LTA 12

NASA - AMATYC - NSF
Project Coalition

Kennedy Space Center

Mission Control:
We Have Energy Savings

Mathematics for Engineering Technology

Architecture
Industrial and Management

Capital Community College

NASA Research Building at Cape Canaveral Air Force Base

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Mission Control: We Have Energy Savings

Mathematics for
Architecture Engineering Technology
Industrial and Management Engineering Technology

Alice Kaseberg - AMATYC Writing Team Member
Lane Community College, Eugene, **Oregon**

Alice Kaseberg has been a faculty member at Lane Community College since 1985. She has taught statics and strength of materials in a pre-engineering program as well as a full range of mathematics courses. Alice has been active in AMATYC, NCTM, and ICTCM, and she has written a variety of materials including an elementary algebra text, an intermediate algebra text and graphing calculator supplements. Alice has been interested in activities that encourage participants of women in mathematics and co-authored an EQUAL handbook.

Janet Tarjan - AMATYC Writing Team Member
Bakersfield Community College, Bakersfield, **California**

Janet Tarjan has taught mathematics at Bakersfield College for 12 years. Janet won the BC 1998 Margaret A. Levinson Award for faculty leadership. She also was one of the honorees for the 1998 Named Gift Awards from the Bakersfield Branch of the American Association of University Women (AAUW) for her service as the chair of Girls Enjoying Math and Science. Janet serves as Member-at-Large of the Executive Board of the California Mathematics Council of Community Colleges.

Catherine Alexander - NASA Scientist/Engineer
Kennedy Space Center, **Florida**

Catherine Alexander has served as a Requirements Analyst, Resource, Budget and Program Management. Currently, she is the Customer Support Manager for the Joint Performance Management Office responsible for Base Support services for Kennedy Space Center, Cape Canaveral Air Station, and Patrick Air Force Base.

Project Grant Team

John S. Pazdar
Project Director
Capital Community College
Hartford, Connecticut

Peter A. Wursthorn
Principal Investigator
Capital Community College
Hartford, Connecticut

Patricia L. Hirschy
Principal Investigator
Asnuntuck Community College
Enfield, Connecticut

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Mission Control: We Have Energy Savings

Background Information

The National Aeronautics and Space Administration (NASA) was established in October 1958 for the peaceful exploration of space. NASA adapted facilities at the Cape Canaveral Air Station (Cape) for its early rocket launches. In May 1961 President John F. Kennedy announced that the United States would send men to the Moon and back by the end of the decade. The program, called Apollo, would require the largest rocket ever built, the 363-foot-tall Saturn V. However, the Cape facilities were inadequate for launching the Saturn V rockets. A new launch facility was built north of the Cape Canaveral Air Station and in November 1963 was renamed the John F. Kennedy Space Center (KSC). Over the years, facilities at both Kennedy Space Center and the Cape continued to serve both manned and unmanned space activities.

The activities in this LTA focus on energy use at NASA. Two factors have led NASA to study energy use at the Cape.

First, many Cape Canaveral Air Station facilities are old and not designed for their current uses. The facilities at the Cape were built as airplane hangars, service and repair facilities, and barracks. Today the same buildings are used for activities and equipment as diverse as: electronic monitoring and control units for launches, assembly facilities and clean rooms for preparation of payloads to be delivered to space, and biological experiments that test food and oxygen sources for long term space travel. The facilities lack most or all modern energy saving features or equipment.

Second, the federal government has mandated energy savings through the Energy Policy Act of 1992 (EO 12902). This act requires energy reductions in federal buildings by 2005 and permits contracts with private companies to install energy-saving equipment. An energy savings performance contract (ESPC) specifies cost saving measures to be performed, projects energy reductions, and provides for the government to pay the private contractor with savings from reduced energy costs in the future.

Section 1

Utilities and Energy Use

Part A   Reflecting on Energy Use

Utilities provide the sources of energy (electricity, natural gas, fuel oil) that make our homes, recreational facilities, offices, and stores comfortable for human use.

Exercises

Answer the following questions based on your life experiences.

1) Have you or your parents ever complained about a utility bill?

2) Have you or your parents weatherized your home or called a utility company to request an energy audit?

3) Assume that you are searching for an apartment. Would you ask who pays the utility bills or what you should expect to pay for utilities?

4) Is someone at your place of work or at your college trying to cut the cost of energy?

