THE SATURN STUDENT WORKBOOK

Study guides for *Residential Energy,* the *Saturn Energy Auditor Field Guide,* and the *Comprehensive Home Energy Curriculum.*

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TABLE OF CONTENTS

Elements of the Saturn Curriculum

The Saturn Curriculum is based upon a solid foundation of proven building science, helping you build an accurate understanding of modern buildings. Each topic includes an overview of the technology, examples of typical installations and their defects, procedures for performing audits, and guidelines for analyzing potential retrofits. A balanced approach to building performance is presented that addresses energy efficiency, building durability, and human health.

The Curriculum addresses the topic areas required for the *Building Analyst* certification offered by the Building Performance Institute (BPI), the *Home Energy Rater* (HERS Rater) certification offered by the Residential Energy Services Network (RESNET), and the *Core Competencies for Weatherization* developed by the Weatherization Trainer's Consortium.

This *Study Guide* shows you where to find each resource and describes how the components fit together. You might choose to mark-up this *Study Guide* to track your progress through the course.

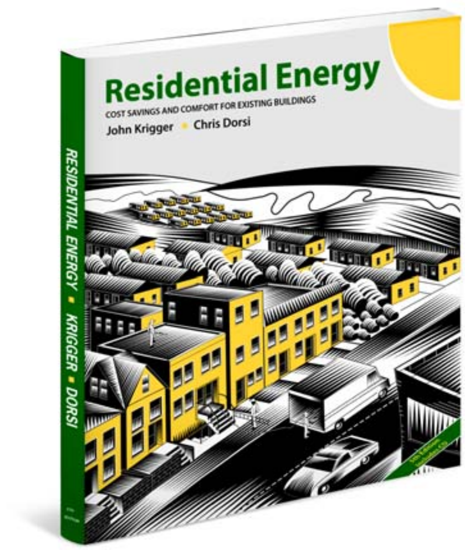
TEXTBOOKS, SLIDE SHOWS, AND OTHER RESOURCES

Your course will include reading assignments from the textbooks *Residential Energy* and the *Energy Auditor Field Guide*. Your instructor will project slide shows and videos in the classroom from the *Comprehensive Home Energy Curriculum (CHEC*). In the online Student Study Hall, you'll be able to view the *CHEC* slide shows and videos on your own, engage interactive lessons, and download and read publications from the Document Download Center.

Residential Energy: Cost Savings and Comfort for Existing Buildings

The textbook *Residential Energy* provides the scientific basis upon which your course is based. It illustrates the background and principles of building science, focusing on methods and materials that are in common use. *Residential Energy* doesn't contain step-by-step procedures. Those detailed protocols are presented in the *Energy Auditor Field Guide*.

Table of Contents: Residential Energy
Principles of Energy
Energy and the Building Shell
Air Leakage
Insulation
Windows and Doors
Heating
Lighting and Appliances
Cooling
Water Heating
Health and Safety
Appendices



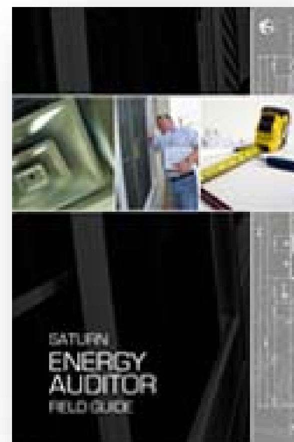
Residential Energy is divided into ten chapters that explore topics progressively from more general and theoretical to more specific and practical. The appendices alone are a great resource for energy specialists. Look to *Residential Energy* to learn how buildings are constructed and why they function as they do.

Saturn Energy Auditor Field Guide

The *Saturn Energy Auditor Field Guide* provides guidance for your field work. It describes the responsibilities that are assumed by the energy analyst, outlines time-tested audit procedures, and provides detailed procedures for pressure diagnostics, combustion analysis, and building shell assessment. It also includes client education protocols and health and safety guidelines.

Look to the *Energy Auditor Field Guide* to learn about step-by-step procedures for evaluating buildings and recommending improvements. It has a strong spiral binding so you can take it with you when doing field work.

Table of Contents: Energy Auditor Field Guide



Comprehensive Home Energy Curriculum (CHEC)

The *Comprehensive Home Energy Curriculum (CHEC)* includes hundreds of color slides that are illustrated with line drawings, photographs, charts, and tables. Your instructor may project *CHEC* slideshows in the classroom, or you may choose to view them online in the Student Study Hall.

The *CHEC* slide shows are divided into seven main divisions: Basic Building Science, Building Assessment Skills, Air Leakage Diagnostics, Heating and Cooling Systems, Building Shell, Durable Healthy Homes, and Water Heating and Baseload Measures. Its hypertext navigation system allows you to navigate among the slides very rapidly.

This *Student Workbook* includes note-taking sheets that are keyed to the slide shows in CHEC.

Topic Areas: Comprehensive Home Energy Curriculum
Basic Building Science
Building Assessment Skills
Air Leakage Diagnostics
Heating and Cooling Systems
Building Shell
Durable Healthy Homes
Water Heating and Baseload
RESNET and BPI Standards

STUDY GUIDE

Topic 1: Building Science

The building science principles presented within this topic provide a foundation for the remainder of the course, and include the most essential physical principles of building science.

Textbooks	Residential Energy Chapter 1: Principles of Energy • *What is Energy?* • *Energy Transformation and Heat Flow* • *Energy, Comfort, and Climate* • *Converting Energy for Home Use*	Energy Auditor Field Guide Chapter 7: Health and Safety • *Electrical Safety*
Online Resources	CHEC • *Temperature and Heat* • *Heat Loss and Gain* • *Air Pressure and Flow* • *Electric Power and Energy* • *Electrical Systems (optional)* Video • *Home Energy Outline* • *Building Science*	Lesson: Calculating Heat Loss *Introduces the calculation of conductive heat flow through a building section. Be sure to review the CHEC modules Temperature and Heat and Heat Loss and Gain before starting this lesson.*
	Document Download Center • *RESNET: Mortgage Industry National HERS Standards (MINHERS): Chapter 1* • *BPI: ANSI/BPI-1200-S-2015 Standard Practice for Basic Analysis of Buildings: Section 10*	
Learning Objectives	1. Learn why BTUs and kWh measure energy, not power. 2. Learn why BTUs/hr and kW measure power, not energy. 3. Learn how to convert kWh to BTU, and kW to BTU/hr. 4. Learn how to convert BTU to therms to decatherms. (100,000 BTU = 1 therm, 10 therms = 1 decatherm [dct]) 5. Learn how to convert natural gas volume to BTUs. (1 c.f. = approx. 1000 BTU) 6. Learn the heat content of fuel oil. (1 gal = approx. 140,000 BTU) 7. Learn how BTUs measure heat (1 BTU can raise the temperature of 1 lb. of water by 1°F) 8. Learn how to calculate heating degree-days for a location. ([65°F – avg. outdoor temp.] x # of days) 9. Learn how to convert Pascals to inches of water column (IWC). (1 IWC = 249 Pascals) 10. Understand thermal bridging and thermal breaks. 11. Understand how temperature difference (Delta-T or Delta-T) is the driving force for heat transmission. 12. Recognize the drivers of air movement in homes: stack effect, wind, and mechanical fans. 13. Understand the neutral pressure plane. 14. Learn about the types of internal heat gains.	

Topic 2: Building Assessment Skills

The focus of this topic is the energy audit. We'll also study utility bill analysis and computer auditing, and basic math. The math is important for energy bill analysis, building measurements, and load calculations.

