ENERGIZED LEARNING

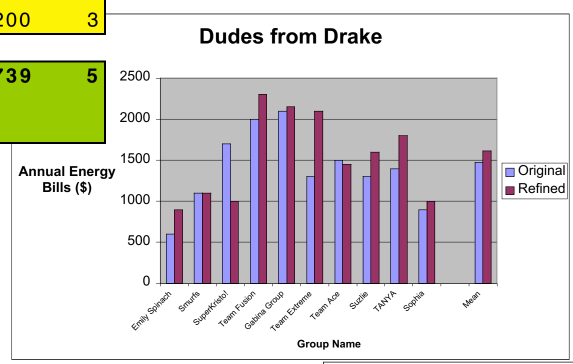
First-year Start-up Report

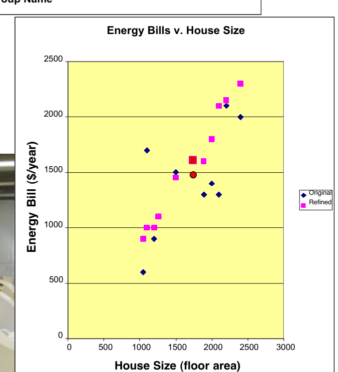
http://www.lbl.gov/Education/CSEE/el_site/index.html

"I was very impressed with the power of the program and would especially like to work in the statistics aspect as a class activity." – *Mary Carabell, Teacher*
Drake High School

"I thought the entire process was very positive and we should find a way to promote it to everyone possible."- *Student*

Group	Energy Bill	Floor Area (sq ft)	# Occu-pants
Emily Spinach	600	1050	7
Smurfs	1100	1260	4
SuperKristo!	1700	1100	5
Team Fusion	2000	2400	6
Gabina Group	2100	2200	6
Team Extreme	1300	2100	5
Team Ace	1500	1500	4
Suzlie	1300	1890	5
TANYA	1400	2000	3
Sophia	900	1200	3
Mean	**1478**	**1739**	**5**
SD ("sigma")	**465**		
CV (or %SD)	**31%**		





ENERGIZED LEARNING
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December 20, 2002

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Sponsors[1]
U.S. Department of Energy, Office of Building Technologies
U.S. Department of Energy, Office of Science

[1] The research described in this article was supported by the Assistant Secretary for Energy Efficiency and Renewable Energy, Building Technologies Program, U.S. Department of Energy, under Contract No. DE-AC03-76SF00098.

CONTENTS

Welcome to Energized Learning

The *Energized Learning* web site is designed for middle and high school students, their teachers and their parents. The site includes lessons and activities that develop specific skills and knowledge students are expected to learn in science, mathematics, economics and social sciences and politics. Energy supply, conversion and use is central the quality of life for all people. It is our hope that students, teachers and parents will develop a better understanding of energy and its complex interrelationships.

Mathematics, science, economics, social and political science teachers will find a list of student lessons and activities with keys to subject matter standards. As students work through the standards-based lessons they areexposed to the following five concepts:

- Energy and the environment are linked – students will compare the amount of carbon dioxide, a greenhouse gas, emitted to the atmosphere as a result of energy use choices in their homes.

- Quality of life can be increased without increasing energy use – students analyze the impact of energy efficient options for services, such as lighting and heating that provide for conveniences, comfort, and entertainment

- Achieving energy efficiency is an investment, not an expenditure – students analyze the impact of energy efficient investments on their annual energy costs.

- Understanding and managing energy use requires concepts and information from many areas – Students learn that planning for an energy efficient future involves knowledge of science, mathematics, economics and social science.

- Modeling (e.g. with computer simulation tools) is central to science, but can have severe limitations. "The map is not the territory." Scientists who use models need to have a healthy skepticism about their predictive power.

At the core of the Energized Leaning site is an interactive Web-based energy calculator and home energy audit toolkit developed by the US Department of Energy scientists at the Lawrence Berkeley National Laboratory. The Home Energy Saver (http://hes.lbl.gov) is a consumer-oriented tool used in predicting residential building performance. The Energized Learning web interface makes the Home Energy Saver available, for the first time, for use in the classroom.

This report describes the initial phase of work. Considerable progress was made, including launch of a preliminary website and several interactions with high school students and teachers to help refine the product. We developed, tested, and implemented a detailed lesson, with student and teacher support materials, and conceptualized a set of follow-up lessons. LBNL's Center for Science and Engineering Education became an active partner in the project, and contributed considerable in-kind resources to leverage the resources from BTS. CSEE's work is funded by DOE's Office of Science.

From the Lab to the Classroom

Energized Learning is rooted in a collaboration between two groups at LBNL: The Environmental Energy Technologies Division (EETD) and The Center for Science and Engineering Education (CSEE). EETD's activities span R&D on energy efficiency and the relationship between energy use and the environment. CSEE conducts a broad spectrum of education activities at the Laboratory, guided by the following goals:

• To promote equal access to scientific and technical careers for all students, including women, minorities, the handicapped and economically disadvantaged

• To improve the quality of science and engineering teaching by supporting increased classroom emphasis on the scientific process and frontier science and technology

• To increase the number of U.S. students who become scientists and engineers by developing and implementing strategies to provide continuity of opportunity from elementary through graduate school.

• To promote scientific literacy, including an understanding of the relationships among frontier science, technology and society.

Accomplishments in FY02

• Developed the "Energized Learning" core concept

• Designed the initial "Getting Started" lesson (Appendix A) and sketched out follow-on lessons (Appendix B)

• Documented ways in which Energized Learning supports Education Standards, including the AAAS Benchmarks for Science Literacy (Appendix C)

• Created and launched the Energized Learning website

• Conducted pilot tests with students and teachers from Bay Area High Schools

Collaborations

We sought involvement of students and teachers in developing the concept and materials.

• *Eli Marienthal*, student at Berkeley High School, participated in early discussions and helped craft the exercises (lessons) described in Appendix B. Eli worked through these exercises and presented them to his class.

• *Mai Sue Change* is completing her training as a High School teacher at Fresno State University and came to LBNL under the DOE's Pre-service Teacher's program (see http://www.scied.science.doe.gov/scied/PST/about.htm). Mai Sue helped to further refine the Lessons and to map the lessons onto Education Standards for Mathematics.

• *Michael Thibodeau*, high school teacher, worked at LBNL in the summer of 2002 helping to coordinate the pre-service teacher program. The project benefited considerably from his experience at providing science education at a high school level.

• *A briefing was made to several teachers during the LBNL Open House*. Feedback was received on the Energized Learning concept.

