ENERGY OFFICE

# LESSON PLAN

# Energy by Design

High School

## SUMMARY

Energy-efficient appliances are just the beginning. Today, we have energy-efficient options for almost every home fixture and even the home itself. The focus of this project-based activity is to teach students how choosing the proper home site and home building design can help conserve energy.

## LESSON OBJECTIVES

Upon completing this lesson the students will:

- Examine how controlling solar radiation can improve energy efficiency;
- Discuss home design for energy efficiency; and
- Create their own home design for energy conservation.

## ESSENTIAL QUESTION

How does home design and location affect energy efficiency?

## DURATION

The activity requires one to two class periods plus time for student projects and research.

## MATERIALS

- Handouts (included with this lesson)
- A Bright Flashlight
- A Cardboard Box
- A Magic Marker

## COLLEGE & CAREER-READY SCIENCE STANDARDS 2021

### HIGH SCHOOL PHYSICS

**STANDARD**

**P-PS3-1. Create a computational model to calculate the change in the energy of one component in a system when the following are known: 1) the change in energy of the other component(s) and 2) the energy flowing in and out of the system.**

**DISCIPLINARY CORE IDEA (DCI)**

**PS3.B: Conservation of Energy and Energy Transfer**

Conservation of energy means that the total change of energy in any system is always equal to the total energy transferred into or out of the system. Energy cannot be created or destroyed, but it can be transported from one place to another and transferred between systems.

**CROSS-CUTTING CONCEPTS (CCC)**

**Systems and System Models**

Models can be used to predict the behavior of a system, but these predictions have limited precision and reliability due to the assumptions and approximations inherent in models.

## ENGAGE

Have the students view this introduction video below on a passive solar community in Colorado. Geos Neighborhood in Arvada, Colorado has charged ahead in the quest for sustainable, net-zero, solar, fossil-fuel-free homes. In this video, Developer Norbert Klebl shares the secret formula to how these homes work. Visit **youtu.be/4y8NJCXuqgE**. Also see a net-zero energy home community in Greenville, SC. For more information, visit **www.addison-homes.com/service/our-model-homes**. Additional information also is available at **www.veic.org/clients-results/case-studies/high-efficiency-modular-homes-are-an-affordable-housing-solution**.

## EXPLORE

Place the cardboard box on a table so that the students can see it. The box will simulate a house. Using a marker, draw in windows and doors. Use the flashlight to simulate the sun rising in the east, tracking across the wall and roof of the box house, and setting in the west. (See the sun's path in the illustration on the student information sheet.) Ask the class the following questions:

- ***What difference does the orientation of a house facing east, west, north, or south make in siting a home?*** (It will determine how the sunlight/heat streams into the house.)
- ***Can you think of any reasons why you might want to consider which way the house faces?*** (You may want to avoid intense sunlight in summer and/or use sunlight to help heat your home in winter.)
- ***Which direction does your bedroom window face?***
- ***Do you prefer warm sunlight streaming in in the morning, or would you prefer to have the afternoon sun warm your room?***
- ***How about light and heat coming into the kitchen?***

## EXPLAIN

Hand out the student project information and worksheets and explain to the students that they are going to select a lot in a neighborhood, site a house on the lot and make decisions on landscaping and building designs for energy efficiency. Have the students read through the handout ***Design Considerations for Energy Efficiency***. The students can use the following websites as a starting point for their research.

- **www.energy.gov/energysaver/energy-efficient-home-design/passive-solar-home-design**
- **www.energy.gov/energysaver/energy-efficient-home-design/ultra-efficient-home-design**
- **www.youtube.com/c/Addison-homes/featured**
- **www.veic.org/clients-results/case-studies/high-efficiency-modular-homes-are-an-affordable-housing-solution**

## ELABORATE

Allow the students to investigate other building materials that can improve the energy efficiency of the home. Using this online lab, the students will test which materials insulate a home better during certain seasons. The students then can begin researching energy-efficient design to complete the design task. Give the students at least a full class period (or more if time allows) to read the research on the energy-efficient design information and to complete the worksheets.