5) Do you turn off the lights when you leave a room?

6) Have you noticed motion sensor lights in your college or work place?

7) Do you leave the water running while you wash dishes?

When NASA examines energy use, it groups the 385 different KSC and Cape facilities into types, examines their energy needs, and identifies savings that can be achieved. These facilities range from cement pads with fences around them (garbage collection centers) to Launch Control Centers and Research Labs.

Exercises

8) What types of buildings are you in during the day? Think of all the different activities you do each day. Possible examples are school, grocery store, and home.

9) Group the types of buildings into 3 or 4 categories.

10) Explain why you have grouped certain types of buildings together.

Now select a building type such as school, home, or workplace, and respond to the following questions.

11) What types of energy are used in your building type?

12) What are the possible energy saving sources?

You will now do activities and exercises designed to give you an appreciation of an energy savings project. Instead of going out and collecting data from actual buildings, you will obtain information about energy usage and window/wall areas from the diagrams on pages 12.7, 12.9, 12.10 and 12.11. The diagrams are of two types: floor plans and front wall outlines.

Part B Light Fixtures and Lamps

Exercises

13) Carry out the following bulleted activities with respect to information from the floor plan on the next page. The objective of this exercise is to find the total number of watts-hours used per day by lighting fixtures and lamps in the home with the given floor plan. Complete Table 1 by following the steps below.

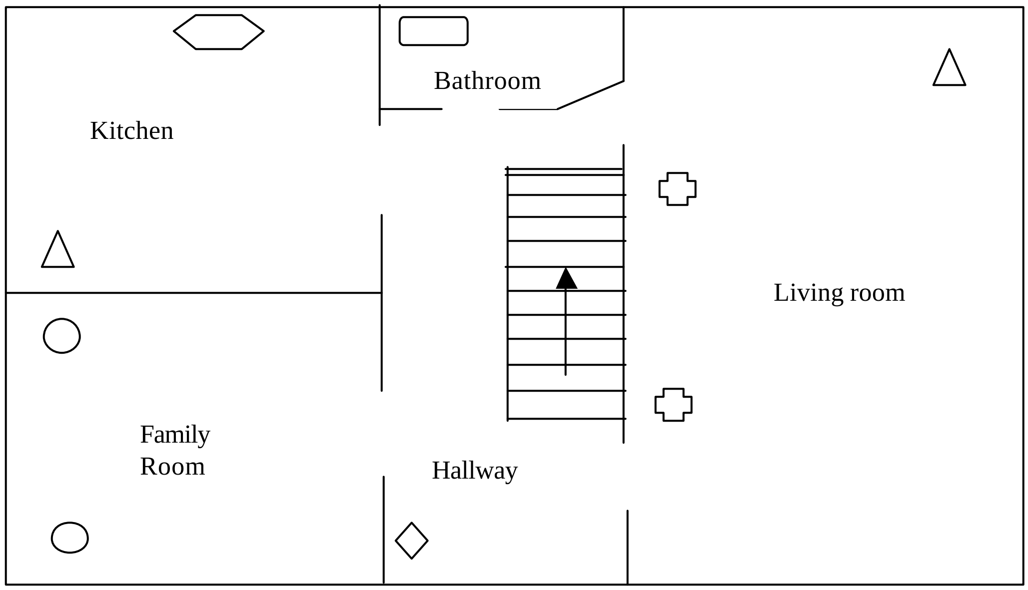
- On separate paper, make a table with the column headings shown in Table 1. Your table will need many more rows than Table 1.
- Locate, identify and count the type of each light bulb in the building and its wattage. Record your findings in columns 1 and 2 of your table.
- Estimate a reasonable number of hours that each light fixture is used in a 24 hour period, and record your estimates in column 3 of your table.
- Calculate the watt-hours used by each light fixture, and record your results in column 4.
- Record the total number of watts used in a 24 hour period in the bottom cell of column 4.

