

# TEAMS Activity



## Sustainability in the Urban Environment

In a perfect world, a sustainable city would have no ecological impact beyond its own city limits. It would provide all of its own food, energy, and water as a closed ecosystem. Using this ideal model as the goal, this scenario will focus on several examples of how building design and lifestyle choices affect the quality of life in a community.

The American Society of Heating, Refrigerating and Air-conditioning Engineers (ASHRAE) has set a goal that by the year 2030, all new buildings will be defined as Net Zero Energy Buildings (NZEB). That means that within their property boundaries each building will provide 100% of the energy needed to condition the building and provide all of its hot water and electrical power needs throughout the year. The key word "net" means that the building would produce more electricity than it needs on a summer day, and use more than it produces on a winter night. But at the end of the year, the electric meter will indicate the same value as it did at the beginning of the year.

Given that the U.S. consumes 20% of the world's energy resources annually to support just 3% of the world's population, this is a challenging goal. ASHRAE realizes that buildings consume almost 50% of the annual energy use in the United States, and the technology and materials already exist to reduce building energy loads by almost half. Once building thermal and electrical loads are reduced to that lower manageable level, renewable sources such as solar and wind could provide the remaining energy needed on a sustainable basis. Reaching that goal will require changing some societal values and attitudes.

Your team will use resources and scenario information to analyze several features that might be found in a residential NZEB. Those features include:

- Energy for heating and cooling is minimized by a good insulation package and supplemented by passive solar features. The rest is provided by a **geothermal** heat pump system.
- Indoor Air Quality is maintained with minimal heat loss by installing an **Energy Recovery Ventilation** system.
- **Domestic Hot Water (DHW)** is primarily supplied by a solar thermal energy system.
- The quantity of electricity used for lighting is reduced through the use of **daylighting**, and **phantom** losses in appliances and entertainment are minimized so the remainder can be generated onsite using solar **photovoltaic (PV)** panels.
- Some of the fruits and vegetables for the community are grown on-site each summer, reducing the **embodied** processing and transportation cost of buying groceries year-round. An emphasis on reducing, reusing, and **recycling** is maximized to further reduce the loss of embodied energy.
- Yard waste (grass clippings and leaves) is **composted** at the community center to provide humus to fertilize the gardens.

## Assumptions and Givens

Green Acres is a fictitious apartment building/co-housing complex located in Seattle, Washington.

The formula for percentage change is  $\frac{\text{new value}-\text{old value}}{\text{old value}} \times 100$

- The residents of Green Acres have set the goal to be living in a zero net energy building by 2020 (to generate as much energy as they use). As a first step, the residents want to reduce the energy use in each apartment from the current average of 450 kWh to 120 kWh. What is the percentage change in energy use for this reduction?
  - 73.3%
  - 7.3%
  - 0%
  - 7.3%
  - 73.3%
- To achieve the goal of a zero net energy building, Green Acres residents are installing a solar panel array on its roof. The array costs \$125,000, and the installation is an additional \$2,200. The residents are told that the array will generate the equivalent of \$6,800 in electricity every year. If the array is installed in January 2014, in what year will the residents have recovered its total cost?
  - 2028
  - 2029
  - 2030
  - 2031
  - 2032
- The residents of Green Acres have also decided to install a rainwater catchment system on the roof to reduce their reliance on the city water supply. The designer of the catchment system claims that a 1,000 sq. ft roof can collect up to 600 gallons of water for every inch of rainfall. If Green Acres' roof has an area of 2,550 sq. ft, what is the maximum amount of water it can collect for every inch of rain?
  - 600 gallons
  - 1,530 gallons
  - 2,250 gallons
  - 3,630 gallons
  - 4,250 gallons

Work it Out



## Assumptions and Givens

The formula for the area of a rectangle is  $A = l \times w$ , where  $l$  is the length and  $w$  is the width of the rectangle.

4. The solar panel array on the roof prevents Green Acres from using the entire roof to collect rainwater. Two rectangular areas have been set aside for rainwater catchment. The first is length of 32 ft long and 5 ft wide, and the second is 14 ft long and 17 ft wide. Each square foot of the catchment system can collect 0.6 gallons of water for every inch of rain. What is the maximum amount of water Green Acres can collect for every inch of rain?
- a. 159.1 gallons
  - b. 182.4 gallons
  - c. 202.9 gallons
  - d. 238.8 gallons
  - e. 264.1 gallons

Work it Out



5. One important concept for a zero net energy building is the idea of "net energy." Even though Green Acres may use more energy during the winter, it will produce more energy during the summer, so that over the course of the year the total (net) energy consumed is equal to zero. The table below lists the energy (in kWh) the residents' used each month.