Textbooks	Residential Energy Introduction • *Wise Energy Use* • *Energy and the Consumer* • *Energy-Efficiency Ratings of Buildings* Chapter 2: Energy and the Building Shell • *Building Construction* • *Building-Shell Heat Flow* • *Building Inspection and Diagnosis* Appendices • *Energy Related Formulas* • *Geometry* • *Analyzing Energy Costs*	Energy Auditor Field Guide Chapter 1: Energy Audits and Customer Relations • *What is an Energy Audit?* • *Understanding Energy Usage* • *The Work Scope and Contracts* • *Customer Relations*
Online Resources	CHEC • *Construction Basics* • *Energy Auditing* • *Technical Math Skills* • *Analyzing Consumption* Video • *Math Operations* • *Measuring a House*	Lesson: Area and Volume of Buildings *Calculations of irregular and complex shaped building areas and volumes.* *Review the CHEC modules Energy Auditing and Technical Math Skills before starting this exercise.*
	Document Download Center • *RESNET:HERS Standards of Practice: Pages 3-6: Purpose and Scope* • *RESNET: Rater Code of Ethics: Pages 1 & 2* • *RESNET: MINHERS: Appendix A: Onsite Inspection Procedures: Pages A-1 through A-10* • *BPI: ANSI/BPI-1200-S-2015 Standard Practice for Basic Analysis of Buildings: Section 10*	
Learning Objectives	1. Learn how to use an architect's scale. 2. Learn how to use the Pythagorean theorem to calculate the sides of a right triangle. ($a^2 + b^2 = c^2$). 3. Learn how to calculate heat flow through a building assembly (UxAxDelta-T) and seasonal heat consumption (UxAxHDD). 4. Learn how determine home orientation with a compass. 5. Learn how to calculate the perimeter, wall area, floor area, and conditioned volume of a building. 6. Learn to recognize foundation types: slab-on-grade, crawl space, basement, and walk-out basement. 7. Learn how to determine whether foundation is conditioned, indirectly conditioned, or unconditioned. 8. Learn how to measure above and below grade foundation wall surface areas for both level and sloped sites. 9. Learn how concrete slabs lose most of their heat in cold climates through the edges. 10. Learn to recognize building construction assemblies: wall, floor, ceiling, and roof systems. 11. Learn how to measure window and door dimensions at the rough opening. 12. Learn how to calculate the R-value of building assemblies and doors. 13. Learn how to determine orientation, shading, U-factor and SHGC of windows and skylights. 14. Learn how to calculate roof pitch. 15. Learn how to assess the type, compass orientation, and aperture area of glazing in greenhouses and solariums. 16. Learn about the assembly of structural insulated panels (SIPS) and critical details such as sealing the joints in panels.	

Topic 3: Diagnosing Air Leakage

Air leakage is a fundamental but complex housing problem that determines energy waste, indoor air quality, and building durability. Within this topic you'll learn how to use a blower door to assess air leakage through the building enclosure. We'll also address guidelines for evaluating potential energy savings, and principles for evaluating natural and mechanical ventilation strategies

If you have access to a blower door, this would be a good time to do some experimentation in the lab or in actual homes.

Textbooks	Residential Energy Chapter 3: Air Leakage • *Air Sealing Principles* • *Blower Door Testing* • *Finding Air Leaks* • *Construction Flaws and Air Leakage* • *Air-Sealing Methods and Materials*	Energy Auditor Field Guide Chapter 3: Diagnosing Shell and Duct Insulation • *Air Leakage Problems and Solutions* • *Air Leakage Testing* • *Discovering Air-Leakage Trouble Spots*
Online Resources	CHEC • *Blower-Door Basics* • *DG3-Manometer (optional)* • *DG-700 Manometer* • *Duct Blower Testing* Video • *Blower Door Testing, Prep, and Setup*	Lesson: Converting Air Flow to Air Change *Converting blower door readings (CFM_{50}) into air change measurements (in ACH_{50}). Review the CHEC modules Blower Door Basics before attempting this lesson.*
	Document Download Center • *RESNET: HERS Standards of Practice: Page 9: Air leakage* • *BPI: ANSI/BPI-1200-S-2015 Standard Practice for Basic Analysis of Buildings: Section 10*	
Learning Objectives	1. Learn how to use a blower door. 2. Learn the difference between the two primary blower door measurements: house pressure and airflow. 3. Learn how to configure a home in the typical heating or cooling mode for a blower door test. 4. Learn how and when to use blower door flow rings. 5. Understand why and how to conduct a blower door depressurization test. 6. Learn how to convert among CFM_{50}, ACH_{50}, and ACH_n. (ACH_{50}: CFM_{50} x 60 ÷ volume) (ACH_n: CFM_{50} x 60 ÷ volume x n) 7. Identify the typical locations of significant air leaks in a home. 8. Learn how to perform a 25-pascal duct blower test, including both total leakage and leakage-to-outdoors. 9. Learn where in the ducts to place the pressure probe when testing duct leakage. 10. Understand how to specify whole-building ventilation (ASHRAE62.2-2013). 11. Understand how to use a pressure pan to roughly determine severity and location of air leaks during a blower door test.	

Topic 4: Heating and Cooling Systems

Heating and cooling systems are the most complicated equipment in most homes. They also consume the majority of energy in many climates. This topic illustrates the range of equipment used, describes the operation of each, and provides guidance for assessing the most critical operating parameters. Assessment of ducts and airflow is included here.

If you have access to combustion testing equipment, this would be a good time to perform some actual combustion tests.

<table>
<tr><td>Textbooks</td><td>Residential Energy
Chapter 6: Heating
• Combustion Heating Basics
• Combustion Safety and Efficiency
• Heating Comfort Controls
• Forced-Air Distribution Systems
• New Energy-Efficient Combustion Furnaces and Boilers
• Combustion Room Heaters
• Electric Heat
Chapter 8: Cooling
• Summer Comfort Principles
• Cooling with Ventilation
• Air Movement
• Air Conditioners</td><td>Energy Auditor Field Guide
Chapter. 4: Evaluating Heating and Cooling Systems
• Testing Gas Furnaces and Boilers
• Inspecting Gas Combustion Systems
• Oil-Burner Safety and Efficiency Service
• Measuring Duct Air Leakage
• Hot-Water Space-Heating and Distribution
• Steam Heating and Distribution
• Evaluating Central A/C Systems</td></tr>
<tr><td rowspan="2">Online Resources</td><td>CHEC
• Identifying Gas Furnaces
• Combustion Safety
• AC and Heat Pump Equipment
• Duct Systems</td><td>Video
• Combustion Safety, Venting, and Efficiency</td></tr>
<tr><td colspan="2">Document Download Center
• RESNET: HERS Standards of Practice: Page 9 & 10: Heating and Cooling
• RESNET: MINHERS Appendix A: Onsite Inspection Procedures: A-28-34: Heating and Cooling Equipment
• BPI: ANSI/BPI-1200-S-2015 Standard Practice for Basic Analysis of Buildings: Section 7</td></tr>
<tr><td>Learning Objectives</td><td colspan="2">1. Learn to identify the types of heating and cooling systems.
2. Learn to identify the types of heating and cooling distribution systems.
3. Learn to identify the types of fuel used by heating systems.
4. Learn to identify the input rating of heating systems in BTUs per hour (BTUH).
5. Learn why output ÷ input = efficiency.
6. Learn the difference between combustion efficiency, AFUE, and delivery efficiency.
7. Learn why output rating is the number of BTUs delivered by the heating system.
8. Learn how to identify both standard thermostat and programmable thermostats.
9. Learn why each ton of AC capacity requires an air-handler airflow of around 400 cubic feet per minute (CFM).
10. Recognize the four main problems with heat pumps and air conditioners: over-sizing, incorrect charge, unbalanced airflow, and duct leakage.
11. Recognize the most effective ways to improve HVAC system efficiency: locating ducts inside conditioned space, designing ducts to maximize airflow, minimizing constrictions during installation, moving ducts to interior walls to shorten duct runs.
12. Learn how to calculate the R-value of distribution system insulation.</td></tr>
</table>

Topic 5: The Building Shell

Within this topic you'll learn how improving the building shell is the key to comfort and seasonal energy savings. Insulation and air sealing are the primary topics here, and a strong case is made for optimizing both measures. Window repair and replacement are also included here.Within this topic you'll learn how improving the building shell is the key to comfort and seasonal energy savings. Insulation and air sealing are the primary topics here, and a strong case is made for optimizing both measures. Window repair and replacement are also included here.