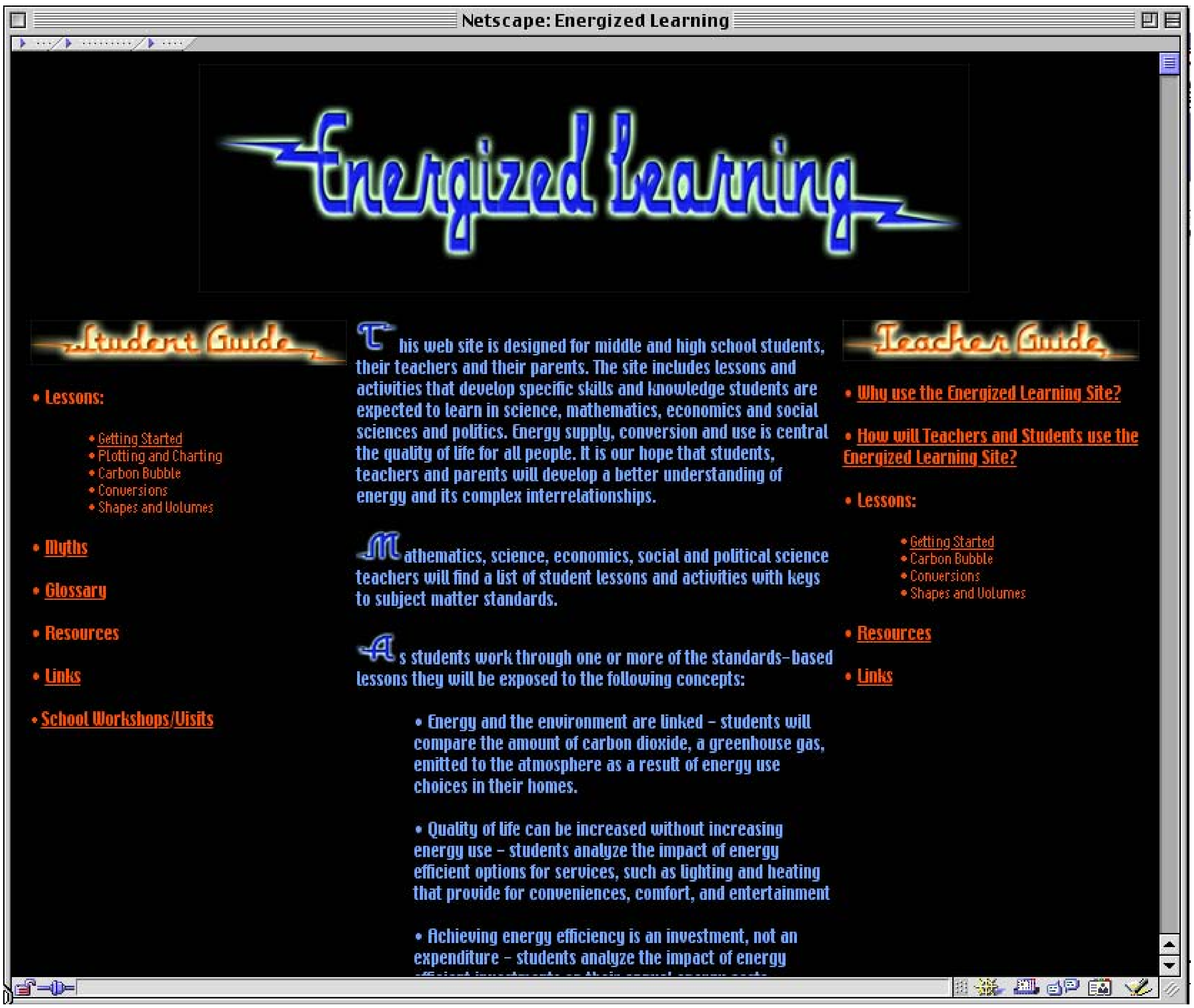
• We conducted an in-depth test of the initial Lesson with approximately 20 students from *Sir Francis Drake High School*, guiding the students through the Lesson. Feedback received from the students and teachers is being incorporated in the site and lesson design. The students also had a rare opportunity to meet the Secretary of Energy, who happened to be visiting the Laboratory that day.

Website Design and Implementation

The initial version of the site contains areas for Students and Teachers, and can be viewed at http://www.lbl.gov/Education/CSEE/el_site/index.html

The student's side offers an archive of lessons (Appendices A currently and ultimately more such as those delineated in Appendix B), links to research information, a how-to video, a glossary of energy-efficiency terminology, etc.

The teachers' side offers notes on implementing the lessons and support material such as PowerPoint slides and downloadable Excel templates for collecting and analyzing data.



Next Steps

Given the very positive feedback received from students and teachers, we would welcome the opportunity to enhance and expand Energized Learning in FY03.

Following are some specific ideas:

- Building on the success with our "Getting Started" lesson, a natural next step would be to build additional lessons and post them on the web site. Examples are shown in Appendix B. The Lessons should have variations for standard and advanced-placement students.

- Develop additional Teacher Resource materials. The availability of ready-made and convenient resource materials provides a huge inducement for teachers to utilize resources such as Energized Learning. Also needed is a "How-To" guide to help teachers learn to use the Home Energy Saver.

- Conduct additional pilot tests in actual classrooms. Gather feedback on the usability of the site and interest in the material.

- Support new LBNL program for bringing high schools to the Laboratory on tours. Conduct two-hour "clinics" in which students receive instruction on Energized Learning.

- Collaborate with LBNL's 2003 Summer Teacher's Program, using the opportunity to train teachers to train their peers in the use of Energized Learning

- Develop content to create continuity between 12th grade and community colleges, i.e. support students who will not go to Universities but are interested in modest vocational education in the area of energy and building management.

- Make technical improvements to the HES website so that it will better serve the education community. Examples include password-protected accounts to allow teachers to review student's work; addition of apartment-type construction (many students live in apartments). Another example would be to add a centralized database into which students from around the country can enter their household energy data. Students and teachers could subsequently "mine" this data using statistical techniques.

Appendix A. Sample Lesson: Getting Started

You will begin by establishing an account in the Home Energy Saver (http://hes.lbl.gov) and printing your first records for analysis and comparison of energy use and efficiency as you change your home's description, services, and energy efficiency levels. All you need to get started is your zip code...

•1• Please read the information on the home page for the Energized Learning web site:
http://www.lbl.gov/Education/CSEE/el_site/index.html
You will be asked to say what you know about the five overall concepts about energy efficiency.

•2• From the Energized Learning home page, go to The Home Energy Saver Web site and enter your Zip Code. You will obtain you first estimated energy use information for a typical house in that zip code area

•3• Select "customize for my home" Make the best estimates you can to answer the questions. Don't worry about mistakes or approximations; you will be able to modify and improve your input later. Click on "estimate energy use." Print the resulting page, which now contains your "session number". Keep this page for future reference. Click on the "carbon emission or energy consumption" link and print the resulting page. This should take no more than 10-15 minutes.

•4• The teacher will discuss the meaning of the information on these pages.

•5• Here are some questions to think about and discuss.

- What are the sources of emissions (combustion of fossil fuels)
- Can you name some of the sinks for CO2? (Photosynthesis, oceans, others)
- Why is CO2 listed as a pollutant in the Home Energy Saver (Greenhouse gas that has the potential to cause climate change)

•6• You will now have about 25 minutes to make changes to your house so that it more accurately describes your home. Print your results and "carbon emission or energy consumption" results.

•7• Now its time to select one or more upgrades to make your house more energy efficient and recalculate the whole-house energy costs, requirements and pollution. Print your results. You now have three sets of data to compare.

•8• What is different before and after the upgrade(s)? What impact can you expect on your quality of life and energy use? Would you consider energy efficiency an investment in services or an added expense in your household budget?

•9• Now you should click on and print your "Whole House Configuration" and keep these for further reference.

•10• You will use your data and your classmates' data to explore the effect of variations and trends in energy requirements. Your teacher will discuss the concept of "data normalization" and guide you in preparing "scatter diagrams" and discussing how to interpret them.

•11• Consider what factors may be responsible for the trends that emerge from the data?

•12• Note the range of concepts and information required to predict energy use.

•13• As a class, compare your views about the five energy efficiency concepts with your views at the beginning of the class.

•14• Close the Browser Window and save your results for another session.

Send us your feedback and suggestions! (mailto:emills@lbl.gov)

ADDITIONAL EXERCISES & EXPERIMENTS

1. Analyze the "outliers" in the scatter diagrams. What are possible physical reasons for the outliers? Could errors in either the computer program or the user inputs be involved? If so, what kinds of errors? How do the statistical metrics (standard deviation and % standard deviation) change if the outliers are removed?

