedo?* [the radiant barrier and anything that was white all had high albedos.] 3. As a class, brainstorm how albedo is related to climate change. ○ *Albedo has a somewhat complex connection to global climate, but an important concept to understand is that sea ice and glaciers have a high albedo, reflecting approximately 80% of the sun's energy. This reflectivity has a cooling effect on the climate. As sea ice and glaciers melt due to rising global temperatures, their cooling effect is diminished further.* 4. Explain how insulation resists heat transfer. ○ *One characteristic of all insulation materials is that they contain millions of tiny air pockets or bubbles within their fibers. Heat is forced to move very slowly through insulating materials as it conducts from air pocket to air pocket. This resistance helps prevent the transmission of heat between indoor and outdoor air.* 4. Show the video of how **Bill Nye** made his house more energy efficient by incorporating passive cooling strategies; Link. Other passive cooling videos are available. Refer to Supplemental content on the teacher portal 5. Hand out the *Clean Energy Analyst: Passive Cooling* sheet. As a class review the Clean Energy	**Handout**: Passive Cooling and Sustainability **HS/MS SEP**: Constructing Explanations and Designing Solutions. **MS SEP:** Engaging in Argument from Evidence **HS CCC:** Stability and Change **HS/MS CCC:** Scale, Proportion and Quantity **MS CCC**: Energy and Matter **Video**: Bill Nye **Handout**: Clean Energy Analyst: Passive Cooling

<table>
<tr><td>Analyst section and complete the RUCM chart in class or as homework. Read and discuss their responses.</td><td></td></tr>
<tr><th>Evaluate
TIME: (15 min)</th><th>Materials or Notes</th></tr>
<tr><td>
Formative: Qualitative Data

1. Revisit the essential questions
  1. How can houses be kept cool without using energy for air conditioning?
  2. How do energy analysts balance appropriate cooling strategies with ones that are the most cost effective and energy efficient?
  3. How can passive cooling strategies help consumers save money as well as reduce the impact of the human footprint on our planet?
2. Assess Progress: Use these questions to reinforce concepts emphasized in the lesson:
  1. What is the difference between passive cooling and other cooling strategies? [Passive cooling strategies do not require energy to operate.]
  2. Name three passive cooling strategies. [Answers will vary but may include shading, insulation, white paint or roof coatings, landscaping, window placement, low-energy windows, etc.]
  3. What is albedo? [Albedo is a measurement of how well an object reflects sunlight.]
  4. What were the reasons for placing trees or other design features as they did during construction. What were they hoping to accomplish?
  5. How could you use what you've learned from this investigation to possibly help lower the cooling expenses in your home?
Summative: Qualitative Data

● Answer a series of questions on the Clean Energy Analyst: Cooling sheet. This assessment can be completed during class or at home.
● Students could research modern sustainability ideas for their own homes. They could create a poster or write-up picking two ideas that would be suitable for their home including costs and long term benefits.
</td><td>
HS/MS SEP: Constructing Explanations and Designing Solutions.
MS SEP:Analyzing and Interpreting Data

HS CCC: Stability and Change
HS/MS CCC: Scale, Proportion and Quantity
MS CCC: Energy and Matter

Handout: Clean Energy Analyst: Cooling
</td></tr>
<tr><th>Clean Up
TIME: (5 min)</th><th>Materials or Notes</th></tr>
<tr><td>
● Students need to keep their houses for the next lesson!
● Provide a large recycling bin for paper scraps and another bin for throwaway refuge from the model house construction. Have an equipment storage site designated for each item used in the investigation. Tell each group to completely clean up their work area.
</td><td></td></tr>
</table>

Vocabulary

- **Passive cooling**: technologies and design features that cool without consuming energy.
- **Active cooling**: technologies and design features that cool while consuming energy.
- **evapotranspiration:** the process of transferring moisture from the earth to the atmosphere by evaporation of water and transpiration from plants
- **Refrigerant**: a special fluid used in air conditioners that heats air when it condenses and cools air when it evaporates.
- **Albedo**: a measurement of how well an object reflects sunlight; higher albedo indicates higher reflectivity.
- **Consumer**: a person who purchases goods and services for personal use
- **Human Footprint**: a measure of *human* impact on Earth's ecosystem

Handouts for: Thermal Systems (Secondary)
Lesson 2: Passive Cooling

1 Passive Cooling: Lab Information - print two pages, double-sided (class set)

2 Passive Cooling: Keep It Cool - print two pages, double-sided (student handout)

3 Passive Cooling: Keeping It Cool - printed building material

4 Passive Cooling and Sustainability Reading - print three pages, double-sided

5 Clean Energy Analyst: Passive Cooling - print two pages, double-sided

Answer Keys available on Teacher Website/Portal

Passive Cooling: Lab Information
Thermal Systems Lesson 2

Directions: Read the introduction and prepare section before beginning the activity.

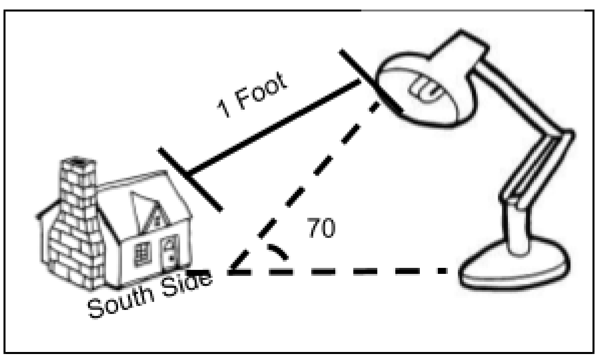
Introduction
Air conditioners are called **refrigeration coolers** because they work the same way a refrigerator does: a fluid **that condenses** releases heat. Throughout the process fans move air through the coils, and blow cool air out into the conditioned space. These pumps and fans require ***a lot*** of electricity. This is called **Active Cooling** because it requires the use of energy

- American homeowners spend about **$29 billion per year** on the electricity (Active cooling) used by air conditioners, and the fossil fuels burned to provide this electricity releases about **117 million metric tons of carbon dioxide** (CO_2) into the atmosphere.