Textbooks	Residential Energy Chapter 3: Air Leakage • *Air Sealing Principles* • *Finding Air Leaks* • *Construction Flaws and Air Leakage* • *Air Sealing Methods and Materials* Chapter 4: Insulation • *Insulation Characteristics* • *Insulation Types* • *Facings and Barriers* • *Retrofitting Insulation* • *Insulation in New Construction* Chapter 5: Windows and Doors • *Window Characteristics* • *Window Structure* • *Selecting New Windows*	Residential Energy Appendices • *Materials/Building Assembly R-values* • *Characteristics of Air Sealing Materials* • *Insulation Characteristics* Energy Auditor Field Guide Chapter 2: Evaluating Insulation • *Evaluating Attic or Roof Insulation* • *Evaluating Wall Insulation* Chapter 6: Windows, Doors, and Exterior Insulation • *Window Replacement* • *Exterior Insulation, Siding, and Windows*
Online Resources	CHEC • *Air Barrier Basics* • *Fibrous Insulation* • *Foam Insulation* • *Floor and Foundation Insulation* • *Energy Efficient Windows* • *Low Energy Cooling (optional)*	Video • *Home Construction Components* • *Defining the Thermal Boundary* • *Measurements and Drawings* • *Windows* Lesson: Calculating R-Value of Insulation *This lesson gives you practice in calculating the R-value of common insulation materials.*
	Document Download Center RESNET: HERS Standards of Practice: Pages 6-9 RESNET: MINHERS Appendix A: Onsite Inspection Procedures • *A-6 & 7: Floor, crawlspace, and slab insulation* • *A-9 to15: Wall insulation* • *A-19 to 21: Attic insulation* • *A-21 to 25: Doors and windows* • *BPI: ANSI/BPI-1200-S-2015 Standard Practice for Basic Analysis of Buildings: Section 10*	
Learning Objectives	1. Learn how to locate a building's thermal boundary. 2. Learn how to determine the type, thickness, and R-value of insulation of floor, walls, ceilings, roofs, perimeter slabs. 3. Learn how to identify rim joists, and evaluate rim-joist insulation type, thickness, and R-value. 4. Learn how to identify the three grades of insulation and the percentage of voids allowable for each.	

Topic 6: Durable Healthy Homes

Energy improvements must be planned and carried out in a way that protects the health and safety of both customers and workers. Moisture management, ventilation equipment, and pollutant source-control are the primary topics for this week.Energy improvements must be planned and carried out in a way that protects the health and safety of both customers and workers. Moisture management, ventilation equipment, and pollutant source-control are the primary topics for this week.

<table>
<tr><td>Textbooks</td><td>Residential Energy
Chapter 10: Health and Safety
• Indoor Pollutants
• Moisture Management
• Whole House Mechanical Ventilation
• Air Conditioners and Dehumidifiers
• Pollutant Control Strategies</td><td>Energy Auditor Field Guide
Chapter 7: Health and Safety
• Evaluating Home Ventilation Levels
• Whole-House Ventilation Systems</td></tr>
<tr><td rowspan="2">Online Resources</td><td>CHEC Modules
• Indoor Air Pollutants
• Basic Moisture Management
• Basic Mechanical Ventilation
• ASHRAE 62.2-2013</td><td>Video
• Exhaust Ventilation Systems</td></tr>
<tr><td colspan="2">Document Download Center
• RESNET: None
• BPI: ANSI/BPI-1200-S-2015 Standard Practice for Basic Analysis of Buildings: Sections 8 and 9</td></tr>
<tr><td>Learning Objectives</td><td colspan="2">1. Learn how to perform the calculations for AHSRAE Standards 62-1989 and 62.2-2007.
2. Learn about carbon monoxide (CO), a poisonous product of incomplete combustion.
3. Learn about carbon dioxide (CO^2), a normal by-product of combustion that contributes to climate change.
4. Learn about the four mechanisms of moisture flow in homes: bulk moisture flow, capillary action, diffusion, and infiltration.
5. Learn about permeance, the rate of water-vapor diffusion through a material.
6. Learn why condensation occurs at the coldest surfaces in a home.
7. Learn why a back drafting combustion appliance could contribute to moisture problems and condensation.
8. Learn why un-vented heaters or fireplaces are a health hazard.
9. Learn how radon enters homes.
10. Learn why asbestos pipe and duct insulation is a health hazard.</td></tr>
</table>

Topic 7: Water Heating and Baseload

Water heating, lighting, refrigeration, and other baseload should never be overlooked in a comprehensive building performance project. In mild climates, they may consume more energy than heating and cooling combined. Appliance replacement in particular is increasingly attractive as technologically advanced equipment comes to market.Water heating, lighting, refrigeration, and other baseload should never be overlooked in a comprehensive building performance project. In mild climates, they may consume more energy than heating and cooling combined. Appliance replacement in particular is increasingly attractive as technologically advanced equipment comes to market.

Textbooks	Residential Energy Chapter 7: Lighting and Appliances • *Lighting* • *Appliances* Chapter 9: Water Heating • *Water Heating Energy Use* • *Storage Water Heaters* • *Alternative Water Heaters* Appendices • *Household Appliance Electric Usage*	Energy Auditor Field Guide Chapter 5: Baseload Measures • *Water Heating Energy Savings* • *Water Heater Replacement* • *Lighting Measures*
Online Resources	CHEC Modules • *Water Heating Basics* • *Residential Lighting* • *Residential Refrigerators*	Lesson: Savings from Lighting Retrofits *Calculating the consumption of lights in both electrical energy and dollars. Review the CHEC modules Electric Power and Energy and Residential Lighting before you starting this lesson.*
	Document Download Center • *RESNET: HERS Standards of Practice: Page 10* • *RESNET: MINHERS Appendix A: Onsite Inspection Procedures: Pages A-35 to 39* • *BPI: ANSI/BPI-1200-S-2015 Standard Practice for Basic Analysis of Buildings: Sections 11, 12, and 13.*	
Learning Objectives	1. Learn how to determine the energy source, location, type, capacity, and energy factor for water heating equipment. 2. Learn how to identify the presence, condition, and R-value of additional tank insulation and water pipe insulation. 3. Learn how to identify types of solar water heating system. 4. Learn how to determine the area, orientation, tilt, and efficiency of solar water heating equipment.	

Topic 8: RESNET and BPI Standards

Within this topic we'll study the HERS Rater and Building Analyst Certifications and the roles of RESNET and the Building Performance Institute.

If you do not plan to take the BPI or RESNET exams, you may skip this topic.