Table 1 Example of Light Fixtures and Lamp Information

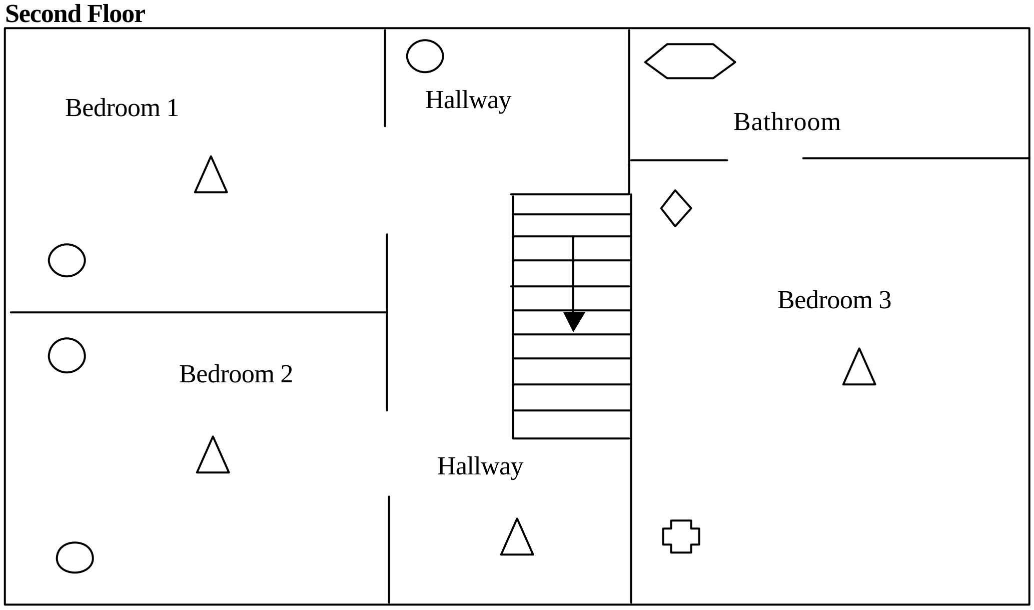
Light Fixture or Lamp	Watts	Hours/Day	(Watt-Hours Per Day)
Kitchen: Fluorescent light (4 bulbs @ 40 W)	160	4	640
Kitchen Ceiling Fixture: (4 bulbs @ 60 W)	240	5	1200
TOTAL			

Floor Plan of a House

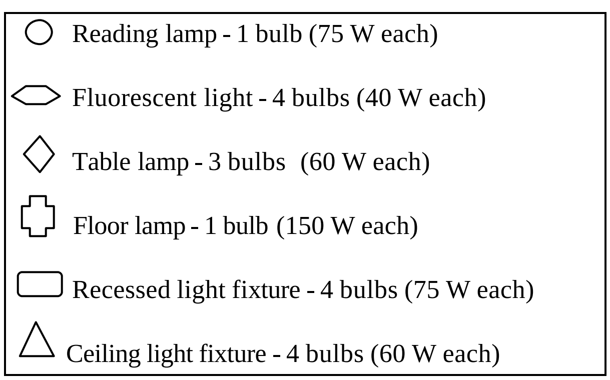
First Floor



Second Floor



Legend:



14) The objective of this exercise is to determine the total energy cost for certain time periods for the light fixtures and lamps in the house that you considered in Exercise 13.

a) Electricity is sold by the kilowatt-hour, kWh. What does the prefix kilo mean?

b) How can we change watt-hours to kilowatt-hours?

c) What is the total cost of one day's lighting if the cost of electricity is $0.05 per kWh?

d) Find an electric utility bill or call your local electric company and find the cost per kilowatt-hour for your electricity. Compare your cost to the NASA figure of $0.05 per kWh.

e) Use the cost per kilowatt-hour of your local electricity to find the total cost of lighting the house for one whole year.

f) Explain any assumptions you make in estimating the cost per year.

Part C Window to Wall Ratio

Exercise

15) In this part, you will find the area of the exterior windows and walls of a building. Exterior windows and walls have one side facing inside the building and the other facing outside the building. Select a building with one of the front wall outlines shown on pages 12.10 and 12.11, and carry out the following activities. Table 2 is an example of the way in which you should organize the information.

- On separate paper, make a table with the column headings shown in Table 2.
- Locate and identify the windows in the "home outline" you have selected and record your results in column 1 of your table.
- Measure the dimensions of the windows and exterior walls to the nearest millimeter. Do not include the attic or garage walls. In some cases, you will have to estimate where the house ends and the attic or the garage begins. Record your results in columns 2 and 4 of your table.

The information in Table 2 is based on the following front wall outline.