Information adapted from: *www.energysavers.gov*

Simple building efficiency improvements that do not require electricity can help provide the same level of comfort at a fraction of the cost. Using technologies and design features that cool without consuming energy is called **passive cooling**. Passive cooling strategies can greatly reduce the energy demand placed on refrigeration coolers, or can even eliminate the need for refrigeration cooling altogether.

Prepare
In this activity, you will be working as an **efficiency contractor** to design a model house that emphasizes passive cooling techniques. Below, your client has made some design specifications that you must follow. **You will have an assortment of materials to choose from, but your team must stay within the $3,000 budget that your client has given you**. After your model house is completed, a heat lamp bulb will be used to simulate the summer sun, and a thermometer inside your house will determine how successful your system is.



	Materials	Cost (Budget: $3000)
☐	White Roof Coating	1000
☐	Attic Insulation	1500
☐	Wall Insulation	2000
☐	Radiant Barrier	1000
☐	Awning	1500
☐	Shade Tree	500

Design Specifications

- You **must** have at least **two windows** on your house on the **South side** that are at least **1 inch by 1 inch** in size.
- You can have a **maximum** of **two trees** on the property. You have 2 types of trees to choose from, coniferous tree and or deciduous tree.
- You must place your house on the property with the correct north/south orientation, indicated on the building materials.

Building Construction Guidelines

Read all guidelines ***before*** constructing your house!

White Roof Coating:
To install a white roof coating, cut out one sheet of white paper to size and glue to the **top of your roof**.

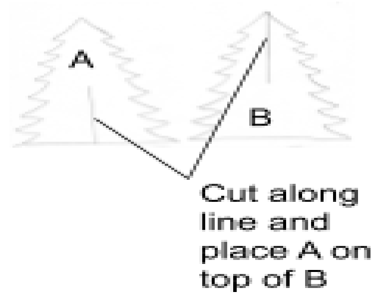
Attic Insulation:
To install attic insulation, glue **one layer** of cotton balls (12) on the **underside** of your roof. You CANNOT expand or condense the cotton ball.

Wall Insulation:
To install wall insulation, glue **one layer** of cotton balls (20) on the **four inside walls** (but not the roof).

Radiant Barrier:
To install a radiant barrier, cut out **one sheet** of aluminum foil to size and glue on the **underside of your roof**. If you also choose to add roof insulation, install the radiant barrier to the underside of the roof ***before*** you install insulation.

Awning:
To install an awning, ask your teacher for the awning building materials, cut out the template, and attach it to the **edge of the roof**.

Shade Tree: 2 Options available- coniferous and deciduous Trees
To make a coniferous shade tree, cut out the template provided.



To make a deciduous shade tree, follow the steps below:

Name:____ Class:__________

Passive Cooling: Keep it Cool!

Thermal Systems, Lesson 2

In order to test how effective your passive cooling system is, you need to measure how hot the same house would get *without* passive cooling insulation, so that you can make a comparison. Unless one has already been built for the class, this is when you need to **assemble a model house and cut <u>two</u> 1 inch by 1 inch windows on its <u>south side</u>**. This second house will serve as the **<u>experimental control</u>**.

How to Take Accurate Temperatures: place the bottom of the thermometer through the small hole outlined on the north side of the house. Be certain to take readings in degrees celsius.

Procedure:

1. Before you start, take the temperature of the inside of the house (through a window or hole in the back depending on the thermometer used). Record your temperatures in the table below.
2. Start a timer.
3. Take measurements every 5 mins through the same window at the same location. Record in table.

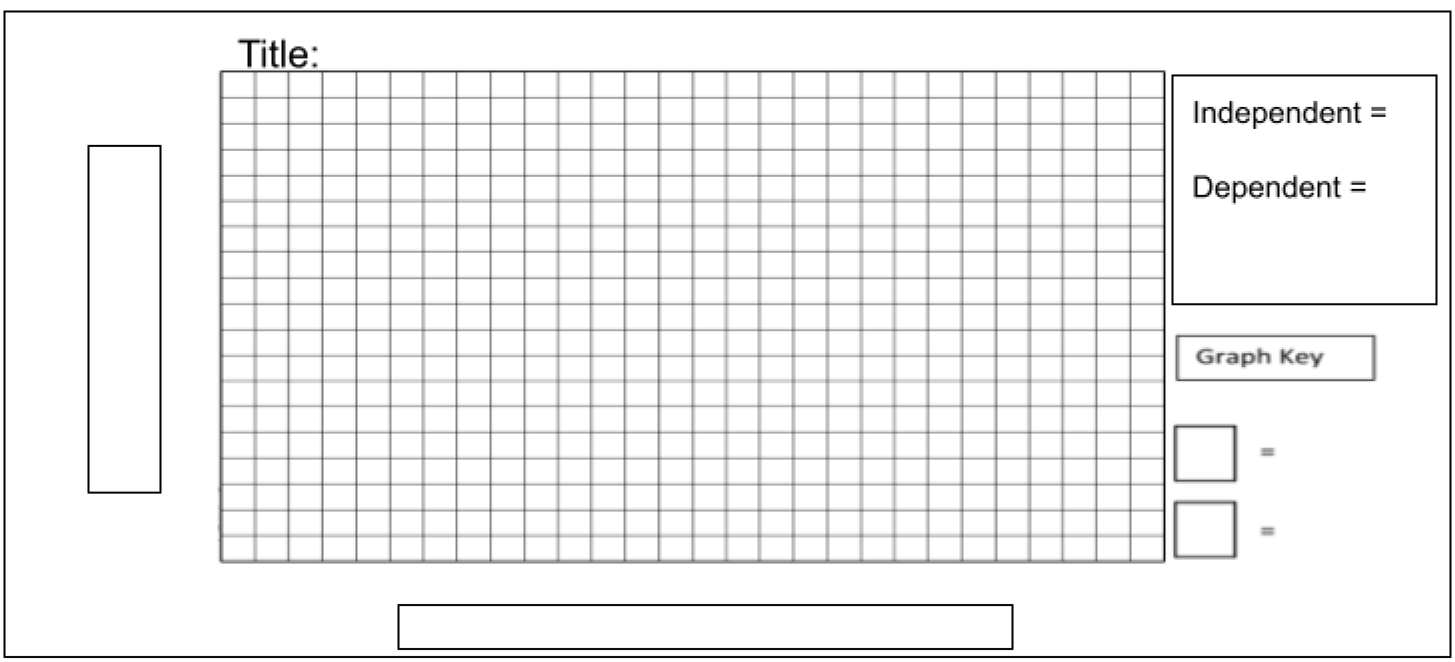
Material(s) used for passive cooling____