<table>
<tr><td>Textbooks</td><td>Residential Energy
• None</td><td>Energy Auditor Field Guide
• None</td></tr>
<tr><td rowspan="2">Online Resources</td><td colspan="2">CHEC (RESNET)
• HERS Rater Certification
• Energy Mortgages
CHEC (BPI)
• BPI Building Analyst Certification</td></tr>
<tr><td colspan="2">Document Download Center
• RESNET: Mortgage Industry National HERS Standards (MINHERS)
• RESNET: Rater Code of Ethics
• RESNET: Standard Disclosure Form
• RESNET: Procedure for Certifying Residential Energy Efficiency Tax Credits
• RESNET: Procedures for Verifying IECC Performance Path
• BPI: Field Evaluation Requirements</td></tr>
<tr><td>RESNET Learning Objectives</td><td colspan="2">1. Learn the difference between a projected rating and a confirmed rating.
2. Learn how a HERS Index accounts for heating, cooling, water heating, lighting, appliances, and onsite power production.
3. Understand the standards for the Rating Report (MINHERS 303.3).
4. Learn how to prepare a financial interest disclosure form.
5. Learn how the HERS Index relates a Rated Home to the Reference Home.
6. Learn how a HERS Rating does not constitute an inspection of any feature of the home other than its energy features, it does not imply any warranty of energy cost or savings, it does not include engineering services or design services.
7. Learn that a Rater is not required to inspect or test detached structures or move personal property.
8. Learn that a Rater is not required to dismantle any system or component except where explicitly required by standards.
9. Learn that a Rater can select default values for features that aren't present or available for inspection.
10. Learn that the maximum rating for an Energy Star home is 80 in a Northern climate is 80, and 85 in a Southern climate.
11. Understand the process of reporting rater violations.
12. Learn how a Rating can include trade-offs between heating and cooling efficiency ratings, design, and installation recommendations.
13. Learn how to estimate duct system leakage based on location and characteristics using the default values from MINHERS Table 303.4.1(3).
14. Identify the duct leakage standard as ASHRAE 152-04.
15. Learn why you can skip a duct air tightness test when the ducts and air handler are visible and inside the thermal boundary.
16. Learn how Raters must verify all but 4 items on the thermal bypass checklist, allowing the builder self-verify up to 4 items.
17. Learn why insulation should have an air barrier on all 6 sides, except sloped vented attic roof assemblies.
18. Learn why wall cavities behind tubs and showers must have an air barrier of polyethylene or spray-foam insulation.
19. Understand the performance factors for the HERS Reference Home (MINHERS 303.4), including: heating and cooling efficiencies, component heat transfer, dishwasher energy use, and natural air leakage.
20. Recognize the differences between an Energy Improvement Mortgage (EIM), Energy Efficient Mortgage (EEM), and a standard mortgage.
21. Learn how an Energy Efficient Mortgage (EEM) uses a Rating to calculate energy savings that can qualify the borrower for a larger loan.</td></tr>
<tr><td>BPI Learning Objectives</td><td colspan="2">1. Become familiar with the history of BPI and their role in establishing small homes certifications.
2. Study the knowledge areas of a Building Analyst and what a Building Analyst does and does not do.
3. Learn about the path to BPI Building Analyst certification, continuing education, and recertification.</td></tr>
</table>

WORKSHEETS

BASIC MATH OPERATIONS

The work of an energy auditor requires the use of several basic math operations. These are used to determine the dimensions of buildings, analyze utility consumption, determine the correct size of equipment, predict the savings from efficiency upgrades, estimate the cost of materials, and many other tasks.

The best way to improve your math skills is through practice. Complete the exercises below, using help from your instructor if necessary. When you have completed the exercises, consider creating your own exercises by applying the calculations to your own home or another building.

For all of these exercises, refer to "*Appendix: Geometry*" in *Residential Energy.*

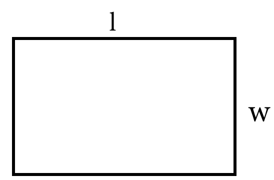
Calculating Perimeter, Area, and Volume

Calculating a home's perimeter, area, and volume are the most basic tasks needed to describe a home for any type of energy analysis or estimate of retrofit costs.

BUILDING PERIMETER

The perimeter (P) is the quantity of linear feet around the home, calculated by adding twice the width (w) to twice the length (l).

$$P = 2l + 2w$$



BUILDING AREA

Areas (A) of rectangles are calculated by multiplying the length times the width. This would be useful for calculating the floor area of a building.

$$Af = l \infty w$$

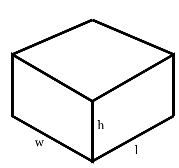
The area of exterior walls is calculated by multiplying the perimeter of the wall times the wall height (h).

$$Aw = P \infty h$$

BUILDING VOLUME

Volume (V) is length multiplied by width, multiplied by height.

$$V = l \infty w \infty h$$



Exercise Calculate the perimeter, floor area, wall area, and volume of the homes described in the table.

Length (l) (ft.)	Width (w) (ft.)	Height (h) (ft.)	Perimeter (P) (ft.)	Floor Area (Af) (sq. ft.)	Wall Area (Aw) (sq. ft.)	Volume (V) (cubic feet)
54	28	11	164	1512	1804	16,632
62	34	9	192	2108	1728	18,972
40	28	8				
70	16	7.5				
66	38	8.5				
80	45	10				
42	32	8				

Advanced Exercises These exercises are based upon the home shown in the drawings that follow.

1. What is the perimeter of the conditioned space of the home in linear feet? Don't count the perimeters of the unheated areas: garage, porch, and entry.

2. What is the floor area of the conditioned space of the home?

3. What is the home's exterior wall area if the exterior wall height is 12 feet?

4. What is the home's conditioned volume, if the interior ceiling height is 9.5 feet?

5. If one bag of attic insulation insulates 30 square feet to a level of R-24, how many bags will be required to insulate this home's attic to R-24?

6. How many cubic feet per minute (CFM) of fan airflow would be required to produce 1 air change per hour (1 ACH)?

7. What is the total window area in square feet? (Either change inches to feet to the nearest tenth of a foot, or multiply inches together and then divide by 144 square inches per square foot). On the drawing, you can enter the square footage of each type of window in the column labeled ft^2. Note that most of the window units have multiple panes.

8. What percentage of the gross wall area is the window area?

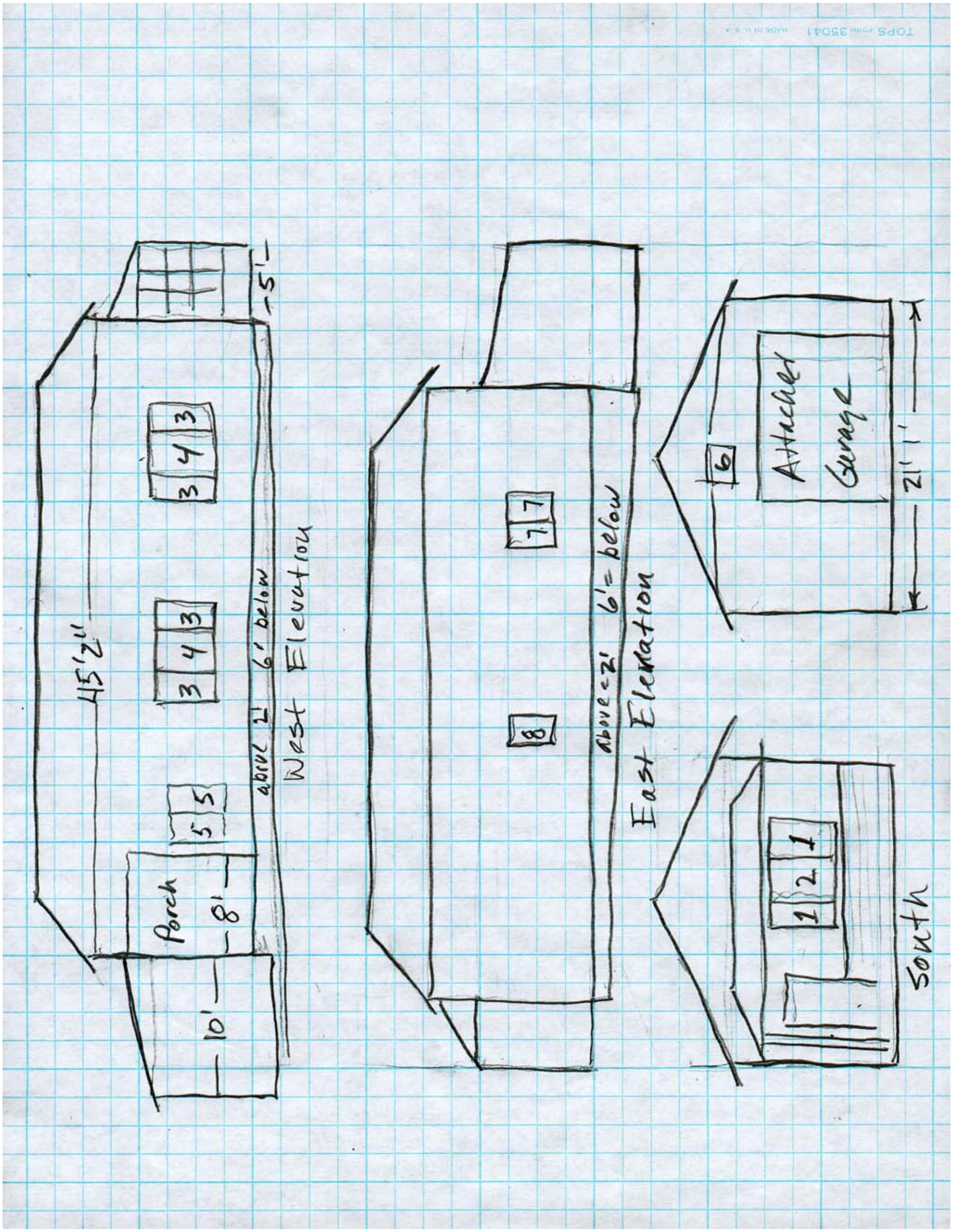
9. About how many 24-pound bags of insulation would be needed to insulate the home's empty 2-by-4 wall cavities to a density of 3.5 pounds per cubic foot? Hint: subtract window area from wall area, calculate the wall's volume, then multiply by 3.5. Assume a framing factor of 20%.