Month	Energy usage (kWh)
January	105,000
February	112,000
March	69,000
April	42,000
May	21,000
June	-
July	-
August	-
September	19,000
October	39,000
November	56,000
December	81,000

June, July, and August are the sunny, summer months when Green Acres produces all of its energy from its solar panel array along with some extra energy that it stores. The solar array does not produce sufficient energy during the rest of the year to meet the residents' needs. If Green Acres is to have zero net energy for this calendar year, how much extra energy does it need to produce during the summer?

- a. 19,000 kWh
- b. 74,000 kWh
- c. 112,000 kWh
- d. 356,000 kWh
- e. 544,000 kWh

Work it Out



6. Passive solar heating is the use of design features to capture the energy from the sun to heat a building for free. The south-facing side of Green Acres (which gets the most sunlight) has 14 residential units, and these residents are considering the installation of floor-to ceiling windows to capture the most light. If each unit has a 9 ft ceiling and a south-facing wall that is 19 ft long, how much glass will they need to order to make this design change?
- 171 sq. ft.
  - 1,522 sq. ft.
  - 2,394 sq. ft.
  - 2,911 sq. ft.
  - 3,569 sq. ft.

### Assumptions and Givens

The rate of heat transfer through a glass window is

$$k \times A \times \frac{(T_1 - T_2)}{d}$$

- $k$  is the heat transfer coefficient of glass (equal to 0.27 in units of  $W/m^{\circ}C$ )
  - $A$  is the area of the glass (in  $m^2$ )
  - $T_1$  and  $T_2$  are the temperatures inside and outside the window, respectively (in  $^{\circ}C$ )
  - $d$  is the thickness of the glass (in  $m$ ).
  - Rate is measured in Watts.
7. Even with a passive solar design, traditional glass windows are a main source of heat loss in modern buildings, especially during winter months. Each window in a unit at Green Acres has an area of  $1.2 m^2$  and is  $0.04 m$  thick. If the average temperature inside the unit is kept at  $22^{\circ}C$  and the average temperature outside is  $4^{\circ}C$  during the winter, what is the rate of heat transfer through this window?
- 78.6 W
  - 92.2 W
  - 108.2 W
  - 131.9 W
  - 145.8 W

Work it Out



8. Green Acres residents are also implementing methods to reduce the amount of trash that they produce. They are composting food waste rather than throwing it in the garbage. The residents estimate that 25% of their trash is food waste. There are 42 units in Green Acres, and each unit produces 135 pounds of trash per month. If each unit composted half of their food waste, how much trash would the community eliminate every month?

- a. 429.93 lbs.
- b. 515.20 lbs.
- c. 664.39 lbs.
- d. 708.75 lbs.
- e. 772.18 lbs.

Work it Out

A large grid for working out the problem, with a pencil icon in the bottom right corner.

## Assumptions and Givens

1 kilogram = 2.2 pounds

9. Many residents at Green Acres drive their cars to work every day. In an effort to reduce carbon emissions, the residents are setting up a car-pooling system. Each resident who drives produces 7,500 lbs. of  $\text{CO}_2$  every year by driving to work alone. A consultant told the residents that the entire Green Acres complex produces 2,000,000 kilograms of  $\text{CO}_2$  every year. If the residents want to reduce their annual  $\text{CO}_2$  emissions by 3.2% using the car-pooling system, how many residents must leave their cars at home and car pool to work?
- a. 18
  - b. 19
  - c. 20
  - d. 21
  - e. 22
10. One of the perks of generating energy at your residence (using solar panels, wind turbines, etc.) is that any excess energy can be sold back to the utility grid. At the end of the year, Green Acres had generated an excess of 279,000 kWh of energy with their solar panel array. They decided to sell this energy and divide the profits equally among the 108 residents (to be reinvested into home improvements). If the local power company pays \$0.09/kWh, how much money will each resident receive?
- a. \$232.50
  - b. \$256.19
  - c. \$282.60
  - d. \$301.56
  - e. \$314.10

Work it Out



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Answers - Middle School Activity

1. A

2. E

3. B

4. D

5. E

6. C

7. E

8. D

9. B

10.A

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