	Room temperature before experiment (C)	**Temperature (C) after 5 minutes**	**Temperature (C) after 10 minutes**	**Temperature (C) after 15 minutes**
Control House				
Passive Cooling House				
			Difference in final temperatures :	

Graph -You will create line graphs to show your results. Please choose a different color for the control house and the passive cooling house - make sure this is clear in your "Key".

1. Be sure to label your two axes, and choose appropriate intervals of time and temperature.
2. Label on your graph which axis is the dependent and independent variables.

Evaluate



Answer the following discussion questions in **at least three complete sentences**.

1. Were you successful in providing passive cooling to your home as compared to the control? Explain using data from your experiment.

2. After comparing your house to others, what part of your design do you think provided the best insulation and why?

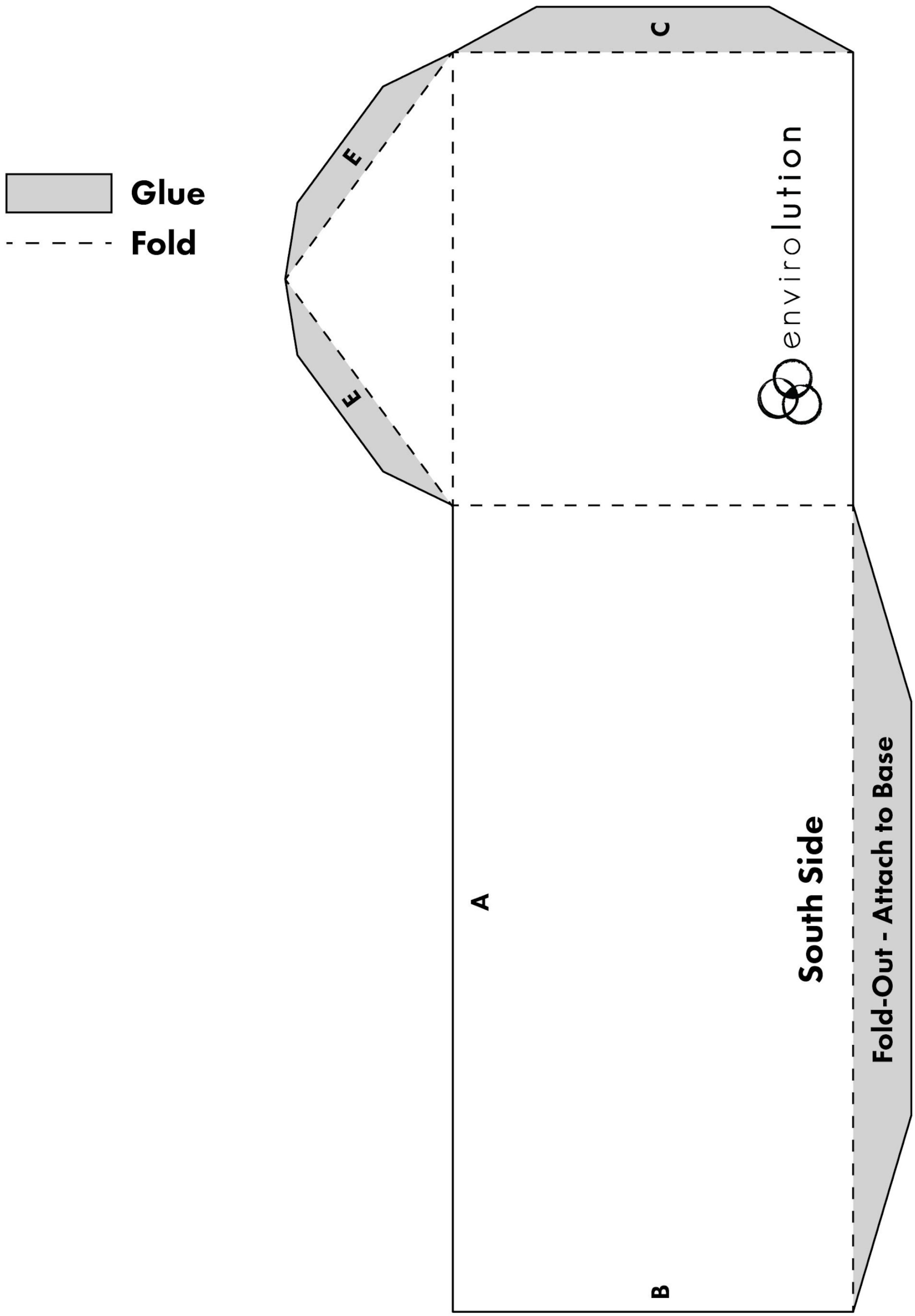
3. Planting trees is a very effective tool in passive cooling. Based on your experiences in this activity, where is the best location to plant a tree and why? What type of tree do you think is better for passive cooling and why? Use the evidence from your design (or another group if you did not use trees) in your answer.

4. Imagine that your house was to be built in an area that experiences relatively cold winters in addition to hot summers. Would you change any part of your design? Why or why not?