10. What would it cost to install 2 inches of foam insulation and siding on the exterior walls if the foam costs $0.85 per square foot installed and the siding costs $3.60 per square foot installed?

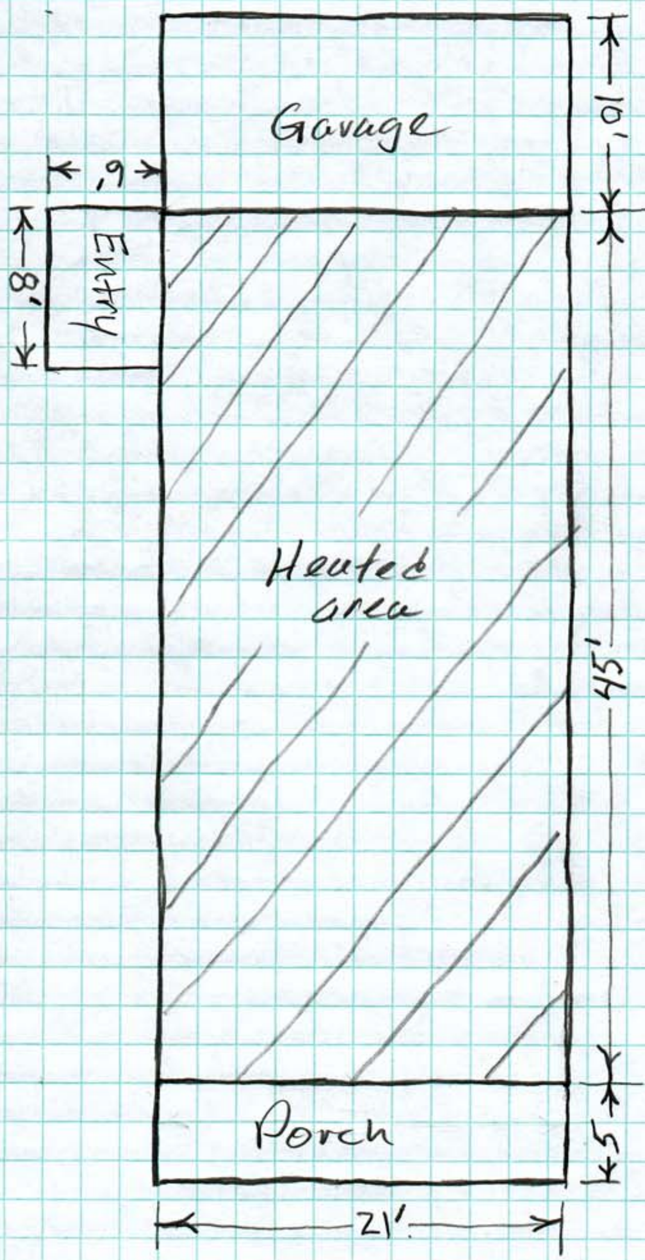
11. How many kilowatt-hours of electricity per square foot does the home consume annually if its total annual electricity usage is 11,200 kWh.

12. If an energy program requires duct leakage (CFM_{25}) to be limited to 5% of the floor area, what would be the acceptable duct-leakage for this home?

House Plans for Advanced Exercise



Floor Plan



Windows

#	Qty	W x H	ft²
1	2	26 x 47	
2	1	34 x 47	
3	4	26 x 57	
4	2	34 x 57	
5	2	26 x 47	
6	1	20 x 20	
7	2	26 x 47	
8	1	16 x 36	

L = 45'

W = 21'

H = 9.5'

Garage, porch and entry are unheated

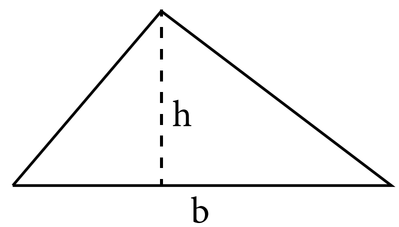
Calculating Area and Volume of Triangles

You'll need to know how to calculate the area and volume of various types of triangles when measuring buildings. The roof structure of most buildings, for example, includes a slope that creates triangles at the gable ends, within the attic, and at vaulted ceilings within the living space. The operations shown here will be used for calculating ventilation requirements, determining the surface area of the building shell or thermal boundary, estimating the amount of insulation required to fill a sloped cavity, and many other auditing tasks.

Finding the Area of a Triangle

The area (A) of a triangle is equal to one-half the base (b) times the height (h). In the case of a home's gable-end, the base would be the horizontal side (running left to right), while the height is the distance from the base to the top of the triangle (running from the base toward the peak of the roof).

$$0.5 \infty b \infty h = A$$



EXERCISE

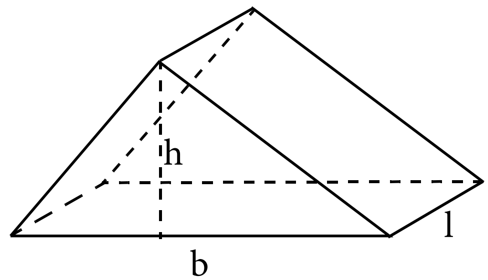
Calculate the area of triangles described in the table.

Base	Height	Area
22	7	77
41	9	
4	14	
17	4	
38	11	
28	7	

Finding the Volume of a Triangular Prism

The volume (V) of a vaulted ceiling has the shape of a triangular prism. A triangular prism is an extension of the triangle, just as a rectangular prism is an extension of a rectangle. The calculation for the volume of triangular vault is simply the triangle's end-area multiplied by the length of the vault.

$$0.5 \infty b \infty h \infty l = V$$



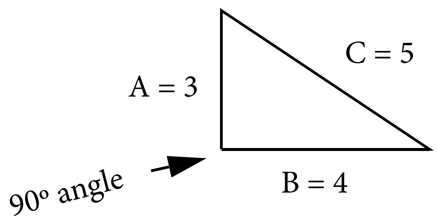
EXERCISE

Use the formula above to find the volume of triangular prisms with the dimensions shown in the following table.