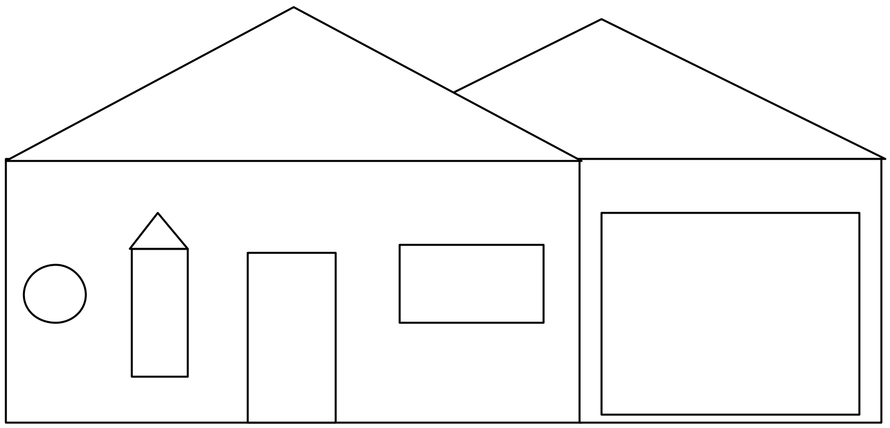


Figure 1: Home Outline Z

Table 2 Example of window and wall information

Home Outline Z	Window Dimension	Window Area	Exterior Wall Dimensions	Exterior Wall Area
Window 1	Circle: radius = 4 mm	p·16 or 50.3 sq mm	35 mm by 76 mm	2,660 sq mm
Window 2 (Window with triangular top)	Triangle: b = 8 mm, h = 5 mm Rectangle: 8 mm by 17 mm	156 sq mm	Same wall	Same wall
Window 3	Rectangle 10 mm by 19 mm:	190 sq mm	Same wall	Same wall
Door	12 mm by 23 mm			
Total	---	396.3 sq mm	---	2,660 sq mm

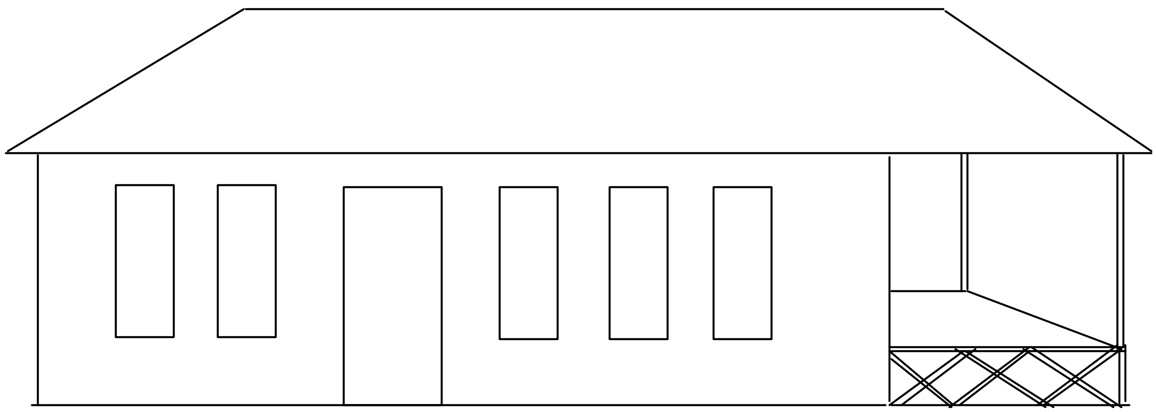
16) In this exercise, you will use the following steps and the information from your table to determine the window to wall ratio for the building you chose. Divide the window area by the wall area to find the window to wall ratio (WWR).

As an example, the window to wall ratio for Home Outline Z is shown below.