## EVALUATE

Then have the students present their energy-efficient design ideas to the class. For more advanced classes, have the students create a model of their home highlighting energy-efficient designs or prepare simple site blueprints showing the placement of the home on the lot, landscaping and other features.

## E-LEARNING ACTIVITY

**INTERACTIVE GAME: YOU HAVE THE POWER**

In this interactive, you select one of three locations and then try to provide 100 percent of that community's electricity needs while staying within your budget of $1,000,000. Each location has different characteristics that affect how much each energy resource costs. To begin, visit **www.nationalgeographic.org/education/connect-transform-future/**. This activity could be used as an additional ELABORATE activity.

STUDENT HANDOUT

# DESIGN CONSIDERATIONS FOR ENERGY EFFICIENCY

## SITING THE HOUSE

Home orientation – facing north, south, east or west – is important to know when planning the layout of rooms, windows, porches and overhangs and even landscaping to maximize energy efficiency. A house with a large bank of unshaded windows facing due west will be expensive to keep cool in the summer. It is important that selection of the lot be made in conjunction with the design of the house and your preferences for comfort. For example, do you want morning sun streaming into bedroom windows or do you prefer afternoon sun coming into bedrooms while you are out? Do you want to have a sunny kitchen for breakfast? Will intense afternoon sun be a problem for the windows in a family room?

As the sun rises in the east, travels across the sky, and sets in the west, the south side of a home receives solar radiation most of the day; the east side only in the morning; and the west side only in the afternoon. The north side does not receive any radiation. The north-facing exterior wall is always the coldest wall. To reduce heat losses in winter, the north-facing exterior wall should have high resistance to heat transmission. It should be protected from winds, perhaps by evergreens. A dark color will help absorb the maximum amount of reflected solar radiation. In the summer, the north-facing wall should have some means for drawing in cool air. The east- and west-facing exterior walls should have more windows than north-facing walls and have provisions for letting light in or shading. Solar radiation is only available during limited hours of the day, so awnings, blinds, shutters and other light controlling devices are good ideas. Deciduous plants – that drop leaves in the fall – can provide summer shade and let in winter sun. The south-facing exterior wall is critical. This is the wall that receives the most heat energy from the sun's rays. It is always the hottest wall of the structure. The possible treatment of this wall is dependent on its function and geography – in colder climates its solar radiation can be used for heating and in warm climates it must reflect solar energy to save on cooling costs.

Large window walls can collect solar heat in winter. In summer when shade is needed, awning, overhangs and other controllable devices such as shutters and blinds help. Deciduous trees can provide summer shade as well. Control of south-facing solar radiation can reduce energy costs considerably. A 40-foot-long, 8-foot-high south wall can receive more than 200,000 Btu on a sunny day (5 hours of direct sun). For a 120-day heating season with only 50 percent sunshine, that is more than 14 million Btu. These savings are lost if the solar radiation isn't controlled in the summer when air-conditioners are running.

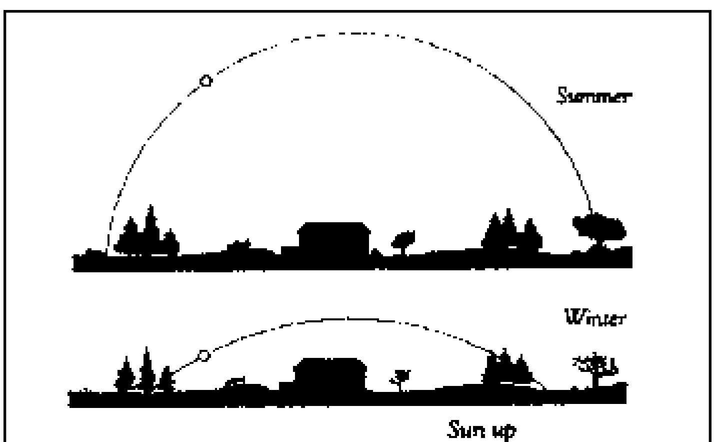
## LANDSCAPING

Landscaping can increase energy efficiency by shading hot summer sun and protecting the house from wind. Planting deciduous trees that provide summer shade and then lose their leaves in winter to let warm sun shine in can be beneficial. Evergreens can be used to shield a house from cold winds.