Base	Height	Length	Volume
42	9	76	14,364
36	4	51	
24	3.5	42	
52	7.5	82	
18	2.5	36	
28	12	60	

Finding the Unknown Side of a Right Triangle

If you know the two shorter sides of a right triangle, you can find the longer side (hypotenuse) by the well-known Pythagorean Theorem: $A^2 + B^2 = C^2$. A right triangle has a 90° angle in one corner.



$3^2 + 4^2 = 5^2$

$9 + 16 = 25$

There are three forms of the equation, depending on which of the sides — A, B, or C — you are solving for.

$$C = \sqrt{A^2 + B^2} \qquad A = \sqrt{C^2 - B^2} \qquad B = \sqrt{C^2 - A^2}$$

Exercise Use the above equations to calculate the missing sides in the examples below. Once completed, what do you see in common with all these examples?

Side A	Side B	Side C
3	4	5
6	8	
9		15
	16	20
27	36	
291		485

WORKING WITH R-VALUES AND U-FACTORS

R-values and U-factors are used to compare building materials and building assemblies to one another. The thermal resistance of insulation of all types is usually measured in R-value. The thermal resistance of window assemblies is usually measured n U-factor.

The heat flow through and assembly such as a wall or ceiling is measured in U-factor. This may appear more difficult than working with R-values

CONVERTING BETWEEN R-VALUE AND U-FACTOR

A material's R-value (thermal resistance) and U-factor (thermal transmittance) have a reciprocal relationship. A reciprocal relationship means that R = 1/U and U = 1/R. R and U are reciprocals of each other. For example, if R is 4, then U is 1/4 or 0.25.

On a simple calculator, there are usually two ways to calculate a reciprocal. Press these keys on a simple calculator: 1 ÷ 4 =. You should get 0.25. Now try this on a simple calculator: 4 ÷ =. Again, you should get 0.25, the reciprocal of 4.

On a scientific calculator, use the 1/x key or x-1 key. Press these keys on a scientific calculator: 4 1/x = or 4 x-1 =. In each case, you should get 0.25.

Exercise In the table that follows, convert R to U and U to R using either a simple calculator or a scientific calculator.

R-value	U-factor	U-factor	R-value
10	0.10	0.33	3
2		0.091	
40		0.033	
5		1.0	
25		0.05	

ADDING R-VALUES OF A BUILDING ASSEMBLY TO FIND R AND U

Many building assemblies have layers of materials. The R-values of the individual layers can be added to find a total R-value of the building assembly. After that, you can find the U-factor by taking the reciprocal of this total R-value, as in the previous exercise.

Exercise In the following table, add the R-values together to get a total R-value and convert the total R-value to a U-factor.

R1	R2	R3	R4	R5	R6	Total R-value	U-factor
0.17	0.81	0.60	11.0	0.45	0.68	13.71	0.072
0.17	0.35	7.8	2.4	0.50	0.68		
0.40	0.88	16	0.45	3.6	0.68		
0.17	0.35	8	21	0.45	0.68		
0.17	3.7	8	0.45	0.68	0.68		

AREA-WEIGHTED AVERAGE U-FACTOR

A building assembly like a wall may have two or more parallel paths of heat flow. For example, a frame wall has two paths.

1. The cavity in between the studs and plates, which may or may not contain insulation
2. Studs, plates, headers and other solid wood sections

The U-factor of a frame wall is the area-weighted average of these two paths. To calculate the area-weighted average, multiply the decimal of one path times its U-factor and do the same for the other path. Then add the two products together to get the area-weighted U-factor (Ua-w).

$$Ua - w = (A1 \infty U1) + (A2 \infty U2)$$

If you have a scientific calculator, you can use the parentheses keys to calculate the area-weighted average U-factor in one step. Simply substitute the numbers from the following table into the formula, putting the parentheses where they belong. If you have a simple calculator, just calculate the answer in two steps: first perform the two multiplication problems, then add the two products together.

Exercise Fill in the blanks below with the area-weighted average U-factor and then take the reciprocal of that number to find area-weighted R-value.

A1	U1	A2	U2	Ua-w	Ra-w
0.22	0.147	0.78	0.0833	0.0973	10.3
0.17	0.095	0.83	0.055		
0.29	0.138	0.71	0.142		
0.13	0.063	0.87	0.0312		
0.15	0.112	0.85	0.0915		

CALCULATING DESIGN HEAT LOSS

U-factors are used to calculate design heat load (***Q***). This is the hourly heat loss at design outdoor winter temperature, and it describes the output needed by a heating device to keep the home at a comfortable temperature. To calculate design heat loss (***Q***), the U-factor is multiplied times area (***A***) times the design temperature difference (***Delta-T***). The units of heat load (***Q***) are BTUs per hour (BTUH). See *"Calculating Heat Load" in Residential Energy.*

$$U \infty A \infty \Delta T = Q$$

U (U-factor)	A (area in square feet)	Delta-T (temperature difference in degrees F)	Q (heat loss in BTUH)
0.08	1400	60	6720
0.98	320	55	
0.05	960	50	
0.125	2100	45	
0.4	530	40	

WALL R-VALUES, U-FACTORS, AND AREA-WEIGHTED AVERAGES

In this exercise you will calculate the clear wall R-value, the whole-wall R-value, the U-factor and the design heat loss of 6 wall sections and enter the answers in the following table. Start this exercise by studying the table *"R-Value and U-Factor Calculation" in Chapter 2 of Residential Energy.*

1. Find the R-values of the walls' components in *"Appendix: Materials/Building Assembly R-Values" in Residential Energy.*
2. For each wall described, add the R-values of the insulated path of the wall together to get a total R-value and then calculate the U-factor from the equation: R = 1/U.
3. Then add the R-values for the framed path of the wall and calculate the U-factor. Be sure to include the interior and exterior air films as shown in the *Residential Energy* example.
4. Finally, calculate the area-weighted average U-factor for the wall and also the area-weighted R-value. (R = 1/U)

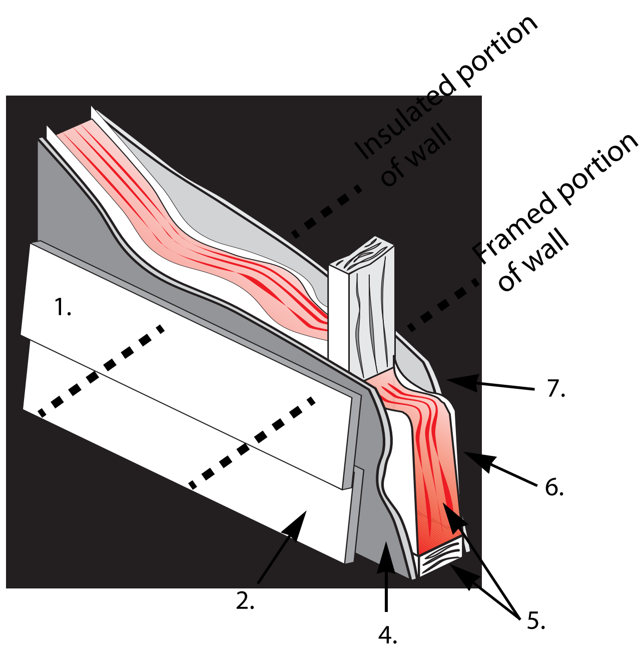
For both the insulated path of the wall and the framed path of the wall, calculate the following.