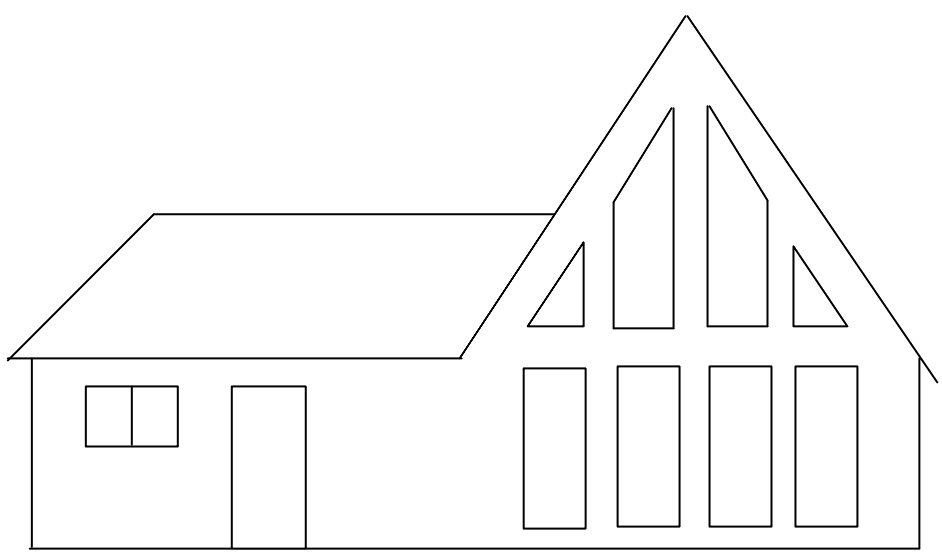
$$\text{WWR} = \frac{396.3 \text{ sq mm}}{2660 \text{ sq mm}} \times 100\% = (0.149) \times (100\%) = 14.9\%$$

House Front Walls

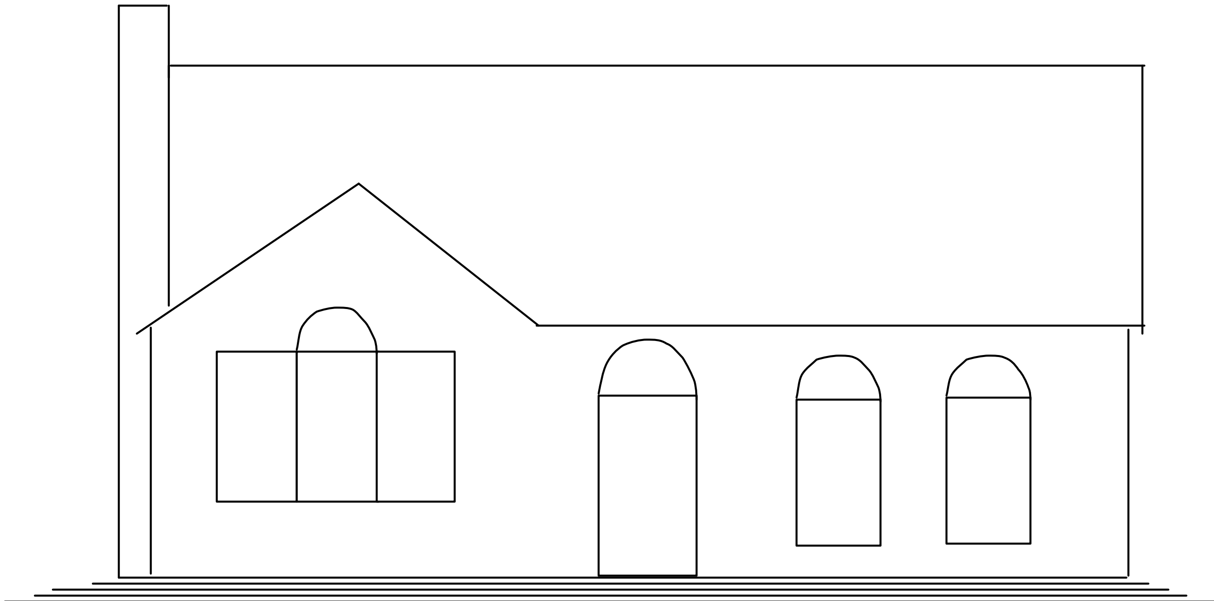
House A



House B



House C

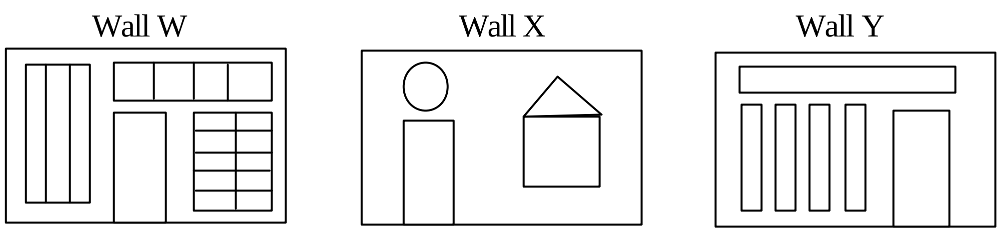


17) Discuss in a group:
   a) How might windows in Alaska and Florida be the same? How might they be different?
   b) What energy savings features for windows are used in <u>your</u> climate?
   c) What energy savings features for windows are used in <u>other</u> climates?
   d) What is it about your climate that makes windows important in energy conservation?