## FIXED OVERHANGS

A fixed horizontal overhang on the south side of a house is a widely used feature associated with passive solar heating systems. An overhang on the south side of a house is used to regulate solar (sunlight and heat) gains on a seasonal basis. Fixed overhangs work by blocking high-angle summer sun while allowing low-angle winter sunlight to reach south facing windows. The concerns in designing a fixed overhang are the length and width of the overhang and the size of the separation between the bottom of the overhang and the top of the window. The length of the overhang is the primary factor that determines the period of time that the overhang will shade the window.

The most effective overhang length will vary among locations, depending on the relationship of the particular site to the sun. For example, a two-foot overhang might shade a window throughout the summer on a house located at 32° latitude but leave the window partially unshaded on the same house at 40° latitude. This is because the summer sun is at a lower altitude angle in northern latitudes, so a longer overhang will be needed to block the direct sunlight (See Figure 1).



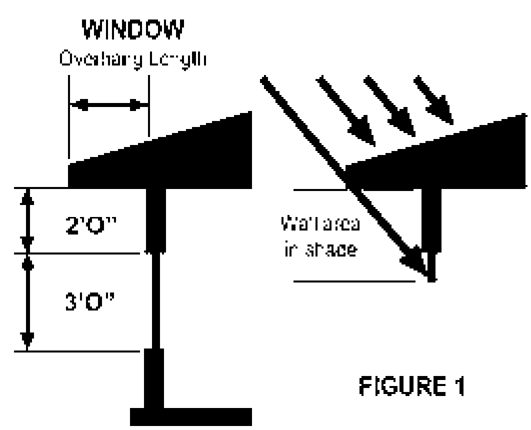




FIGURE 1

The width of the overhang is another design consideration. The overhang should extend beyond the window on either side to block the lower morning and afternoon sun. The extension of the overhang depends on the window configuration. If the window is narrow and long, the overhang should extend a substantial distance beyond the window on either side to provide full shade. On the other hand, if the window is wide and short, the overhang need only extend slightly beyond the width of the window to shade it.

The heating and cooling needs of the individual residence should be considered in sizing an overhang. An overhang that is sized to provide full shade throughout the entire cooling season will also provide some shading during the heating season. For example, equivalent sun angles occur in September and March, at the fall and spring equinox. An overhang that shades a window in September – a time when you may still run air conditioning in most of the South – will also provide shade in March when the warmth of the sun is desirable.

Consequently, it is important to consider the heating and cooling needs of a house in a particular location. An overhang may be totally inappropriate on a house in a cold climate with a large passive solar heating system. The benefit during the cooling season would be offset by the reduced performance of the passive system during the heating season.

Another factor that should be considered is that overhangs only block direct solar radiation. Indirect and diffuse radiation will still cause heat gains even when a window is fully shaded by an overhang, and diffuse radiation can be a significant source of heat. The average solar radiation received in June by a window that is completely shaded by an overhang ranges from 50 percent to 80 percent of the solar radiation received by the same window without any shading. Thus in warm sunny climates, other shading devices, such as operable shutters, blinds or shades, should be used in addition to a fixed overhang.

There are a number of manual design tools available for sizing fixed overhangs. One method was developed by the National Association of Home Builders (NAHB). It consists of a graph that provides a value for feet of vertical wall in shade per each foot of overhang for various latitudes. The method is easy to use but has a fixed rather than user-defined shading period.

An example of overhang sizing is given in Table 1. The base cases consist of a sliding glass door and a conventional window with separation sizing and height of vertical south-facing glazing defined in Figure 2.