1. R total = R1 + R2 + R3 etc. for both insulated part and framed path
2. U-factor = 1/Rtotal
3. Area-weighted average U-factor = (A1 X U1) + (A2 X U2)
4. Area-weighted average R-value = 1/Uaverage

Advanced Exercise Use the details from the list below and enter the necessary data into the table that follows. R-values can be found in *"Appendix: Materials/Building Assembly R-Values" of Residential Energy.*

1. Work Exercise 1 with 2x6 walls filled with 5.5-inch medium density fiberglass batts.
2. Work Exercise 2 with 2x4 walls filled with 3.5 inches of high-density polyurethane.
3. Work Exercise 3 with 2x6 walls filled with 5.5-inch medium density fiberglass batts and add 2 inches of expanded polystyrene foam sheathing between the siding and OSB.
4. Calculate the heat loss (***Q***) for each of these three examples assuming a wall area of 2100 square feet and a design Delta-T of 50° F.

Wall Component	Exercise 1		Exercise 2		Exercise 3	
	Insu-lated path	Framing path *2x6 studs*	Insulated path	Framing path *2x4 studs*	Insulated path	Framing path *2x6 studs*
1. Outside air film	0.17	0.17	0.17	0.17	0.17	0.17
2. Lapped wood siding	0.81	0.81	0.81	0.81	0.81	0.81
3. 2-inch EPS foam						
4. OSB sheathing ($^1/_2$")	0.80	0.80	0.80	0.80	0.80	0.80
5. Framing or insulation						
6. Gypsum wall board ($^1/_2$")	0.45	0.45	0.45	0.45	0.45	0.45
7. Inside air film	0.68	0.68	0.68	0.68	0.68	0.68
R total						
U-factor						
Framing factor	0.80	0.20	0.75	0.25	0.82	0.18
Area-Weighted U-Factor						
Whole Wall U-Factor						
U x A x Delta-T						



Heating Degree Days (HDDs) & Temperature Difference (Delta-T)

Energy auditors must have a good grasp of heat flow. Temperature difference is the driving force for heat transmission. The sizes of heating equipment and predictions of heating energy consumption are based on indoor-outdoor temperature differences. Heating degree days (HDD) is a form of accumulated temperature difference, used to predict annual heating energy consumption. HDD is derived from historical weather data.

Heating Degree Days (HDDs)

Heating degree days (HDDs) are degrees of temperature difference accumulated over a period of time, typically one year. Weather services track the HDDs by averaging the daily high temperature and low temperature and subtracting that average temperature from the 65°F balance point. For example, if the low temperature is 16°F and the high temperature is 34°F, the average is (16 + 34) ÷ 2 = 20°F. Subtract 20°F from 65°F to get 45°F, which is the number of HDDs that accumulated during that particular day.

Exercise The following table gives the daily high and low temperatures. Compute the average temperature and the HDDs.

High Temp. °F	Low Temp. °F	Average Temp. °F	Balance Point °F	HDDs
45	11	28	65	37
33	6		65	
40	22		65	
10	–10		65	
5	–13		65	
47	21		65	
21	7		65	
16	6		65	

TEMPERATURE DIFFERENCES (DELTA-T)

The temperature difference is simply one temperature subtracted from another. For example the daily temperature difference is simply the difference between the high and the low temperatures. If the high temperature on a particular day is 90°F and the low temperature is 60°F the daily temperature difference is 90 – 60 or 30°F.

DESIGN TEMPERATURE

The design temperature is the outdoor temperature that a heating system is designed to cope with. This is the result of accumulated historical weather data. The winter design temperature, for example, for both Flagstaff Arizona and Indianapolis Indiana is 0°F. See "*Appendix: Climatic Data for U.S. Cities*" in *Residential Energy* for Winter *Design Temperature* data.

In sizing heating and cooling equipment, you must first determine the desired temperature in the conditioned space. For the heating season, the temperature used for reference (the balance point temperature) is usually 65°F. Subtracting the outdoor design temperature from the reference temperature gives the design temperature difference. See "*Calculating Heating Load*" and "*Calculating Cooling Load*" in *Residential Energy* for more information.

If you live in Flagstaff or Indianapolis, subtract the winter design temperature of 0°F from the 65°F reference or balance point, you get a 65° F design temperature difference (Delta-T). This temperature difference is the driving force for heat transmission.

Exercise Record the winter design temperature data into the following table and then calculate the design Delta-T.

City	Design Temp. °F	Balance Point °F	Design Delta-T
Albany, NY	–5	65	70°F
Sacramento, CA		65	
Boise, ID		65	
Greensboro, NC		65	
Bismarck, ND		65	
Huntington, WV		65	
Your city		65	

Predicting Annual Heating Consumption

The purpose of this exercise is to compare the BTU consumption of an average home in a wide variety of climates. You can predict annual heating consumption using heating degree days (HDDs), the surface area of the thermal boundary, and a rough approximation of a typical area-weighted average U-factor for the whole building (thermal boundary). The formula for this calculation is as follows.

$$U \infty A \infty HDD \infty 24 = Q$$

U = U-factor, average for the thermal boundary

A = Surface area of the thermal boundary

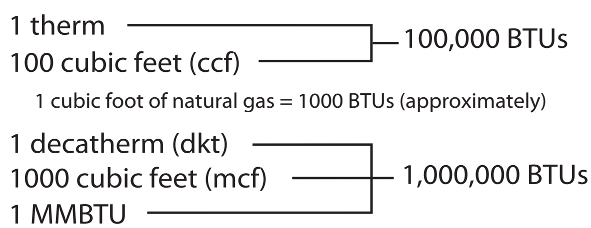
HDD = the number of heating degree days annually for the location (See "*Appendix: Climatic Data for U.S. Cities*" in *Residential Energy*)

24 hours per day is used to convert degree-days to degree-hours

Q = BTUs

The product of this calculation (***Q***) is the number of BTUs consumed per year through the described building section.

Natural gas, a common heating fuel, is usually sold by the cubic foot (1000 BTU), therm (100,000 BTU), or decatherm (1,000,000 BTU).



Exercise This example is a typical North American home. We will calculate the heating consumption per year through the thermal boundary. For this simplified calculation, we ignore heat loss through doors and windows, and the effects of infiltration.

Floor area = 2000 sq. ft.

Ceiling area = 2000 sq. ft.

Wall area = 2000 sq. ft.

Total area of thermal boundary = 6000 sq. ft.

In this example, the average R-value of these components is taken to be R-11, with perhaps R-11 in the walls, R-19 in the ceiling, and R-2 in the floors. This R-11 equals a U-factor of 0.091 (1 ÷ 11 = 0.091).

Calculate the annual consumption for this typical home by multiplying the numbers across the rows. You can derive the HDD data from "*Appendix: Climatic Data for U.S. Cities*" in *Residential Energy*. The product you calculate will be in BTUs. Divide that total by one million (1,000,000) to convert to decatherms.

City	U	A	HDD	hrs/day	BTUs	Decatherms or MMBTU
Wilmington, DE	0.091	6000	4888	24	64,052,352	64.0
Abilene, TX	0.091	6000		24		
Eugene, OR	0.091	6000		24		
Lincoln, NE	0.091	6000		24		
Caribou, ME	0.091	6000		24		
Pensacola, FL	0.091	6000		24		
Fairbanks, AK	0.091	6000		24		
Chicago, IL	0.091	6000		24		

Calculating Whole-Building Ventilation

Understanding ventilation is very important for energy auditors and contractors because air-sealing, and in some cases insulation, typically reduces the natural ventilation rate in homes. We use ASHRAE Standard 62.2-2013 to calculate the minimum whole-building ventilation rate.

ASHRAE 62.2-2013

To calculate the ASHRAE 62.2-2013 required whole-building ventilation rate, you can use a formula or table. Refer to the lesson for more information about the standard like infiltration credits and local ventilation.

FORMULA EXERCISE

Formula:

$$Q_{tot}(CFM) = 0.03A_{floor} + 7.5(N_{br} + 1)$$

Example

Fan Airflow CFM = 0.03(2025) + 7.5(3 + 1)

91 CFM: Required fan airflow

Q_{tot}**(CFM)** = minimum ventilation requirement in cubic feet per minute

N_{br} = number of bedrooms

A_{floor} = conditioned floor area of the home

Use the formula above to determine the ventilation fan CFM for each of the homes characterized in the rows, and enter the result into the third column.