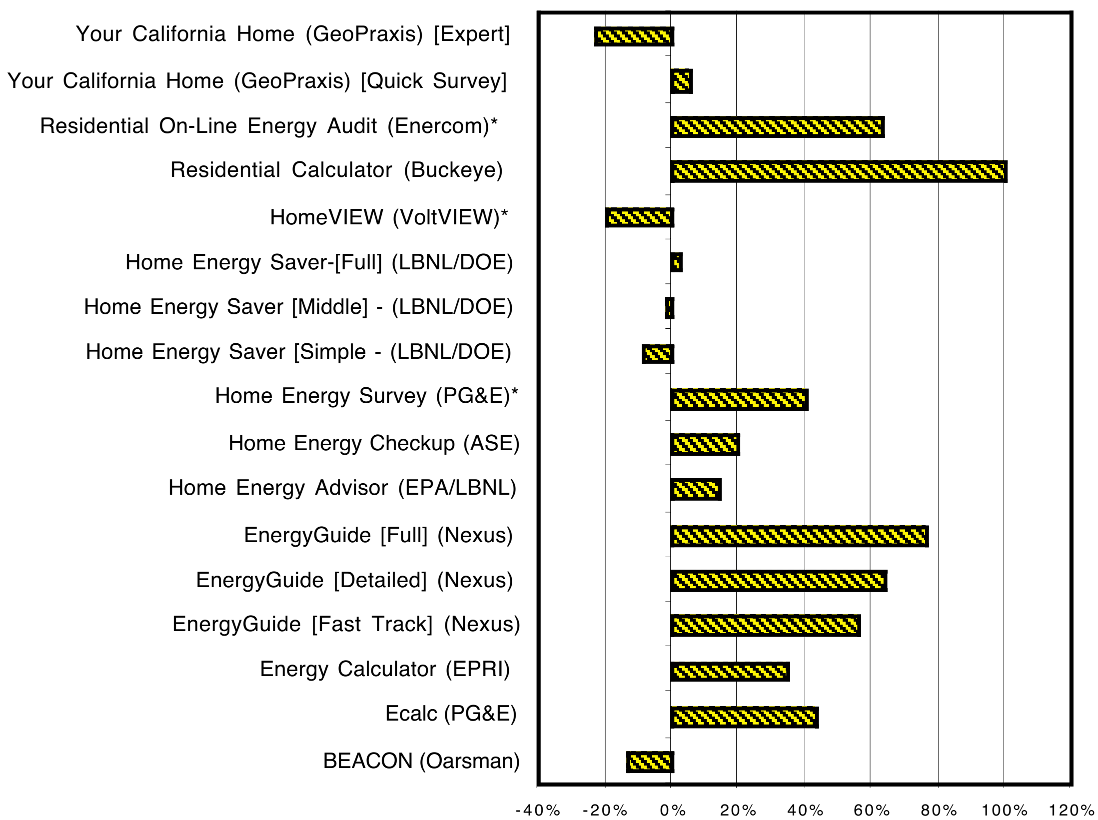
2. Run a series of calculations progressively increasing your ceiling insulation and draw a graph of the results. What does the graph suggest?

3. Find the equation of a line (least-squares fit in the form ax+b) through the correlation diagrams. This is a simplified "model" for predicting energy use in homes. What is the y-intercept, and what does it represent? How accurate would this model be?

4. Create your "dream home", which may be larger and/or have more gadgets and thus use more energy. Find ways to improve the efficiency (e.g. more insulation) so that energy use is no higher than the home you currently live in.

5. Go on the web and find 10 images of the carbon cycle (Hint: do a Google image search). Compare and contrast the images and discuss their strengths and weaknesses both in terms of completeness and method of graphically telling the story.
6. Look at the chart below and discuss the possible reasons for the large variability in predictive power of energy audit tools.

Deviation of Predicted Bills from Actual: Web-based Tools



Source: Mills, E. 2002. "Review and Comparison of Web- and Disk-based Tools for Residential Energy Analysis." Lawrence Berkeley National Laboratory Report No. 50950. http://eetd.lbl.gov/emills/PUBS/SoftwareReview.html

Getting Started for Teachers

Lesson Plan

Students establish an account in The Home Energy Saver Web site and obtain their first printed records predicting their homes energy use and energy saving options...

Pre-class work: Have students run their homes through the Home Energy Saver before class. Work with parents to answer questions. Obtain separate results for both the simple level ("Customize for my Home") and the more detailed screens that follow it. These two sets of results will be compared in class during the statistical analysis. If this is done, steps 2-3 and 6 below can be skipped.

•1• Students read the information on the home page for the Energized Learning web site (5 minutes).

> **•T1•** Teacher asks the student to say what they know about five concepts that they will see repeatedly as they do standards-based lessons.
>
> **•T2•** Teacher records the answers on the board (5-7 minutes).

•2-3• Students go to the Home Energy Saver Web site,enter their Zip Code and obtain their first estimated energy use information. Student then selects "customize for my home" and input their best estimates to the questions. Students should print the resulting page, which now contains their "session number". Student should click on the "carbon emission or energy consumption" and print the resulting page." ***(To allow more time for discussion in class, this can "pre-lab" can be done at home)***

•4• Teacher leads a discussion of the meaning of the information on the pages, first taking questions and then guiding students to note the various factors that they can change to get the most accurate description of their house.

> **•T1•** Teacher leads a discussion of the CO_2 emissions.

•5• Student should discuss what they know about the following questions. This can be done several ways. Have the students pair up in groups of 2 or 3 for five minutes and then offer answers based on their group discussion. Or Teacher leads an full group discussion guiding and recording key points.

Students should discuss the following:

> • What are the sources of the emissions (combustion of fossil fuels)?
> • Can the students name some of the sinks for CO_2? (Photosynthesis, oceans, others)
> • Why is CO_2 listed as a pollutant in the Home Energy Saver (Greenhouse gas that has the potential to cause climate change)

•T2• The teacher graphs the distribution of answers and discusses sources of variation and the value of data-normalization techniques. Discuss the meaninig and use of Standard Deviation.

•6• Students now are given about 15 minutes to make changes to their house so that it more nearly reflects their home. Students print their Whole House Configuration and the details of their whole house annual energy use. ***(To allow more time for discussion in class, this can "pre-lab" can be done at home)***
•7• Students select one or more upgrades to make to their house and recalculate the whole house energy costs, requirements and pollution. Students should print their main results (bar charts) and the "carbon emission or energy consumption". They should now have three sets of data to compare.

•8-9• Teacher leads discussion based on the differences they get before and after the upgrade and it's impact on their quality of life and energy use. Teacher then leads a discussion on energy efficiency as an investment.

Collect the data (e.g. in Excel Spreadsheet) and send to the Energized Learning team, who will merge it into a larger database that can be downloaded from the website and further analyzed in classroom projects.

•10• Teacher leads a discussion to explore the effect of variations and trends using the students' data and an Excel spreadsheet.

•11-12• Teacher discusses the factors that would cause the trends observed in the data, noting the range of concepts and information that would be required to predict energy use.

•13• Students suggest additions and modifications to their original knowledge of the five concepts that were recorded on the board at the beginning of the session.

•14• Teacher leads a discussion of activities or questions that students would like to explore next.

•15• Students should close the Browser Window and save their results for another session.

ADDITIONAL EXERCISES & EXPERIMENTS

1. Analyze the "outliers" in the scatter diagrams. What are possible physical reasons for the outliers? Could errors in either the computer program or the user inputs be involved? If so, what kinds of errors? How do the statistical metrics (standard deviation and % standard deviation) change if the outliers are removed?

   • Teacher Tools: Stress the importance of handling outliers in science. Sometimes they have an important message; other times they are "noise"

2. Run a series of calculations progressively increasing your ceiling insulation and draw a graph of the results. What does the graph suggest?

   • Teacher Tools: The graph will show "diminishing returns", i.e. less and less energy is saved as the insulation gets increased. This suggests that there is probably some sort of optimal level of insulation, beyond which the extra investment would not be justified based on the extra ("incremental") energy saved.