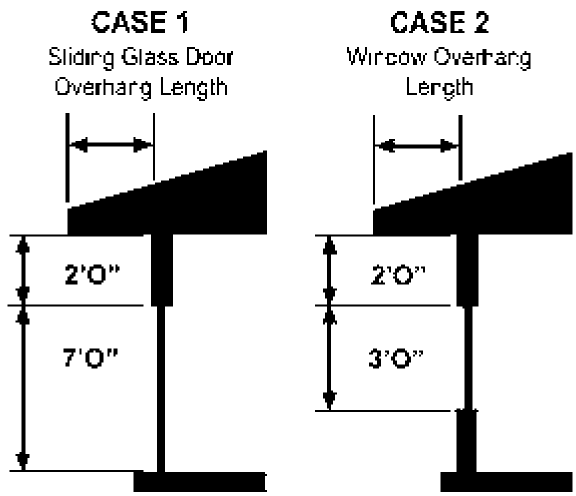



FIGURE 2

| TABLE 1: Example Overhang Lengths for Selected Cities in South Carolina | | | |
|---|---|---|---|
| **LOCATION** | **LATITUDE** | **CASE 1 NAHB Method (feet)** | **CASE 2 NAHB Method (feet)** |
| **Aiken** | 33.5 | 2.00 - 1.45 | 1.25 - 2.90 |
| **Anderson** | 34.5 | 2.20 - 1.60 | 1.36 - 3.17 |
| **Beaufort** | 32.5 | 1.86 - 1.40 | 1.16 - 2.80 |
| **Charleston** | 32.9 | 1.50 - 1.90 | 1.20 - 3.10 |
| **Columbia** | 33.9 | 1.60 - 2.20 | 1.40 - 3.30 |
| **Greenville/Spartanburg** | 34.9 | 1.70 - 2.20 | 1.40 - 3.30 |
| **Greenwood** | 34.2 | 2.13 - 1.54 | 1.33 - 3.08 |
| **Florence** | 34.2 | 2.13 - 1.54 | 1.33 - 3.08 |
| **Myrtle Beach** | 33.7 | 2.05 - 1.47 | 1.28 - 2.94 |
| **Orangeburg** | 33.5 | 2.00 - 1.45 | 1.25 - 2.90 |
| **Rock Hill** | 35.0 | 2.29 - 1.64 | 1.43 - 3.28 |
| **Sumter** | 33.8 | 1.90 - 1.43 | 1.20 - 2.86 |

Consider the recommendations for Case #1 in Columbia. The NAHB method results in a range of overhang lengths of 1.6 to 2.2 feet. This method focuses on keeping the house cool in the summer. Because of the physical requirements of the building itself as well as aesthetic considerations, an overhang much longer than two feet is rarely justified. Also, a very long overhang may block desired solar heating in the winter and may not offer the best protection from summer heat gain. Keep in mind that because of substantial diffuse sun, other shading devices are needed in addition to an overhang for reduction of heat caused by summer sun.

Figure 3 provides a simplified method of calculating shading requirements on south-facing glazed areas. The graph determines the feet of vertical wall in shade at noon on August 1 (summer) and February 1 (winter) per foot of overhang. To use the chart for a particular location, pinpoint where the latitude of the location intersects the heavy curved lines. The values beneath these points are the number of feet of wall in shade for each foot of overhang in the winter and summer. Values for the latitude, 33.9 which is Columbia, are marked on Figure 3.

It is important to note the amount of shade cast by each foot of overhang in the winter, approximately 0.6 for Columbia. This value can be used to size the separation between the bottom of the overhang and the top of the window in order to provide for maximum solar gain during the winter. For example, a two foot overhang in Columbia would permit a window to be placed within the wall area that is 1.2 to 7.2 feet below the overhang.

It should be noted that the different overhang lengths within the recommended range will perform differently. Longer overhangs will provide more shade than shorter overhangs, particularly in the spring and fall. The specific heating and cooling needs of the individual house should be considered in sizing the overhang within this range of lengths.