5. What part of your design did not work well, explain how you would change your design and why? (nothing is not an option)

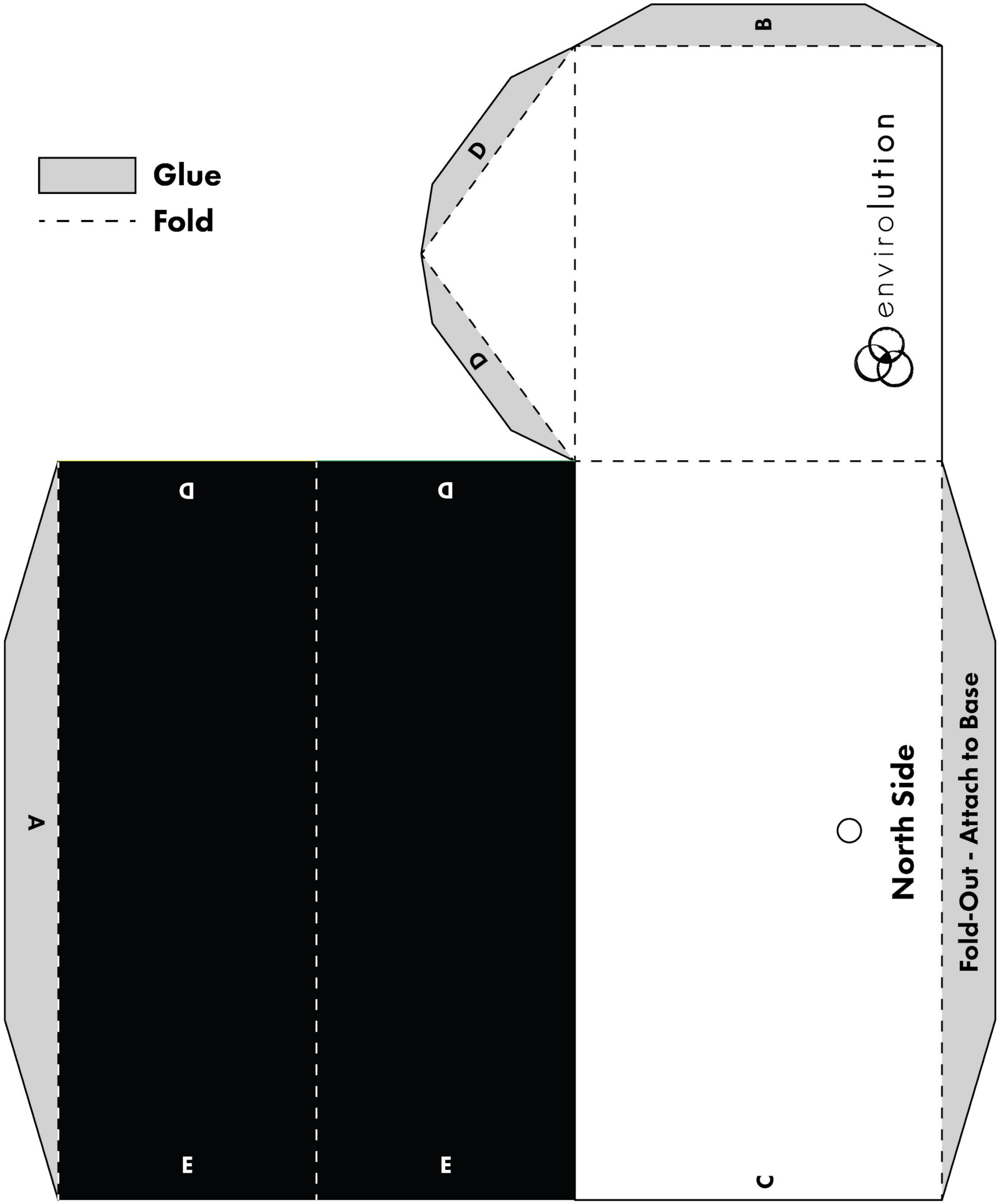
Passive Cooling: Keeping It Cool

Thermal Systems, Lesson 2: Printed Building Material



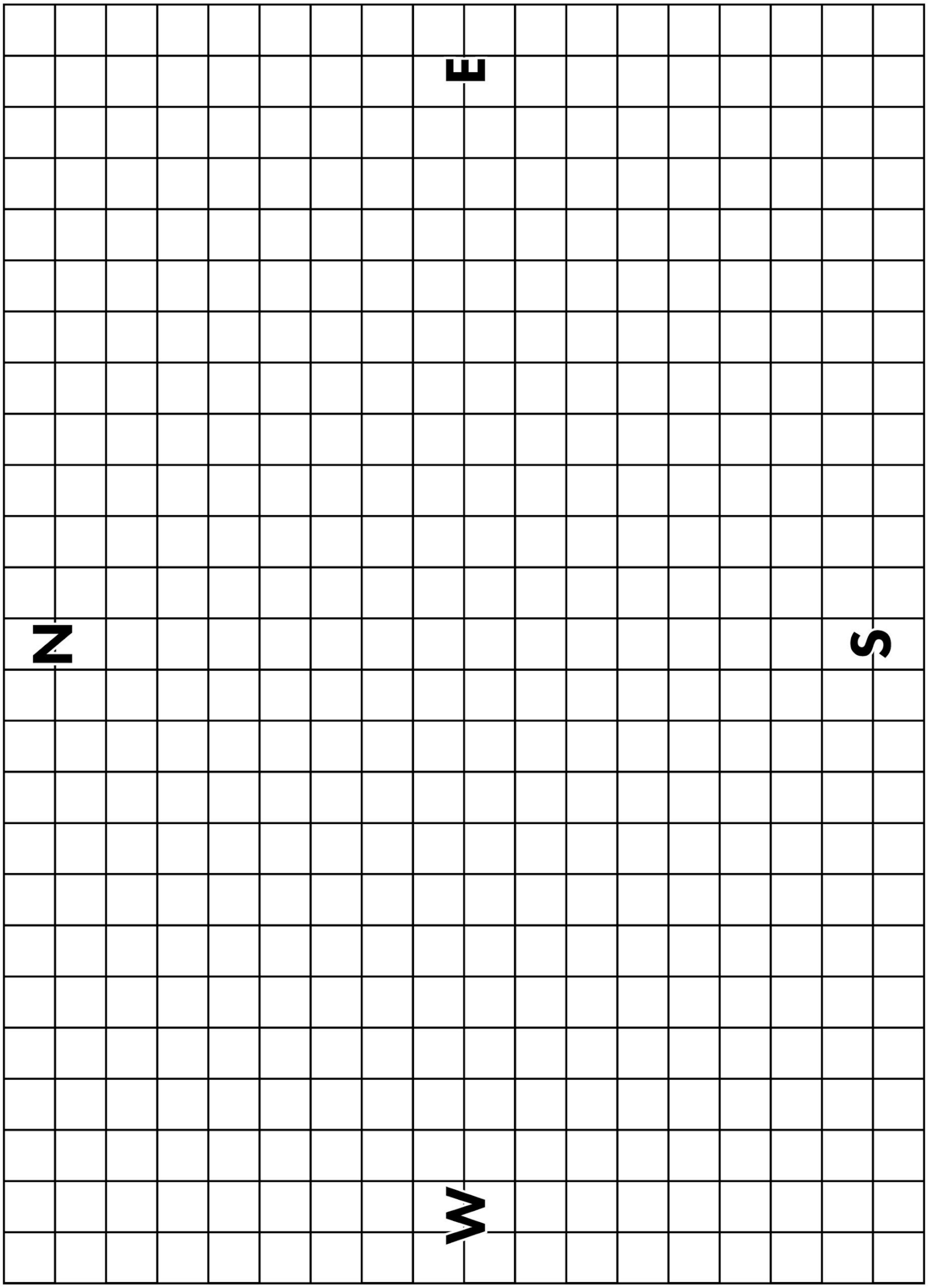
Passive Cooling: Keeping It Cool

Thermal Systems, Lesson 2: Printed Building Materials



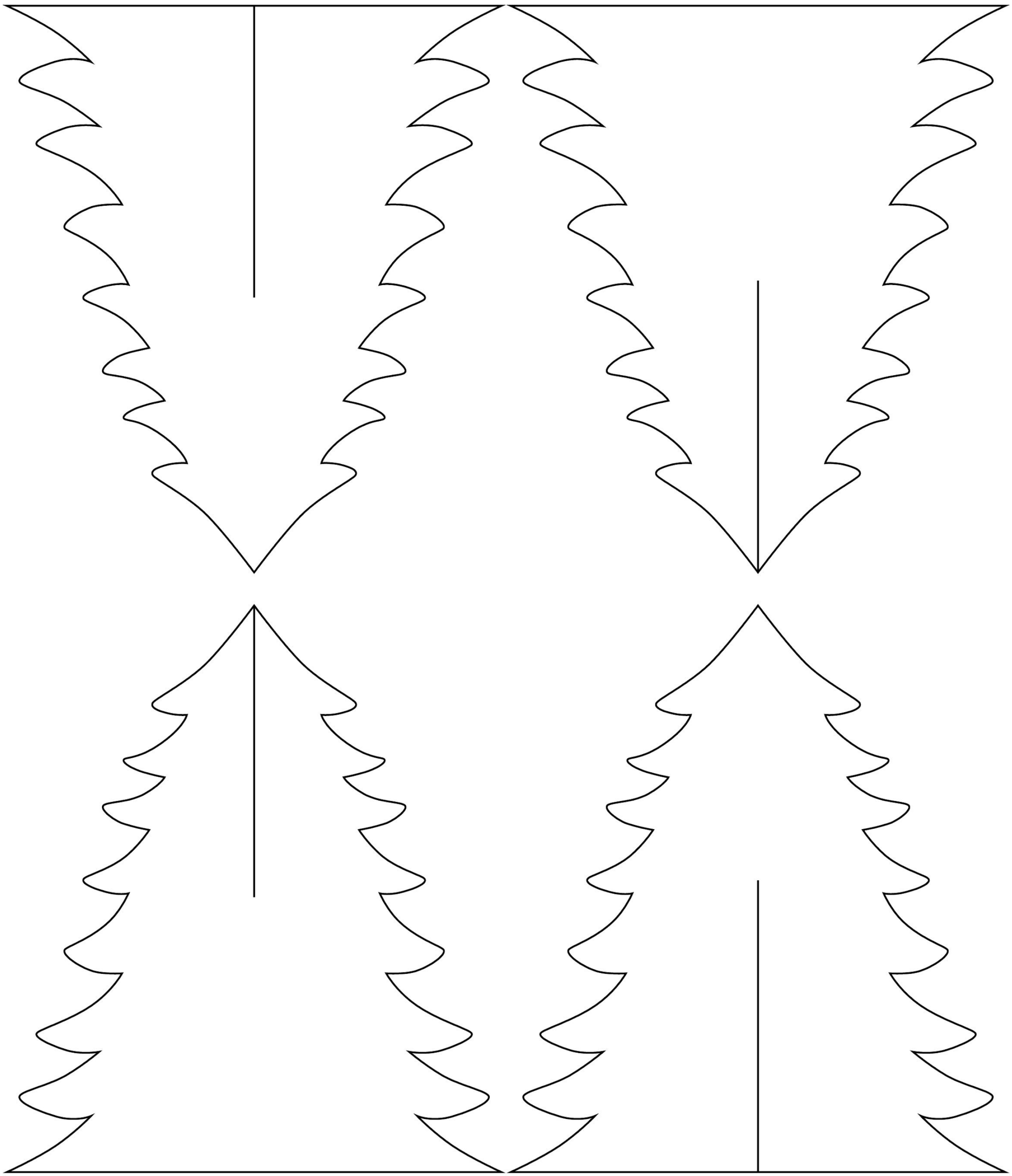
Passive Cooling: Keeping It Cool

Thermal Systems, Lesson 2: Printed Building Material



Passive Cooling: Keeping It Cool

Thermal Systems, Lesson 2: Printed Building Material



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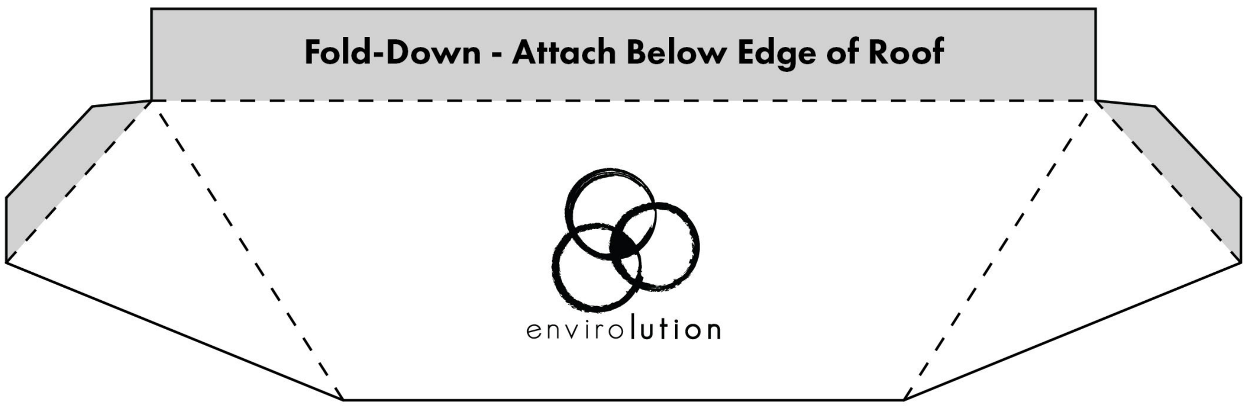
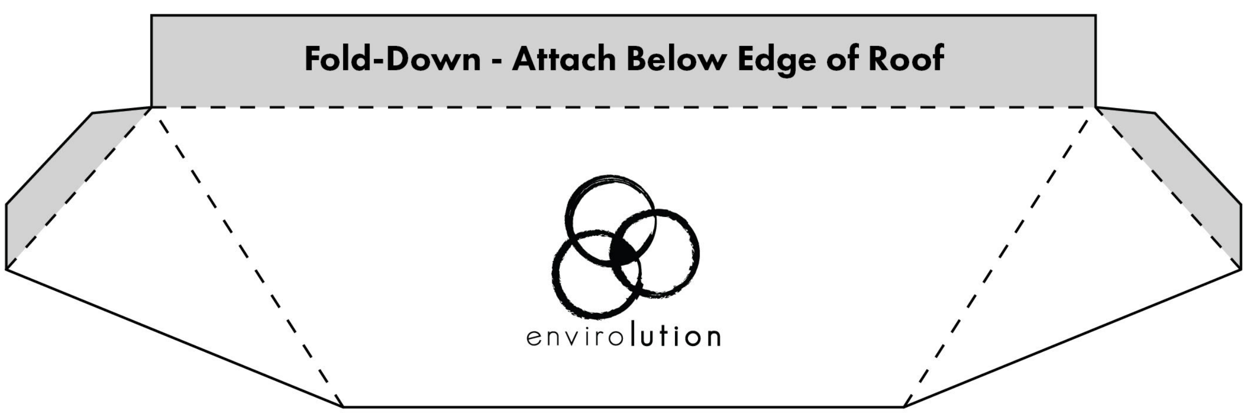


Glue

Fold



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Name:____ Class:_____________

Passive Cooling and Sustainability Reading

Thermal Systems, Lesson 2

Heat Transfer and the Building Envelope - A Quick Review

Heat moves in three ways -- **conduction, convection, and radiation**. Regardless of the mechanism, heat ALWAYS flows from *warmer to cooler* until there is no longer a temperature difference. The exterior walls, doors, windows, floors, and roof of a building make up the **building envelope**, which acts as a barrier between the indoor and outdoor environment. The building envelope helps insulate our home to either trap heat in during the winter or keep heat out during the summer. There are two main strategies that are used to reduce heat transfer: **building insulation and radiant or reflective barriers.