3. Find the equation of a line (least-squares fit in the form ax+b) through the correlation diagrams. This is a simplified "model" for predicting energy use in homes. What is the y-intercept, and what does it represent? How accurate would this model be?

   • Teacher Tools: Use this as a way of introducing "linear regression" concepts and techniques. This can also be done using Excel's "Chart > Add trendline" function. The slope can be found by inspection. The point at which the line intersects the y-axis reflects a house of zero size or zero occupancy (depending which chart is used). This could include things such as fridges that are required irrespective of house size or occupancy.

4. Create your "dream home", which may be larger and/or have more gadgets and thus use more energy. Find ways to improve the efficiency (e.g. more insulation) so that energy use is no higher than the home you currently live in.

   • Teacher Tools: This should support the second of the five overarching objectives, i.e. quality of life (e.g. house size) needn't be compromised to save energy. However, true "conservation" does involve managing things like house size, whereas "efficiency" does not focus on the amount of services consumed.

5. Go on the web and find 10 images of the carbon cycle (Hint: do a Google image search) Compare and contrast the images and discuss their strengths and weaknesses both in terms of completeness and method of graphically telling the story.

- **Teacher Tools: Use this as an opportunity to discuss data visualization and visual communication of science, and to discuss searching for information on the Internet. Note the many weaknesses of the illustrations. What does the source of the illustrations say about their biases or orientations?**

6. Look at the chart below and discuss the possible reasons for the large variability in predictive power of energy audit tools.

(See Students version of Lesson for Chart)

- **Teacher Tools: Study the referenced publication, focusing on the section describing sources of error and disagreement among tools. Use this as a basis for student discussion.**

ENERGIZED LEARNING RESULTS: RAW DATA & ANALYSIS

Input Values

Calculated Values

Original Scenarios

	Group	Energy Bill	Floor Area (sq ft)	# Occu-pants	Energy $ / Occupant	Energy $ / Floor Area ($/year-sq ft)
FORMULAS:		Data	Data	Data	C/E	C/D
	1	600	1050	7	86	0.57
	2	1100	1260	4	275	0.87
	3	1700	1100	5	340	1.55
	4	2000	2400	6	333	0.83
	5	2100	2200	6	350	0.95
	6	1300	2100	5	260	0.62
	7	1500	1500	4	375	1.00
	8	1300	1890	5	260	0.69
	9	1400	2000	3	467	0.70
	10	900	1200	3	300	0.75
This is the average of the entries:	**Mean**	**1478**	**1739**	**5**	**329**	**0.88**
This is the "Standard Deviation, SD":	**SD ("sigma")**	**465**			**99**	**0.28**
This is SD/Mean:	**CV (or %SD)**	**31%**			**30%**	**32%**

Variations (Actual/Mean)

	Raw E (% of mean)	E/Occupant (% of mean)	E/FA (% of mean)
	C(n)/C17	F(n)/F17	G(n)/G17
1	41%	26%	65%
2	74%	84%	99%
3	115%	103%	175%
4	135%	101%	94%
5	142%	106%	108%
6	88%	79%	70%
7	102%	114%	113%
8	88%	79%	78%
9	95%	142%	79%
10	61%	91%	85%