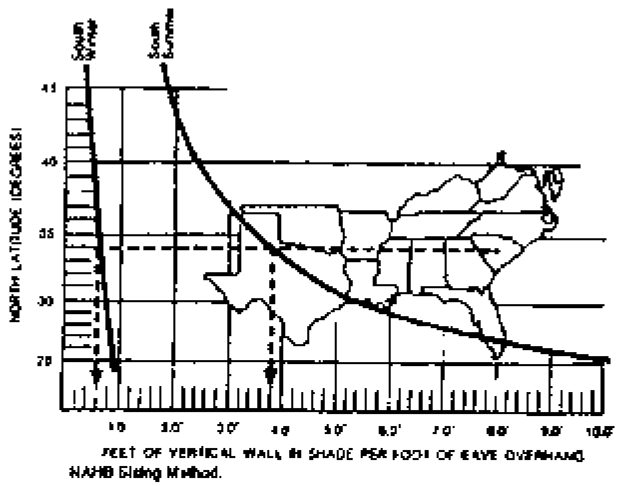



FIGURE 3

## SUNSPACES

A sunspace is a popular addition to any house. It can be used as a home heating system, a year-round garden or as extra living space. Sunlight passes through a sunspace's windows and warms the sunspace's interior. Generally, the interior surfaces include a concrete floor, brick wall, water-filled drums or some other form of storage mass.

Some heat is absorbed and stored in this storage mass. When the sun sets and the sunspace's temperature drops, the storage mass slowly releases the stored heat. The heat not absorbed raises the air temperature inside the sunspace. As long as the sun shines this heat can be circulated into the house by natural convection or drawn in by a low power fan.

## FIVE PASSIVE SOLAR ELEMENTS

Sunspaces must include the following elements to be a complete passive solar heating system:

1. **COLLECTOR** – such as the double layer of greenhouse window glazing (glass or plastic).
2. **ABSORBER** – usually the surfaces of the walls, floors and/or waterfilled containers inside the sunspace.
3. **STORAGE MASS** – normally the concrete, brick and/or water that retains heat.
4. **DISTRIBUTION SYSTEM** – the means of getting the heat into and around the house (for example, fans and natural convective flows).
5. **CONTROL SYSTEM** (or heat regulation device) – such as movable insulation used to prevent heat loss from the sunspace at night, roof overhangs that block the summer sun, thermostats that activate fans, vents for summer ventilation, and doors and operable windows for heat transfer to adjoining rooms.

One of the more important questions to consider when designing a sunspace is how it will be attached to the house. One option is to have the sunspace separated from the house by an uninsulated brick, block or concrete wall. This wall absorbs and stores solar heat. Some heat subsequently moves through the wall over a period of several hours.

The sunspace can also be separated from the house by an insulated masonry wall if there is another form of thermal storage in the sunspace. In either case, most of the heat delivery is by natural convection through windows, doors or vents.

Another option is to have oversized windows and sliding glass doors where the sunspace is attached to the house. The primary storage mass for this sunspace design would be a masonry floor. The masonry should be at least four inches thick (typically, concrete slab covered with ceramic tile or brick). The floor should be left uncarpeted, carpeting prevents heat absorption. A combination of these options may be the best approach.

Selecting sunspace glazing has become complicated in recent years due to the development of glass and plastic products that admit sunlight in a variety of ways. The conventional choice has been double-paned glass windows, or in very cold climates, triple-paned units. In addition to these options, manufacturers currently produce glazings with baked-in coatings.

Some of these glazings reduce heat loss, some increase the amount of sunlight and heat that can be admitted, some reduce heat gain and some reduce only certain types of light. A basic rule when deciding between double-glazing and coated-glazing is to use ordinary double-paned glass if your sunspace is only going to be used during the day and is permitted to get cool in the evening. If you intend to spend time in your sunspace at night also, the higher quality glazings – those with special coatings – are a better choice.