Units and Practice with Window to Wall Ratio (WWR)

18. a) You measured distances in the front wall outline in millimeters. When the WWR was formed, what happened to the units (sq mm) that were attached to the wall and window areas?
    b) If you repeated the work you did using inches instead of millimeters, how would your resulting WWR have changed?
    c) No legend indicating the true size of the front wall of the houses was given. In fact the scaling factor used for different homes was not uniform. Discuss why knowing the true dimensions of a given house is not necessary for determining the WWR.

19) Typical window to wall ratios for buildings are 25%, 50%, and 75%.
   a) Draw the outline of a front wall of a house with WWR of 25%.
   b) Draw the outline of a front wall of a house with WWR of 50%.
   c) Draw the outline of a front wall of a house with WWR of 75%.
   d) Without measuring the following walls, use the experience you've developed to estimate the window to wall ratio of each of the following walls.



Estimated WWR _____ Estimated WWR ______ Estimated WWR ______

Part D Follow Up Exercises Related to NASA

20) In NASA Hangar S at the Cape, workers clean and maintain the Self-Contained Atmospheric Pressure Ensembles (pressurized suits for handling the fuel for the directional engines on the Orbiter). The Energy Saving Performance Contract specifies that replacing lights in Hangar S will reduce energy demand by 20.89 kW for a total of 62,878 kWh saved per year. How many hours of lighting per year does this assume?

21) The Energy Savings Performance Contract specifies $4,471 as the total savings from replacing lights in Hangar S. What cost per kWh does this assume?

22) Hangar S has a window to wall ratio of 5%. If the total exterior wall area of the hangar is 88,000 square feet, find the area occupied by the windows.

23) The Energy Savings Contract shows an estimated $96 per year savings from an application of solar tinting to the windows of Hangar S. It is estimated that the solar tinting will save 1,995 kWh. What is the assumed cost per kWh?

24) How many years would it take to pay for solar tinting from the energy savings of $96 per year if the tinting costs $3,000?

Section 2

Establishing a Baseline for Energy Use

Part A Energy Savings Performance Contract

A contractor has contracted with the 45th Space Wing located at Cape Canaveral Air Station (CCAS or the Cape) to perform $12,000,000 in energy modifications during 1998, 1999, and 2000. The 45th Space Wing will pay the contractor a total of $23,000,000 during the 13 years from 2000 to 2012. The $23 million pay back will be funded by savings resulting from reduced energy consumption and deferred maintenance. NASA and the Air Force will pay back the invested amount in the same way that a family buying a house pays back the invested amount called a mortgage loan. Up to eight energy conservation projects will be implemented in 385 Cape facilities. The energy conservation projects are:

- Upgrade lights and ballasts
- Install energy monitoring and control systems
- Upgrade to premium efficiency motors
- Upgrade air-conditioning units
- Install window tinting
- Convert fuel oil and electric boilers to natural gas
- Install an engine driven chilled water plant
- Upgrade electrical transformers

The government and the contractor must agree on the modifications to be performed, the estimated energy savings targets, and the pay back period. A baseline for energy use enables one to determine whether the contract is fair and reasonable, to estimate budgets for pay back, and to assign energy costs to appropriate programs. While electricity is not the only form of energy addressed by the actual Energy Savings Performance Contract, it will be the focus of the remaining exercises.

Part B Fiscal Year and Calendar Year - Baseline For Electricity Use

Definition: A **fiscal year (FY)** is a selected 12 month period used by organizations to keep their financial records. The fiscal year may start on different months for different organizations.

Exercises

1) Name the first and last dates of the calendar year.

2) Why might the fiscal year for a school be July 1 to June 30?

3) NASA's fiscal year 1998 begins October 1, 1997. When does it end?

4) In what NASA fiscal year does December 1997 belong?

5) In what calendar year does November of NASA's FY1996 belong?