Input Values

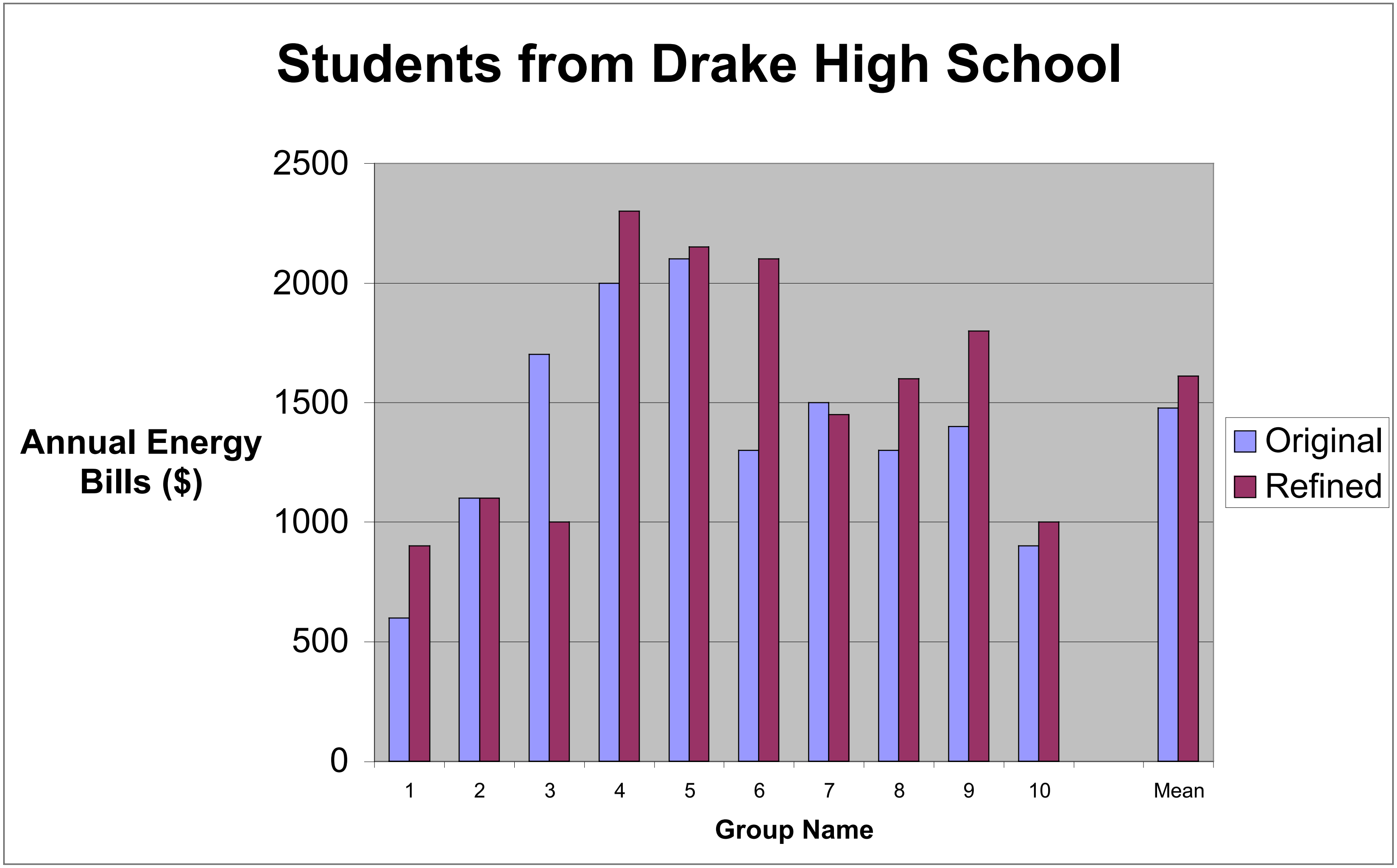
Calculated Values

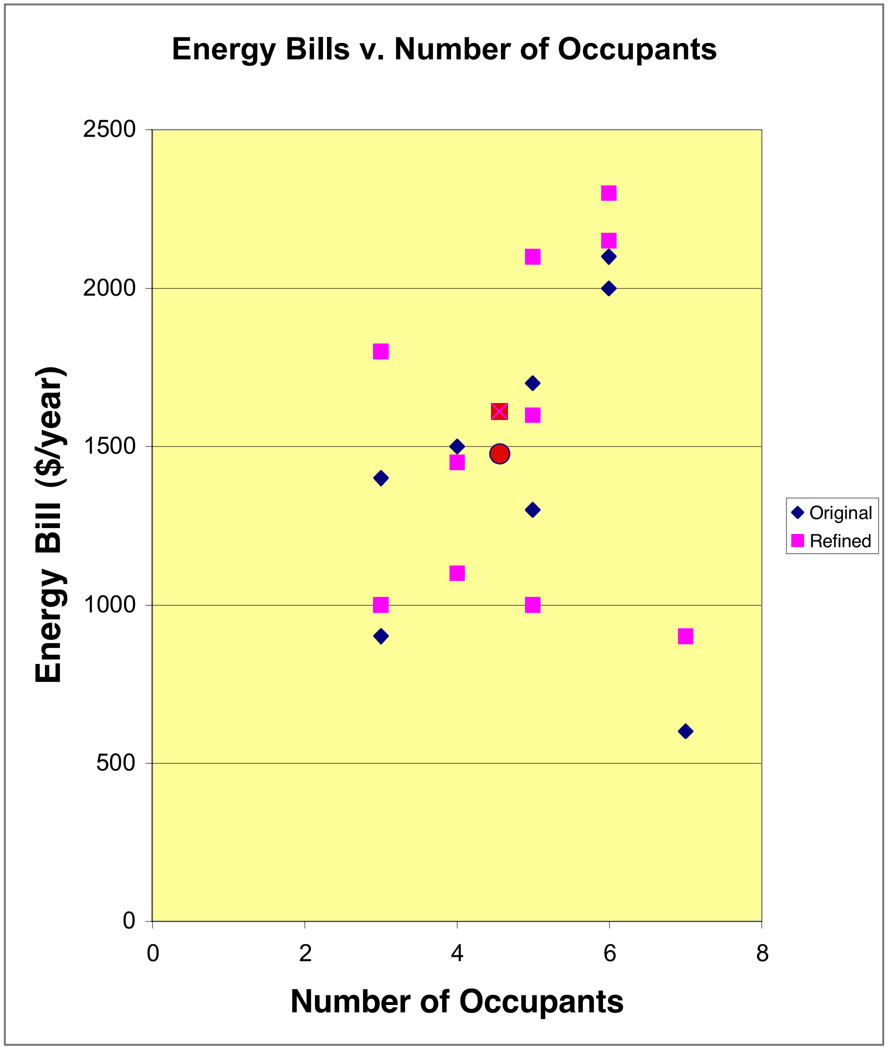
Refined Scenarios

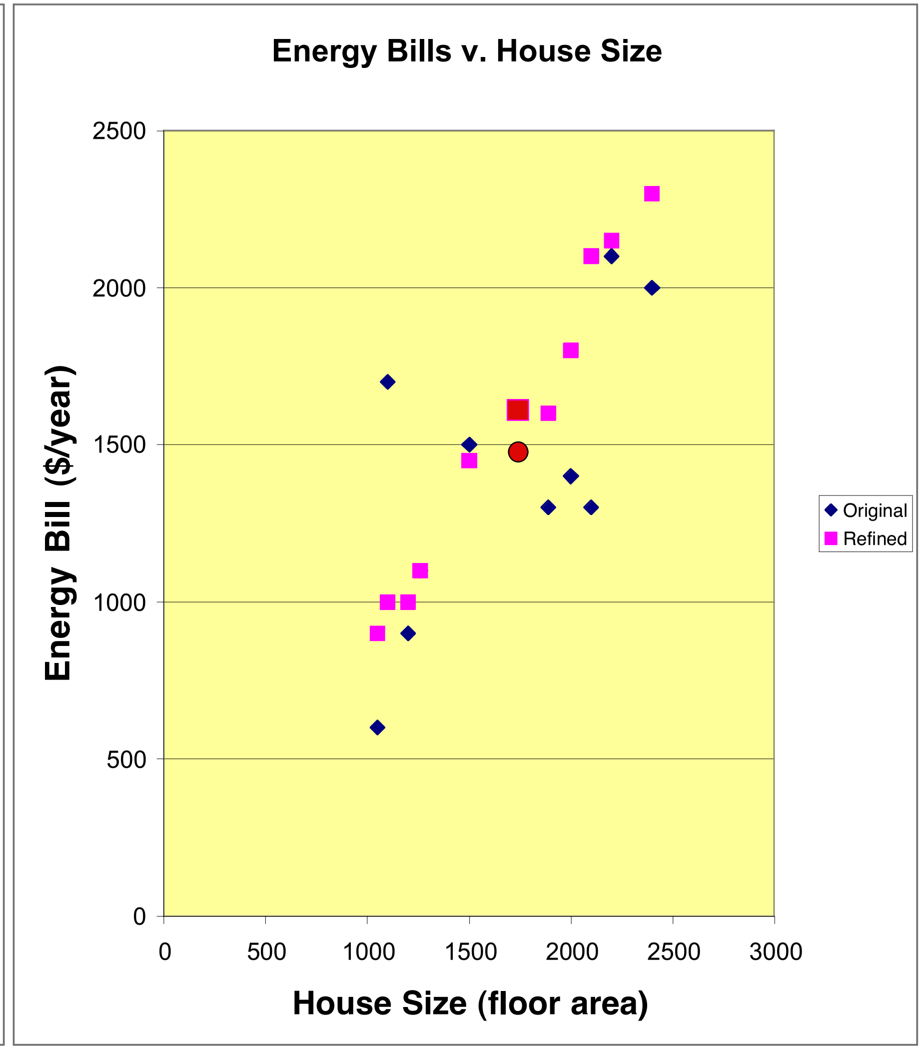
	Group	Energy Bill	Floor Area (sq ft)	# Occu-pants	Energy Cost / Occupant	Energy $ / Floor Area ($/year-sq ft)
FORMULAS:		Data	Data	Data	C/E	C/D
	1	900	1050	7	129	0.86
	2	1100	1260	4	275	0.87
	3	1000	1100	5	200	0.91
	4	2300	2400	6	383	0.96
	5	2150	2200	6	358	0.98
	6	2100	2100	5	420	1.00
	7	1450	1500	4	363	0.97
	8	1600	1890	5	320	0.85
	9	1800	2000	3	600	0.90
	10	1000	1200	3	333	0.83
This is the average of the entries:	**Mean**	**1611**	**1739**	**5**	**361**	**0.92**
This is the "Standard Deviation, SD":	**SD ("sigma")**	**530**			**127**	**0.06**
This is SD/Mean:	**CV (or %SD)**	**33%**			**35%**	**7%**

Variations (Actual/Mean)

	Raw E (% of mean)	E/Occupant (% of mean)	E/FA (% of mean)
	C(n)/C17	F(n)/F17	G(n)/G17
1	61%	39%	97%
2	74%	84%	99%
3	68%	61%	103%
4	156%	117%	108%
5	145%	109%	110%
6	142%	128%	113%
7	98%	110%	109%
8	108%	97%	96%
9	122%	182%	102%
10	68%	101%	94%


Students from Drake High School
Annual Energy Bills ($)
2500
2000
1500
1000
500
0
1
2
3
4
5
6
7
8
9
10
Mean
Group Name
Original
Refined


Energy Bills v. Number of Occupants
Energy Bill ($/year)
2500
2000
1500
1000
500
0
0
2
4
6
8
Number of Occupants
Original
Refined


Energy Bills v. House Size
Energy Bill ($/year)
2500
2000
1500
1000
500
0
0
500
1000
1500
2000
2500
3000
House Size (floor area)
Original
Refined

APPENDIX B. Six Potential New Lessons

1. The Power of Unit Conversions for Environmental Analysis

CORE PROBLEMS:

A. Convert pounds of CO2 to cubic meters

<u>Problem Statement:</u> Rollie and Thanh are working on this; including some science standards

<u>Solution:</u> Rollie and Thanh are working on this; including some science standards

B. Car versus house exercise

<u>Problem Statement:</u> Determine the fuel use of a car and convert to CO2. Express as a percentage of emissions for your house.