The sunspace window, specially designed to easily transmit sunlight, becomes a problem when the sun sets. The loss of heat back through the glass may result in losses greater than the daytime solar gain. Movable insulation is one solution. Night insulation improves the sunspace's performance as a solar heat collector.

Results from monitoring homes indicate that well designed sunspaces can provide up to 60 percent of a home's heating requirements during the winter. The percentage depends on the square footage of the sunspace glazing, local climate, the heat requirement of the house and other design details of the sunspace/house combination.

Because your goal in the summer is to cool your house rather than heat it, your sunspace requires different maintenance at this time. Sunlight must be kept out of the sunspace and heat that accumulates must be vented.

The same movable insulation used to prevent heat loss on winter nights can be used to prevent heat gain on summer days. Exterior shades are more effective since they block the sun's heat before it enters the sunspace.

If your sunspace has vertical windows, a carefully sized solid roof overhang will block some of the summer sun while still admitting sunlight in the winter. Retractable awnings or reflective shades are other choices. Deciduous trees or shrubs provide shade but must be placed carefully to avoid blocking winter sun. For venting heat, the sunspace may use an exhaust fan.

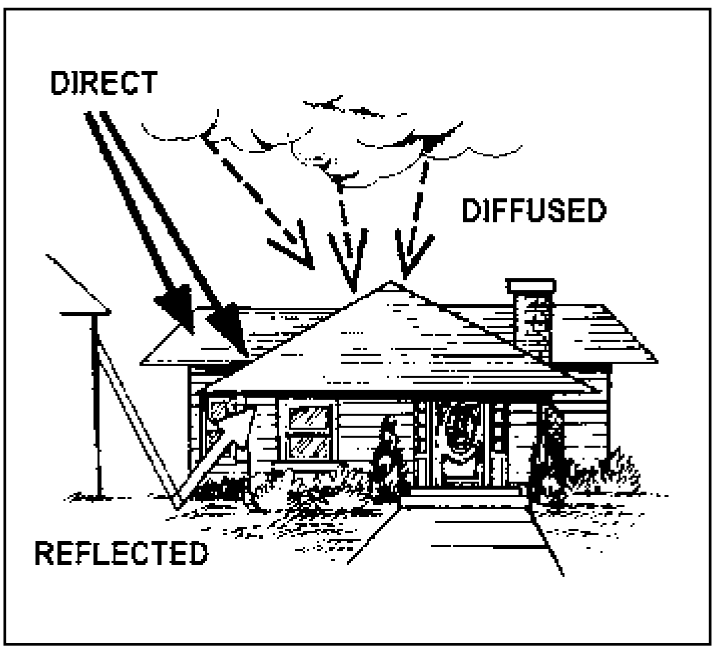
Intensive use of a sunspace for growing plants significantly decreases the area's heat output. Depending on the kind and number of plants grown, evaporation from leaves can cut your sunspace's heat gain in half. A general rule is to expect your sunspace's heat output to be reduced by the percentage of floor area the plants occupy.

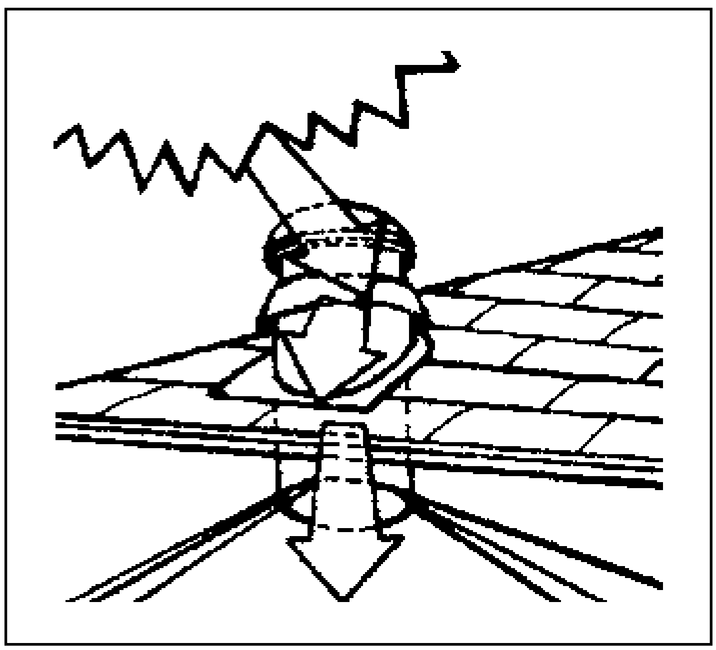
Plants can have a positive effect. They can act as natural humidifiers, making sunspace gardening especially beneficial for dry climate regions. Many plants cannot tolerate the high temperatures and temperature swings that occur in sunspaces designed for heating. Plants in sunspaces designed primarily for heat should be limited to a small number of plants that can tolerate the high temperatures of the sunspace.