** Most common building insulation materials work by trapping heat in tiny air pockets, slowing the transmission of conductive and convective heat. The material's ability to slow heat transfer is measured as its thermal resistance, or (R-value). *Higher R-values indicate greater thermal resistance*. The effectiveness of insulation depends on its physical properties, specifically its thickness, density. The effectiveness of an insulation material's resistance to heat flow also depends on how and where the insulation is installed. Radiant barriers and reflective insulation systems work by reflecting heat ways back into the environment. To be effective, the reflective surface must face an air space. Albedo is a measurement of how well an object reflects sunlight; a higher *albedo indicates higher reflectivity*.

Insulation and the Seasons

During winter, convection moves heat directly from all heated living spaces to adjacent unheated attics, garages, basements, and even to the outdoors. Heat flow can also move indirectly through interior ceilings, walls, and floors, wherever there is a difference in temperature. During the summer, convection transfers heat from the outdoors to the interior of a house. Insulation in buildings helps trap heat in during the winter and traps the heat outside in the summer.

To maintain comfort, the heat lost in the winter must be replaced by your heating system, and the heat gained in the summer must be removed by your cooling system. Properly insulating your household not only reduces heating and cooling costs but also improves comfort.

Passive Solar Cooling

It is important to consider keeping a house cool <u>without</u> using a cooling source such as air conditioning. Passive cooling includes technologies and design features that cool without consuming energy. **Passive solar design** takes advantage of a building's