<u>Solution:</u> Miles/year x gallons/mile = gallons/year
Emissions factor (carbon/gallon) * gallons/year = carbon/year
For comparison, carbon/year for a house comes from HES results page.
Additional unit conversions can be done for metric<-->English, e.g.
HES result is in pounds.

C. Energy mixes

<u>Problem Statement:</u>
i. Convert gallons of heating oil to carbon per million BTUs
ii. Convert therms of natural gas to " " "
iii. Convert kWh of electricity to " " "
a. electricity generation mix in terms of % coal; % oil, % hydro, % nuclear

<u>Problem Statement:</u> How does the overall carbon/kWh change for different mixes of input fuels?

D. Calculate global carbon-dioxide emissions, given global use of various fuels.

<u>Problem Statement:</u> Calculate the global carbon dioxide emissions for global energy use

energy type	**global use (2000)**		**Emissions factor**
Oil	ABC	millions of barrels per day	xxx kg/joule
Natural Gas	DEF	trillion cubic feet per year	yyy kg/joule
Coal	GHI	billion short tons per year	zzz kg/joule

<u>Solution:</u> Using unit coversions, change each of the "raw energy" values into annual energy use (joules) and then into carbon emissions.

Background links & readings:

U.S. Environmental Protection Agency Global Warming Site
http://www.epa.gov/globalwarming/
http://www.epa.gov/globalwarming/kids/index.html

EXTRA CREDIT:

Look up the energy use and population for the following countries: The United States, Sweden, Poland, China, Nigeria, Brazil.
Calculate the annual carbon emissions per capita.
Discuss the reasons for the differences you observe

2. How Big is Your Carbon Bubble?

CORE PROBLEMS:

A. Size of various shapes (cones, cubes, spheres) for a given amount of carbon dioxide; same for carbon.

Problem Statement: Review the equations fo rthe volume of various shapes; calculate dimensions assuming filled with a given amount of carbon or carbon dioxide. Recalcuate dimensions if filled with student's home's annual emissions of CO2, per HES.

Solutions:

B How large is the "Carbon Bubble" for your home?

Problem Statement: Use the Home Energy Saver to describe your home and determine the annual carbon dioxide emissions
Translate those emissions into a spherical volume and determine the size.
Mai Sue can develop the details based on our "Carbon Bubble" formulas
and any other mathematics or chemistry she would like to introduce to increase
relevance to the National Education Standards and/or AAAS Benchmarks

Background links & readings:
Introduction to the greenhouse effect.
The Greenhouse Effect. Science and integrity (e.g. letter from 18,000 "scientists")
The "skeptics" and "naysayers"
Impact of climate change on ecosystems (IPCC material)
National Oceanic and Atmospheric Administration (NOAA) website on climate change
http://www.ngdc.noaa.gov/paleo/globalwarming/home.html

EXTRA CREDIT:

C. Critical thinking about the atmosphere, climate, weather, earth-atmosphere interactions.

Problem Statement: Study the 100-year chart of atmospheric CO2 concentrations over the past century.

a. Why does it vary in a sawtooth-type of pattern within each year?

b. What would the chart look like if there were zero CO2 emissions from human activities?

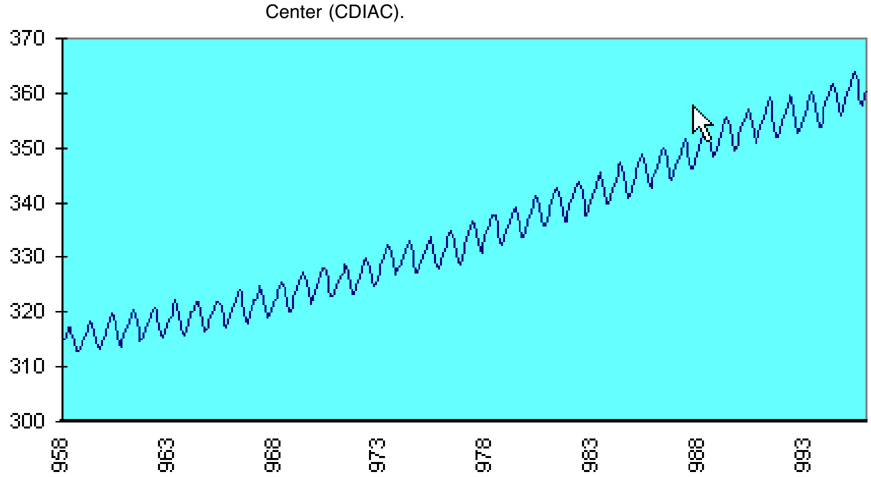
c. What is the difference between weather and climate?
http://www.epa.gov/globalwarming/kids/climateweather.html
http://www.ngdc.noaa.gov/paleo/globalwarming/paleo.html

Solutions: a. There is an annual cycle of increased and decreased carbon dioxide concentrations. Concentrations decrease during springtime, when plants are growing and absorbing carbon from the atmosphere. Concentrations increase again in the winter as deciduous trees lose their leaves, grasses turn brown, etc, and their carbon is released to the atmosphere.

b. Without human carbon emissions, the chart would be a horizontal "sawtooth" pattern, rather than an upward-sloping one.

c. Climate is the long-term average manifestation of weather. Changing weather does not necessarily mean changing climate.

Atmospheric CO2 concentrations in parts per million, Mauna Loa, Hawaii. Source: C.D. Keeling & T.P. Whorf, Scripps Institute of Oceanography. Data available from the Carbon Dioxide Information Analysis Center (CDIAC).



Using Geometry and Chemistry to Calculate the "Carbon Bubble"* for Your Home

---> Putting together geometry, chemistry, and environmental science...

Evan Mills, LBNL, 14-Jan-2002

* [The "Carbon Bubble" is the size of a sphere required to contain all of the annual carbon-dioxide emissions associated with your home's annual energy use, at the same C02 concentration as was present in the pre-industrial atmosphere.]

Q1. What is the volume of one kilogram of carbon dioxide (CO2) emissions (in cubic meters)
Q2. How many cubic meters of CO2 are emitted to the atmosphere from the energy used by your house in one year, adjusting for natural (pre-industrial) concentrations of CO2 at 275 parts per million (ppm)?
Q3. How large is your carbon bubble (diameter of the equivalent sphere, in meters; and volume, in cubic meters)?
Q4. How large is your carbon bubble compared to the size of your house?
Q5. How do the emissions associated with your house compare to those of the typical car?
Q6. How large is the "carbon bubble" representing annual emissions of all U.S. households, assuming your house is average?

Inputs		
Home Energy Saver Carbon Emissions Output	14,000	pounds/year
House Size	2,000	square feet
Useful Variables & Conversion Factors		
Gas constant	22.4	liters/gram-mole (at STP, Standard Temperature and Pressure)
Molecular weight of Carbon	12	grams per gram-mole
Molecular weight of Oxygen	16	grams per gram-mole
Molecular weight of CO2	44	grams per gram-mole: 1 carbon (12) + 2 oxygens (16+16) = 44
Ratio of CO2 to other atmospheric gasses	0.000275	275 parts per million / one million (at pre-industrial concentrations)
Pi	3.1416	
pounds/kilogram	2.2046	
feet per meter	3.2810	
liters per cubic meter	1,000	
square feet per square meter	10.76	
Basic Formulas		
Diameter of a sphere	2	x radius
Volume of a sphere		4/3 x Pi x r^3 = 4/3 x 3.414 x r^3

Q1. What is the volume of one kilogram of carbon dioxide (CO2) emissions (in cubic meters)?