## BRIGHT IDEA: THE ENERGY-SAVING SUN PIPE

This 13-inch-diameter stainless steel tube, easily installed in the roof without sawing through joists or rafters, is a new, low-cost way of illuminating your home. It works (even on overcast days) by capturing and reflecting sunlight down the interior of the highly polished tube into a domed ceiling globe.

The gadget provides natural light and costs nothing to operate. Unlike a skylight, it does not pour unwanted heat into a room in summer or lose heat in winter. There are many companies that sell this device. One is Sunpipe. For more information, visit **www.sunpipe.com**.

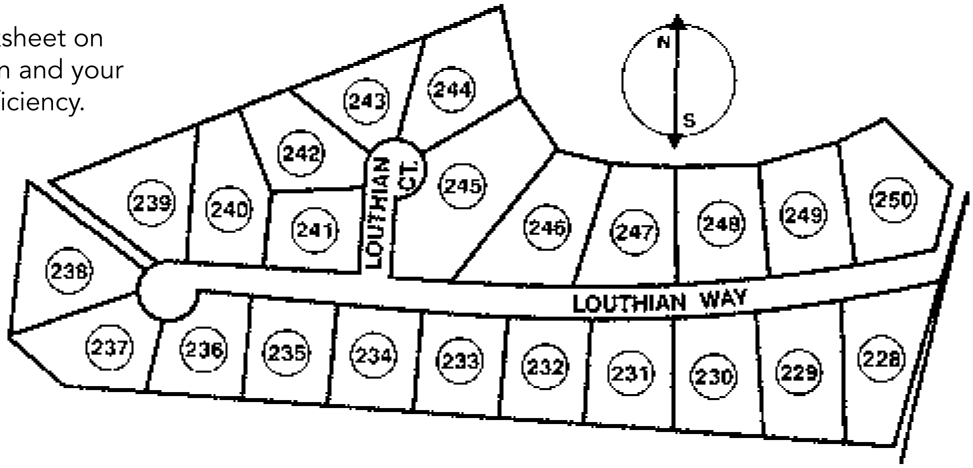


STUDENT WORKSHEET NAME: ______________________________

# DESIGN FOR ENERGY EFFICIENCY

Complete this worksheet on your home selection and your ideas for energy efficiency.




**LOT SELECTION**

Study the orientation of the various lots in the neighborhood and mark your selection of a site for your home on the site plan. Draw in a box to represent how your home would sit on the lot. Note which way your home will face in reference to the sun. Your Lot Number is:________.

Explain an energy-efficient consideration for your selection:______________________________

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**LANDSCAPING**

On your chosen lot, indicate any trees you would plant with an X. What type of tree (evergreen or deciduous) would you plant? Why?

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**OVERHANGS**

Would you use overhangs? If so, what length? On which windows? What other window treatments would you use?

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**YOUR BEST IDEAS FOR SAVING ENERGY**

Describe any special features of your home that would help it be energy efficient.

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**SUN SPACES**

Would you include a sun space? Why or why not? Where would it be located? In the box draw a simple floor plan to show the layout of your home (label the rooms) with or without a sun space.