site, climate, and materials to minimize energy use. A well-designed passive solar household first reduces heating and cooling loads through energy-efficiency strategies and then meets those reduced loads in whole or part with solar energy. A portion of the south side of the house must have an unobstructed "view" of the sun. Because of the small heating loads of modern households, it is crucial to avoid oversizing south-facing glass and ensure that south-facing glass is properly shaded to prevent overheating and increased cooling loads in the spring and fall.

In simple terms, a passive solar household collects heat as the sun shines through south-facing windows and retains it in materials that store heat, known as thermal mass. The share of the household's heating load that passive solar design can meet is called the passive solar fraction and depends on the area of glazing and the amount of thermal mass. The ideal ratio of thermal mass to glazing varies by climate. Well-designed passive solar households also provide daylight all year and comfort during the cooling season through the use of nighttime ventilation.

Thermal mass in a passive solar household (commonly concrete, brick, stone, and tile) absorbs heat from sunlight during the heating season and absorbs heat from warm air in the house during the cooling season. In well-insulated households in moderate climates, the thermal mass inherent in household furnishings and drywall may be sufficient, eliminating the need for additional thermal storage materials. Solar heat is transferred from where it is collected and stored to different areas of the house by conduction, convection, and radiation. In some households, small fans and blowers help to distribute heat.