Liters (volume) per gram of CO2 emissions	0.509	liters/gram-mole (gas constant) x (1/atomic weight) =	= 22.4 liters/gram-mole x (1 gram-mole/44g)
Liters CO2 per kilogram CO2	509	liters/gram x 1000 grams/kilogram = liters/kg	= M x 1000 = 0.509 x 1000
A1. Cubic meters CO2 per kilogram	**0.509**	liters/ kilogram x 1m3/1000 liters = cubic meters	= N/1000 = 509/1000

Q2. How many cubic meters of CO2 are emitted to the atmosphere from the energy used by your house in one year, adjusting for natural (pre-industrial) concentrations of CO2 at 275 parts per million (ppm)?

weight of emissions	14,000	pounds of pure CO2	Output from hes.lbl.gov
weight of emissions	6,350	kilograms of pure CO2	= P/G = ___ pounds/2.2
A2a. Volume of annual CO2 emissions	**3,233**	cubic meters of pure CO2	= QxO = kilogramsx0.509 liters/kilogram
A2b. Volume at pre-industrial concentrations	**11,756,035**	cubic meters	= QxO/E = volume = kilograms CO2 x m3CO3/kg x 10^6 parts air / 275 parts pure CO2
A2c. Volume at pre-industrial concentrations	**415,029,897**	cubic feet	= SxHxJ = cubic feet of CO2 emissions/year

Q3. How large is your carbon bubble (diameter of the equivalent sphere, in meters; and volume, in cubic meters)?

Diameter

Volume of a sphere in terms of radius, "r"		V = 4/3 x pi x r3 r3 = (V x 3)/(Pi x 4) r = [(V x 3)/(Pi x 4)]^(1/3)
Sphere radius as a function of CO2 emissions	r =	[(m3CO2/pi x 3)/(4xPi)]^1/3 = r = meters
	141.06	= [(S/F) x (3/4)]^(1/3) = r = radius = meters
A3. Sphere diameter	**282**	= W x K = d = diameter = meters
	926	= X x H = diameter = feet

Q4. How large is your carbon bubble compared to the size of your house?

House size	186	= area in square feet x m2/ft2 = = ft2 x 1m2/10.76ft2 = area = m2
House volume	465	= floor area (in square meters) x 2.5 meters (height) x number of floors = volume = m3
A4. Ratio	**25,299**	= S/AC = (unitless ratio)

Q5. How do the emissions associated with your house compare to those of the typical car?

Emissions factor for gasoline	19.6	pounds CO2 per gallon of gasoline	Source: www.eia.doe.gov/oiaf/1605/factors.html
Miles driven per year	10,000		
Miles per gallon (fuel economy)	20		
Gallons per year	500	gallons of gasoline per year	
Emissions per year	9,782	pounds of CO2	
Emissions per year	4,437	= AI/G = __ pounds CO2/2.2046 = kilograms of CO2	
A5. Ratio of House Emissions to Car Emissions	**1.4**	= Q/AJ = number of "cars" corresponding to house-related emissions (unitless ratio)	

Q6. How large is the "carbon bubble" representing annual emissions of all U.S. households, assuming your house is average?

Volume for single home	11,756,035	cubic meters	From row S, above
Volume for 100 million homes	1.2E+15	cubic meters	From row V, above
	r	= radius = [(V x 3)/(Pi x 4)]^(1/3)	
	65,472	= [(3xAM)/(4xF)]^(1/3) = r = meters	
	130,944	= W x K = d = diameter = meters	
	429,629	= AP x H = diameter = feet	
	81	Diameter = miles	

3. Energy Services -- a central concept!

Energy is only a means to an end. For example, it's a way to get light for reading or to keep food fresh (by refrigeration). Scientists call these "ends" energy services. As you can imagine, using energy more efficiently means less energy used to get a particular service.

One way to observe this is to study historical patterns of economic growth and compare them to the use of energy over those same periods. For most parts of the world, the trend is that energy demand began to grow more slowly than the economy <FIGURE>. Thus, society figured out how to get more energy services (in this case, measured in terms of economic activity) from a given amount of energy. It was formerly believed that in order to have economic growth, more energy had to be used. Now, it is understood that this is not necessarily the case.

Let's look at the case of lighting.

About 2 billion people in the world today lack electricity. They use enormous amounts of kerosene each year to provide flame-based lighting. This translates into about 1.7 million barrels of oil per day, or $50 billion per year!

CORE PROBLEMS:

A. Comparing energy services, energy use, and energy cost for lighting in the industrialized and developing world.

Problem Statement: efficiency "compact fluorescent" lighting

Solutions: Results shown in table below. Mai Sue to organize into a formal exercise.

	Compact Fluorescent Lamp	Simple Kerosene Lamp	Units	Comment
Assumptions				
Energy price	10 c/kWh	$0.50/liter		
Energy consumption	15 Watts	0.05 liters/hr		
Energy services provided	975	10	lumens	
Ratio	**98**		**:1**	**CFL provides nearly 100-times more light output**
Primary Energy Consumption				
Electricity	10.47		MJ per kilowatt-hour	
Kerosene		37.6	MJ per liter of kerosene	
Energy per equal service (975 lmn	0.015	4.875	kWh or liters	
MJ per service (975 lumen-hours)	0.15705	183.3	MJ	
Ratio		**1167**	**:1**	**Kerosene lamp requires 1167-times more energy to deliver a unit of services (lumens)**
Cost per unit of energy services				
Operating time for equal service	1	98	hours	Operating time to generate a set amount of light output (975 lumens, in this case)
Services	975	975	lumen hours	
Cost for equal service	$0.0015	$2.44	$/lumen-hour	Cost for providing set amount of light output
Ratio		**1,625**	**:1**	**Kerosene lamp costs 1625-times more than CFL to deliver the same level of energy serice (975 lumen hours)**

Background links & readings: Holdren Scientific American Article: Energy in Transition
Fuel-based lighting: Large CO2 Source
http://195.178.164.205/IAEEL/iaeel/newsl/1999/tva1999/NatGlob_a_2_99.html
Fuel-based Lighting in the Workplace
http://195.178.164.205/IAEEL/iaeel/newsl/2000/etttva2000/NatGlob_b_1-2_00.html
Jaws

EXTRA CREDIT:

Discuss why the rate of US energy use grew at the same speed of the economy up until the early 1970s and then slowed compared to the economy. (use IPCC chart)

How can people in the developing world be helped to get more services (illumination) for the money they spend?

4. Shrinking Your Carbon Bubble

A. Compare your house to average (in terms of carbon bubble, using HES)
i. explain the differences

B. How large would the carbon bubble be if your home was in Alaska or Florida?
i. Find ways to shrink the bubble for these two locations

C. Find ways to shrink your carbon bubble

Problem Statement: Redo for your dream home (in any city)
Does the home have a larger or smaller carbon bubble than your current home?
Find ways to reduce the size of your Dream Home Carbon Bubble

Solutions: The "Dream Home" bubbles will likely be larger because the houses will be larger, have pools, etc. The choice of climate might also affect it. Student is to think about the driving factors and how to compensate for them (e.g. more insulation).

D. Compare results (bubble sizes for your current house) to those that other students in the class found
i. statistics, gaussian distributions, standard deviations, means, medians

ii. normalization to reduce spread (e.g. carbon/square meter; carbon per person; carbon per person per square meter….)

Background links & readings:
Energy R&D funding history; discussion

EXTRA CREDIT:

Compare the results obtained with HES to your home's actual energy bills over one year. Explore and discuss the sources of the differences.

Using HES, change the microclimate around your home and evaluate the impacts on energy use.

Identify ways in which the government has promoted energy efficiency

5. Investing in Energy Efficiency

To improve the energy efficiency of a home sometimes (but not always!) requires some investment. It might be an investment in more insulation, a better fridge, or new lighting.