Floor area (A_{floor})	Bedrooms (N_{br})	Fan CFM
1870	4	94
2130	3	
3480	7	
2130	8	
1200	2	
970	1	

TABLE EXERCISE

Floor Area (ft^2)	Number of Bedrooms				
	1	2	3	4	5
<500	30	38	45	53	60
501–1000	45	53	60	68	75
1001–1500	60	68	75	83	90
1501–2000	75	83	90	98	105
2001–2500	90	98	105	113	120
2501–3000	105	113	120	128	135
3001–3500	120	128	135	143	150
3501–4000	135	143	150	158	165
4001–4500	150	158	165	173	180
4501–5000	165	173	180	188	195

Fan flow in CFM. From ASHRAE Standard 62.2-2013, Table 4.1a

Use the table above to determine the ventilation fan CFM for each of the buildings characterized in the table below. Note the table option doesn't require Nbr + 1 like the formula. Just the number of bedrooms.

Floor area (A_{floor})	Bedrooms (N_{br})	Fan CFM
1150	2	68
1875	3	
2100	4	
2630	5	

Tools for Field Work

These are some of tools you'll need for energy auditing. You will likely develop your own longer list. Many auditors build a dedicated tool bag for each task.

General Inspection Tools

- Ladder(s)
- Calculators
- Tape measures (25- and 100-foot)
- Flashlights
- Screwdrivers, pliers, utility knife
- Thermometers
- Extra batteries for all equipment
- Wood skewers for probing wall insulation
- Boroscope

Combustion Testing

- Carbon monoxide tester
- Workspace CO monitor
- Manometer
- Vinyl tubing: 50' clear, 6' clear
- Static pressure probe
- Gas detector and/or bubbling solution
- Clock or stopwatch
- Smoke and/or mirror
- Metal flue tape and hi-temp red silicone
- Matches or lighter
- Drill with 3/8" metal-cutting bit

Blower Door Testing

- Blower door (fan, frame, fabric or panels)
- Manometer
- Second manometer for zone testing (optional)
- Vinyl tubing: 6' red, 6' green
- Smoke generator
- Extension cord

Duct Testing

- Duct blower and fittings
- Manometer with hoses
- Scrap cardboard
- Wide masking tape
- Duct masking sheets
- Fogger (optional)
- Drill with 3/8" metal-cutting bit
- Extension cord

Reference and Record Keeping

- *Energy Auditor Field Guide*
- Technical reference sheet
- Clipboard and paper
- Pens and pencils
- Digital camera

RESOURCES AND OTHER INFORMATION

American Council for an Energy-Efficient Economy (ACEEE) — 1001 Connecticut Ave. NW, Suite 801, Washington, DC 20036. 202-429-8873. *www.aceee.org* ACEEE collaborates with other groups on research into the benefits of energy efficiency, and publishes many reports. Publishes the excellent book *Consumer Guide to Home Energy Savings.*

American Solar Energy Society, Inc. (ASES) — 2400 Central Ave. G-1, Boulder, CO 80301. 303-443-3130. *www.ases.org* ASES is a nonprofit educational organization that encourages the use of solar energy technologies. ASES publishes the magazine *Solar Today.*

Building Performance Institute — 107 Hermes Road Suite 110, Malta, NY 12020. 518-899-2727. *www.bpi.org* Certifies energy auditors and related professionals working in the weatherization and home performance fields. Provides accreditation for home performance contractors. Manages both written and field testing of technicians. Maintains a list of accredited home performance contractors.

California Energy Commission (CEC) — 1516 Ninth Street, P.O. Box 944295, Sacramento, CA 94244-2950. 916-654-4287. *www.energy.ca.gov* The CEC publishes extensive written and web-based resources on building technology and energy efficiency.

Centers for Disease Control and Prevention (CDC) — 1600 Clifton Rd, Atlanta, GA 30333. 800-311-3435. *www.cdc.gov* Provides written and web-based information on home health hazards such as asbestos, radon, carbon monoxide, and household chemicals.

Department of Housing and Urban Development (HUD) — 451 7th Street S.W., Washington, DC 20410 (202) 708-1112. *www.hud.gov* HUD manages a vast information network on homeownership in general, with topics that include buying and selling homes, identifying the most favorable mortgages, and improving home efficiency.

ENERGY STAR® — The ENERGY STAR website is one of the best online resources for information on building efficiency. *www.energystar.gov*

The Energy & Environmental Building Association (EEBA) — 6520 Edenvale Boulevard, Suite 112, Eden Prairie, MN 55346 952-881-1098. *www.eeba.org* EEBA's goal is to provide education and resources to transform the residential design and construction industry to profitably deliver energy efficient and environmentally responsible buildings and communities.

Florida Solar Energy Center (FSEC) — 1679 Clearlake Rd., Cocoa, FL 32922. 321-638-1015. *www.fsec.ucf.edu* FSEC is an important resource for anyone who owns a home in a hot, humid climate. They offer publications on topics such as passive cooling, radiant barriers, moisture control in hot climates, shading techniques, air leakage, air-conditioner performance, and more.

Home Energy — PMB 95, 2124 Kittredge St., Berkeley, CA 94704. 510-524-5405. *www.homeenergy.org* Publishers of *Home Energy Magazine*, the premier U.S. publication on home energy efficiency.

Journal of Light Construction — 186 Allen Brook Lane, Williston, VT. 802-879-3335. *www.jlconline.com* JLC publishes an excellent professional journal for the construction trades.

National Renewable Energy Laboratory (NREL) — 1617 Cole Blvd., Golden, CO 80401-3393. 303-275-3000. *www.nrel.gov* The DOE's solar and renewable energy laboratory. Performs many kinds of building energy research. Produces publications for both professionals and consumers.

North American Technical Excellence (NATE) — 4100 North Fairfax Drive #210, Arlington, VA 2220 3(703) 276-7247. *www.natex.org* NATE provides a national certification for the most skilled heating and cooling technicians. They maintain an online database of certified technicians.

Passive House Institute U.S. — 110 S. Race St. Ste 202, Urbana, IL 61801. *www.passivehouse.us* The Passive House Institute works to establish European super-efficient construction standards in the U.S. They provide technical assistance, offer training, and certify homes that are built to Passive House standards.

PVwatts, National Renewable Energy Lab — *www.rredc.nrel.gov/solar/calculators/PVWATTS* The online PVWatts calculator allows you to estimate the output of solar electric systems. The website also includes other solar design tools and research materials.

Residential Energy Services Network (RESNET) — P.O. Box 4561, Oceanside, CA92052. 760-806-3448. *www.resnet.us* National organization of home energy raters (HERS Raters) and rating organizations. Their mission is to develop a national market for home energy rating systems and energy efficient mortgages. Maintains a list of certified HERS Raters.

Saturn Resource Management, Inc. (SRMI) — 324 Fuller Ave., Helena, MT 59601. *www.srmi.biz.* Saturn is the producer of this Student Workbook and other elements of the Saturn Curriculum.

Solar Energy International (SEI) — P.O. Box 715, Carbondale, CO 81623 970-963-8855. *www.solarenergy.org* SEI offers the industry's best hands-on workshops and online courses on renewable energy and sustainable construction.

Southface Energy Institute — 241 Pine St. NE, Atlanta, GA 30308. 404-872-3549. *www.southface.org* Nonprofit educational institute focuses on energy-efficient building for the southern states. Website has a good question-and-answer section.

U.S. Green Building Council (USGBC) — 1800 Massachusetts Ave. NW Suite 300, Washington, DC 20036. 202-828-7422. *www.usgbc.org* USGBC administers the LEED program (Leadership in Energy and Environmental Design), an educational and rating system for green buildings