Although conceptually simple, a successful passive solar household requires that a number of details and variables come into balance. An experienced designer can use a computer model to simulate the details of a passive solar household in different configurations. In a **direct gain** design, sunlight enters the house through south-facing windows and strikes masonry floors and/or walls, which absorb and store the solar heat. As the room cools during the night, the thermal mass releases heat into the house. Some builders and household owners use water-filled containers located inside the living space to absorb and store solar heat.

An **indirect-gain** passive solar household has its thermal storage between the south-facing windows and the living spaces. The most common indirect-gain approach is a Trombe wall. The wall consists of an 8-inch to 16-inch thick masonry wall on the south side of a house. A single or double layer of glass mounted about one inch or less in front of the dark-colored wall absorbs solar heat, which is stored in the wall's mass. The heat migrates through the wall and radiates into the living space. Heat travels through a masonry wall at an average rate of one inch per hour, so the heat absorbed on the outside of an 8-inch thick concrete wall at noon will enter the interior living space around 8 p.m.

The **isolated-gain** passive solar household design is the most common and is a sunspace that can be closed off from the house with doors, windows, and other operable openings. Also known as a sunroom, solar room, solarium, a sunspace can be included in a new household design or added to an existing household. Sunspaces serve three main functions: (1) provide auxiliary heat, (2) serve as a sunny space to grow plants, and (3) serve as a pleasant living area.

Directions: Use the reading to answer the following questions in complete sentences.

1. Provide your own example for Conduction, Convection, and Radiation.
    a. Conduction____
    b. Convection____
    c. Radiation____
2. Do you want your insulation to have a high or low R-value? Explain.
3. Explain two ways you could improve a building's insulation.
4. What is albedo? List three materials you think would have high albedo.
5. What is the difference between direct-gain, indirect-gain, and isolated-gain? Which do you think is the most effective? Explain.

Name:____ Class:_____________

Clean Energy Analyst: Passive Cooling

Thermal Systems, Lesson 2

Directions: Read the following to discover how energy analysts evaluate cooling systems.

The Challenge

Cooling systems represent one of the most variable elements of energy use - the same building could spend as little as $10 per month or as much as $500 per month on cooling costs, depending on how well designed the cooling system is. Although many people associate air conditioners with cooling, well planned cooling systems consist of more than just a single appliance and are instead composed of a combination of efficient strategies designed to achieve maximum comfort at minimal cost.

The Solution

When evaluating a building's cooling system, energy analysts identify a combination of the most appropriate, cost effective, and energy efficient strategies that will keep the building at a comfortable temperature.

Cooling Strategies

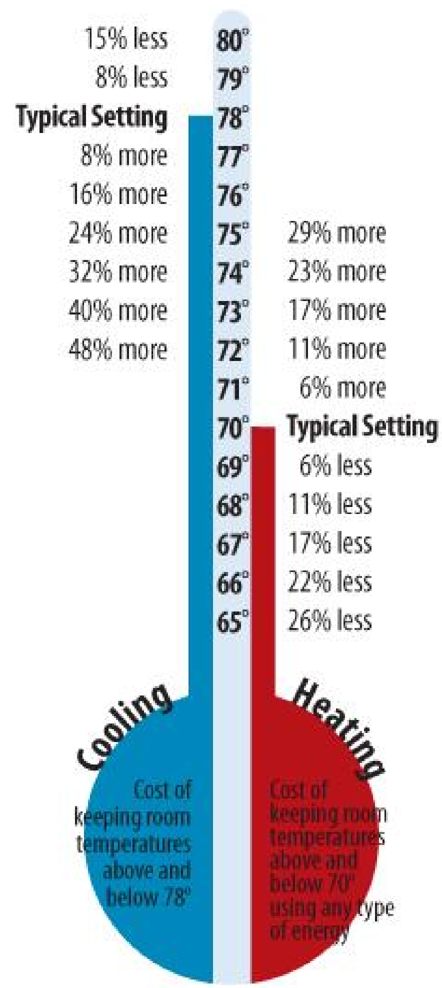
Window Treatments and Shading: Windows are thermal "**weak spots**" in a building shell, where heat is gained and lost easily. In hot, sunny climates, window upgrades can help resist this heat transfer. New windows with a **low-E coating**, which is designed to let light through but keep heat out, are available but expensive. Less expensive upgrades include window shades and awnings, or trees and shrubs positioned to provide window shading. Shading with plants has an additional benefit - plants release water vapor in a process called **evapotranspiration**, which helps cool the air around them.

Ventilation and Air Movement: Air movement and ventilation strategies work simply by moving hot air out of buildings and by creating a small amount of wind chill. Floor fans and ceiling fans are some of the most cost effective cooling devices, and can be used in conjunction with evaporative or refrigerated cooling systems to increase their effectiveness. Buildings can be vented naturally by opening windows in the mornings and evenings and closing them during the hottest parts of the day, and can be cooled cheaply with fans that push hot air outdoors.

Evaporative Cooling: Evaporative coolers (also known as **swamp coolers**) are an effective and efficient option for buildings in dry climates. Evaporative coolers use about 75% less energy than refrigeration coolers, yet achieve the same levels of comfort. Additionally, the coolers themselves usually cost less to purchase and install than most air conditioners.

Refrigeration Cooling: Refrigeration coolers (**air conditioners**) are the least efficient cooling option. However, improving existing air conditioning systems can significantly increase their efficiency. This can be done by cleaning or replacing dirty filters and cleaning air conditioner coils once a year.

Cooling Controls: Programmable thermostats can reduce the time that air conditioners are in use, as well as the intensity of the energy they consume. Energy analysts recommend keeping thermostats set to 78° F during the cooling season.



Please Note:
Percentages of change are approximate and are for air conditioning and heating costs only, not total energy bill.