6) In what calendar year does May of NASA's FY1997 belong?

You are the contracts manager for NASA and must verify that the contract saving estimates are reasonable. As part of your analysis, you need to establish a baseline for electricity use for each of the buildings. The baseline is a number that describes expected monthly energy use. Use the information in Tables 3, 4, and 5 as you explore energy use at the Cape. The tables and exercises use NASA's fiscal year, not calendar year.

Exercises

7) In each table, there is a blank column labeled "Baseline (Monthly Averages)". Find the monthly average for electricity use in kWh in each of the three buildings for each month of FY96 through FY98. For example, to find the average number of kilowatt hours used during October in the E&O (Engineering and Operations) Building refer to Table 3 that follows, add 79,130; 70,320; and 87,120; and divide the sum by 3. Round your answers to the nearest hundred.

Table 3 E & O (Engineering and Operations) Building - Electricity Use in kWh*

Month	FY96 (kWh)	FY97 (kWh)	FY98 (kWh)	Baseline (Monthly Averages) (kWh rounded to nearest hundred)
Oct	79,130	70,320	87,120	
Nov	67,910	61,920	60,720	
Dec	58,010	56,280	60,650	
Jan	51,870	80,720	56,280	
Feb	50,990	52,560	47,880	
Mar	55,570	69,000	47,040	
Apr	64,500	58,560	59,020	
May	75,600	71,760	69,210	
Jun	75,600	77,520	80,400	
Jul	86,140	90,240	89,870	
Aug	93,550	93,240	95,290	
Sep	96,010	97,920	95,330	

* The data for FY97 and Oct to Mar FY98 are actual data from NASA. Other data are estimated from NASA data. The E&O Building is an administrative office building at Cape Canaveral Air Station.

Table 4 Hangar S - Electricity Use in kWh #

Month	FY96 (kWh)	FY97 (kWh)	FY98 (kWh)	Baseline (Monthly Average) (kWh rounded to nearest hundred)
Oct	92,890	116,360	97,520	
Nov	81,200	100,000	82,080	
Dec	69,940	80,180	71,280	
Jan	61,890	84,320	67,800	
Feb	59,000	77,520	61,760	
Mar	61,990	101,440	59,480	
Apr	70,120	94,600	64,980	
May	81,410	87,840	74,780	
Jun	93,080	95,240	86,600	
Jul	102,290	103,440	97,530	
Aug	106,780	92,240	104,910	
Sep	105,440	101,240	106,920	

The data for FY97 and Oct to Mar FY98 are actual data from NASA. Other data are estimated from NASA data. Hangar S is the building where the Self-Contained Atmospheric Pressurized Ensemble (SCAPE) suits are maintained, cleaned, and refurbished. The SCAPE suits protect workers as they load the hydrazine fuel into the Orbiter's maneuvering engines and auxiliary power unit.

Table 5 Hangar AF - Electricity Use in kWh *

Month	FY96 (kWh)	FY97 (kWh)	FY98 (kWh)	Baseline (Monthly Average) (kWh rounded to nearest hundred)
Oct	120,230	288,000	139,520	
Nov	134,270	218,880	103,680	
Dec	166,850	229,120	125,440	
Jan	210,000	236,800	122,880	
Feb	253,150	264,960	149,760	
Mar	285,730	296,960	154,880	
Apr	299,780	248,320	253,150	
May	291,830	268,800	285,730	
Jun	222,700	199,680	299,780	
Jul	178,430	376,320	291,860	
Aug	141,890	185,600	263,860	
Sep	152,020	162,560	180,000	

* The data for FY97 and Oct to Mar FY98 are actual data from NASA. Other data are estimated from NASA data. When the two white Solid Rocket Boosters are recovered from the Atlantic Ocean after Shuttle launch, they are taken to Hangar AF. They are then refurbished before being refueled for another launch.

Part C Exploring Electricity Use Patterns

Use the information found in the foregoing Tables 3, 4, and 5 above to do the following exercises.

Exercises

8) Search for patterns in monthly electricity use. Graphing your data may help you understand it better. Describe patterns you find.

9) Do you expect October through March electricity use in kWh to be the same as April through September in general? Explain.

10) For Hangar AF, find the six month average electricity use for the FY98 October through March and the six month average for FY98 April through September. Compare them.

11) Find the total electricity use for each fiscal year in each building.

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