We can think of this as an "investment" rather than an "expense" because in return the home's occupant gets a lower energy bill that helps pay for the initial cost of making the efficiency improvements.

It's important to know how much to invest in saving energy. Investing too little means sky-high energy bills every month; investing too much may mean many years to get your money back.

This can be studied using cost-effectiveness formulas.

CORE PROBLEMS:

A. Lifecycle Cost
Problem Statement: TBD
Solutions: TBD

Background links & readings:

EXTRA CREDIT:

APPENDIX C. Linkages between Energized Learning and the AAAS Benchmarks for Science Literacy

MAPPING OF ENERGIZED LEARNING PROJECTS AN D CONCEPTS TO THE AAAS BENCHMARKS

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Draft of July 6, 2002

This matrix lists the grade 9-12 Benchmarks from "Benchmarks for Science Literacy" (AAAS). The columns show the five project areas proposed for Energized Learning. The corresponding "cells" are shaded to indicate whether or not there is a connection between a given benchmark and one or more of the projects. The areas shaded by dark green are directly cultivated by the projects. Light green areas have a potential connection that could be developed independently by the instructor or in future versions of Energized Learning.

http://www.project2061.org/tools/benchol/bolframe.htm

KEY: No connection (yellow) | Firm connection (dark green) | Potential connection (light green)

	Project 1 **Unit Conversions** Fuel mix -> Carbon CO2 -> volume Car vs. House	Project 2 **Carbon Bubble** Carbon -> Various shapes Your House Dream House	Project 3 **Energy Services** Incandescent lighting vs. kerosene	Project 4 **Energy Efficiency** Location Scenarios Efficiency Scenarios Compare to those of other students	Project 5 **Economics** Lifecycle costs
1. THE NATURE OF SCIENCE					
The Scientific World View					
Scientists assume that the universe is a vast single system in which the basic rules are the same everywhere. The rules may range from very simple to extremely complex, but scientists operate on the belief that the rules can be discovered by careful, systematic study.					
From time to time, major shifts occur in the scientific view of how the world works. More often, however, the changes that take place in the body of scientific knowledge are small modifications of prior knowledge. Change and continuity are persistent features of science.			Advent of the concept of "Energy Services" and why it was so important		
No matter how well one theory fits observations, a new theory might fit them just as well or better, or might fit a wider range of observations. In science, the testing, revising, and occasional discarding of theories, new and old, never ends. This ongoing process leads to an increasingly better understanding of how things work in the world but not to absolute truth. Evidence for the value of this approach is given by the improving ability of scientists to offer reliable explanations and make accurate predictions.			Emergence of new ways of looking at energy use and ways to meet the needs of society		
Scientific Inquiry					
Investigations are conducted for different reasons, including to explore new phenomena, to check on previous results, to test how well a theory predicts, and to compare different theories.				The Home Energy Saver simulation model is a virtual laboratory for testing how the energy use in a home responds to changes in the physical characteristics and operation of that home.	
Hypotheses are widely used in science for choosing what data to pay attention to and what additional data to seek, and for guiding the interpretation of the data (both new and previously available).				Using HES, various hypotheses can be tested about how to reduce energy use of a home.	
Sometimes, scientists can control conditions in order to obtain evidence. When that is not possible for practical or ethical reasons, they try to observe as wide a range of natural occurrences as possible to be able to discern patterns.					

In the short run, new ideas that do not mesh well with mainstream ideas in science often encounter vigorous criticism. In the long run, theories are judged by how they fit with other theories, the range of observations they explain, how well they explain observations, and how effective they are in predicting new findings.			For centuries, energy was seen to be a means to an end (I.e. quality of life). Efficient use of energy decouples energy consumption from quality of life.		
New ideas in science are limited by the context in which they are conceived; are often rejected by the scientific establishment; sometimes spring from unexpected findings; and usually grow slowly, through contributions from many investigators.			Energy efficinecy was once seen as an unimportant solution to the energy problem.		
The Scientific Enterprise					
The early Egyptian, Greek, Chinese, Hindu, and Arabic cultures are responsible for many scientific and mathematical ideas and technological inventions.		Roots of geometry	Flame-based light was a major innovation, but it has since been usurped by newer technologies		
Modern science is based on traditions of thought that came together in Europe about 500 years ago. People from all cultures now contribute to that tradition.					
Progress in science and invention depends heavily on what else is happening in society, and history often depends on scientific and technological developments.			Societal problems arising from the cost and use of energy inspired new thinking.		
Science disciplines differ from one another in what is studied, techniques used, and outcomes sought, but they share a common purpose and philosophy, and all are part of the same scientific enterprise. Although each discipline provides a conceptual structure for organizing and pursuing knowledge, many problems are studied by scientists using information and skills from many disciplines. Disciplines do not have fixed boundaries, and it happens that new scientific disciplines are being formed where existing ones meet and that some subdisciplines spin off to become new disciplines in their own right.		<-----	(Interdisciplinary themes run through the exercises)	----->	
Current ethics in science hold that research involving human subjects may be conducted only with the informed consent of the subjects, even if this constraint limits some kinds of potentially important research or influences the results. When it comes to participation in research that could pose risks to society, most scientists believe that a decision to participate or not is a matter of personal ethics rather than professional ethics.					

Scientists can bring information, insights, and analytical skills to bear on matters of public concern. Acting in their areas of expertise, scientists can help people understand the likely causes of events and estimate their possible effects. Outside their areas of expertise, however, scientists should enjoy no special credibility. And where their own personal, institutional, or community interests are at stake, scientists as a group can be expected to be no less biased than other groups are about their perceived interests.		The Greenhouse Effect and Global Warming. The role of science; unscientific deception by "naysayers"			
The strongly held traditions of science, including its commitment to peer review and publication, serve to keep the vast majority of scientists well within the bounds of ethical professional behavior. Deliberate deceit is rare and likely to be exposed sooner or later by the scientific enterprise itself. When violations of these scientific ethical traditions are discovered, they are strongly condemned by the scientific community, and the violators then have difficulty regaining the respect of other scientists.		Why do a handful of "naysayers" have almost equal weight to thousands of other scientists in the popular media?			
Funding influences the direction of science by virtue of the decisions that are made on which research to support. Research funding comes from various federal government agencies, industry, and private foundations.				The history of government funding for energy technologies reflects national and political priorities.	
2. THE NATURE OF MATHEMATICS					
Patterns and Relationships					
Mathematics is the study of any patterns or relationships, whereas natural science is concerned only with those patterns that are relevant to the observable world. Although mathematics began long ago in practical problems, it soon focused on abstractions from the material world, and then on even more abstract relationships among those abstractions.					
As in other sciences, simplicity is one of the highest values in mathematics. Some mathematicians try to identify the smallest set of rules from which many other propositions can be logically derived.					
Theories and applications in mathematical work influence each other. Sometimes a practical problem leads to the development of new mathematical theories; often mathematics developed for its own sake turns out to have practical applications.					
New mathematics continues to be invented, and connections between different parts of mathematics continue to be found.					
Mathematics, Science, and Technology					
Mathematical modeling aids in technological design by simulating how a proposed system would theoretically behave.				A variety of exercises using the HES simulation model.	
Mathematics and science as enterprises share many values and features: belief in order, ideals of honesty and openness, the importance of criticism by colleagues, and the essential role played by imagination.		Discussion of the fole of math and science in the "climate change debate"	The concept of "energy services" was accepted, but with difficulty.		
Mathematics provides a precise language for science and technology—to describe objects and events, to characterize relationships between variables, and to argue logically.		Using the "carbon bubble" to give life to large, abstract numbers	Using math to compare seemingly dissimilar systems and technologies	Analysis of simulation results.	Economic analysis contributes to the evaluation of technology options