Passive Cooling: Reduce, Upgrade, Control, and Maintain

Directions: **Energy conservation measures (ECMs**) for cooling can be classified by the acronym **RUCM**: Reduce, Upgrade, Control, and Maintain. Using what you know about the strategies of Clean Energy Analysts, write your recommended ECMs in the chart below.

RUCM: Passive Cooling
Reduce: How can we reduce the energy we use for cooling?
Upgrade: How can we upgrade existing cooling systems to make them more efficient?
Control: How can we control the energy we use for cooling?
Maintain: How can maintenance strategies improve cooling efficiency?

Reflection Questions: Why might these **ECMs** be important for homeowners to consider? Likewise, how could these changes help reduce the environmental impact that people are having on Earth's ecosystems?

Appendix B: List of Classroom Materials

"D" Cell Battery	Energy Example Cards: Lit Match	Multimeter
"D" Cell Battery Holder	Energy Example Cards: Nuclear	Neodymium Magnets
1.5W LED mini bi-pin bulbs	Energy Example Cards: Sun	Paper Clips- Small
11mm Wrench	Energy Stick	Philips #1 Screwdriver
16 oz.Compostable Clear Plastic Cup	Flashlights	Pinwheel spinners
20awg PVC coated wire - 12"	Foam Board Squares (3.5" x 5.5")	Protractor (4")
20awg PVC coated wire - 40"	Geothermal materials	Real Denim Building Insulation
30 awg Enameled Copper Wire	Glue Stick	Reflective Insulation 4" X 10.5"
32 oz Plastic Containers	Great Stuff (2" X 2")	Rubber Band
60W equivalent CFL bulb	Green Copy Paper (half sheet)	Sandpaper (4.5" X 4.5")
60W equivalent LED bulb	Hand Generator	Scotch tape
60W incandescent bulb	Heat Lamp Bulb	Small stamps
Aluminum Foil	Heat Resistant Gloves	Solar Panels
Balsa Wood Sheet	Heating Pad	Steel Block
Bar Magnet (2 ea.)	Hex Bolt / Carriage Bolt (3" x 1/4")	Storage Bin (6 Quart)
Box Fan	Infrared Thermometer	Tennis Ball
Brown Copy Paper	Ink Pad	Test Tubes
Bubble Wrap	Iron Filings (+/-) 150gr	Thin plastic (poly) piece (2" X 2")
Bulb Holders (small)	KidWind Basic Wind Turbine	Tin Cans w/out Lids
Chipboard	Kill-A-Watt Meter	UV Changing Beads
Clamp Lamp	Masking Tape	UV Flashlight
Compostable Sugarcane / Bagasse 10" Plate	Metal Thermometers	Water pump
Compostable Sugarcane / Bagasse 6” Plate	MINI KidWind Wind Turbine	White Copy Paper (quarter sheet)
Compostable Sugarcane / Round Bowl	Mini Light Bulbs (1.5V)	Wind up Toys
Cotton balls	Mini Water Pump w/ Alligator Clips	Wood Block (3" X 2" X 1/2")

Appendix C: Project ReCharge Counties and Schools

Nevada

Washoe County School District
Caughlin Ranch Elementary School
Coral Academy of Science Middle School
Florence Drake Elementary School
Lemelson STEM Academy
Roy Gomm Elementary School
Billinghurst Middle School
Clayton Middle School
Cold Springs Middle School
Depoali Middle School
Desert Skies Middle School
Dilworth Middle School
O'Brien Middle School
Incline Middle School
Mendive Middle School
Pine Middle School
Shaw Middle School
Sky Ranch Middle School
Sparks Middle School
Swope Middle School
Traner Middle School
Vaughn Middle School
AACT
ACE Charter High School
Damonte High School
Galena High School
Hug High School
North Valleys High School
Reed High School
Sparks High School
Sage Ridge High School
Wooster High School
Heritage HomeSchool
Turning Point Middle and High School

Carson City School District
Bordewich Bray Elementary
Carson City High School
Carson City Middle School
Eagle Valley Middle School
Empire Elementary School
Pioneer High School

Clark County School District
Jim Bridger Middle School
Advanced Technologies Academy High School
Boulder City High School
Canyon Springs High School
Charles I West Prep Elementary School
Findlay Middle School
Jo Mackey iLead Academy for the Digital Sciences Elementary School
Kenny C. Guinn STEM Academy Middle School
Laughlin Jr/Sr High School
Merit Academy of Cimarron Memorial High School
Sandy Valley High School
Sawyer Middle School
Shadow Middle School
Southeast Career Technical Academy High School
The Delta Academy Combined
William Bailey Middle School
Leavitt Middle School
Sunrise Mountain High School
Sierra Vista High School
Boulder City High School
Centennial High School
Mojave High School
Roy W. Martin Middle School
East Career Technical Academy
Cannon Jr. High School
Mike O'Callaghan Middle School
Cannon Junior High School
Del Sol Academy
Pinecrest Sloan Charter
West Career And Technical Academy High School

Churchill County School District
Churchill County Middle School

Douglas County School District
Carson Valley Middle School
CC Meneley Elementary School
Douglas High School
Jacks Valley and Pinon Hills Elementary Schools
Pau Wa Lu Middle School
Whittell High School

Elko County School District
Elko High School
Owyhee Combined School
West Wendover High School

Lyon County School District
Dayton Elementary School
Dayton High School
Dayton Intermediate School
Fernley High School
Silverland Middle School
Riverview Elementary School

Lander County School District
Battle Mountain High School

Nye County School District
JG Johnson Elementary School
Manse Elementary School
Round Mountain High School
Tonopah Middle School

Pyramid Lake Bureau of Indian Education
Pyramid Lake Middle and High School

Arizona

Mesa Public School District
Stapley Middle School

Queen Creek School District
Queen Creek High School

Scottsdale Unified School District
Ingleside Middle School

California

Sierra Plumas School District
Loyalton High School

Tahoe Truckee Unified School District
Sierra ELS Elementary and Middle School

Nevada City School District
Seven Hills School
Britney Prep High School

Colorado

Denver Public School District
Vista Academy High School

New York

Buffalo Public Schools
Tapestry Charter School

Rhode Island

Portsmouth School District
Portsmouth Schools K-8