Weatherization: Baseline Metrics

In order to measure the ñenergy efficiencyò of a building or to evaluate the efficacy of energy efficiency interventions, it is necessary to establish and implement metrics. Baseline data should be collected prior to any interventions but, ideally, the data sources should continue to be monitored during and after the interventions in order to evaluate the impact of the work and to help determine whether there was a return on the investment. In addition to quantitative metrics, there are also qualitative assessments that can help measure the success of interventions. For example, an observation that a window is less drafty is helpful feedback even if not quantifiable.

Energy Efficiency Testing Guidelines

- Collect baseline data for the project before the implementation of any interventions in order to understand the effects of the changes.
    - The following are standard metrics for energy efficiency and are the data points Historic New England relies upon for analysis:
        - Utility usage: Usage information provides real data on energy consumed. However, additional calculations must be made in order to compare data from year to year because one year may be hotter or cooler than another.
        - Air Leakage: The amount of air leaking in or out of a house can change heating or cooling needs tremendously. A blower door test can measure the amount of air leakage by attempting to pressurize or de-pressurize your house. Measuring leakage before and after a project can provide real data on improvements.
    - Energy Auditors may also present a homeowner with the Home Energy Rating System (HERS), a calculation that analyzes different factors relating to a structure in order to provide an index number that can be compared to similar buildings.
    - Additional tools:
        - Thermal imaging: One can use infrared cameras to support findings and verify effectiveness of work by comparing and contrasting imagery and surface temperatures before and after a project. They are particularly effective when used in conjunction with a blower door test to identify points of air leakage.
        - Smoke pencil or stick: a small device that produces smoke, allowing the user to identify drafts and wind currents within a room.
- The average project should also include measurements at its completion. Historic New England may also take measurements in the course of a project and in specific rooms to better understand what individual measures accomplish with regards to efficiency.
- At the completion of a project, anecdotal information can help support findings. However, this type of data is hard to quantify because of its subjective nature.

Testing and Measurement Tools

Utility Bill Analysis

Retrospective analysis of utility bills (electricity, natural gas, heating oil) should be completed for the previous 2-3 years. While the amount of money spent would seem to be an obvious metric to use, the most helpful information is the amount of energy consumed (kilowatt hours, therms, or gallons). The prices of these energy sources constantly varies so simply tracking costs will not provide information regarding energy use.

In combination with the utilization of energy, one should keep track of ñdegree daysò. A degree day is a measurement that is designed to reflect the demand for energy ï either heating or cooling. Degree days are often based on a temperature of 65ºF. A degree day is the difference between 65 and the average daily temperature of a selected day. For example, if the average temperature was 45ºF, then that day would be calculated to be 20 heating degree days; if the average temperature were 85ºF, then that day would be calculated to be 20 cooling degree days. Heating degree days are generally calculated using publically available data from the weather station nearest to your site.

Degree days can be used to help normalize data over different heating seasons. In this way, the energy consumption per degree day could be calculated, which would provide for a better comparison of energy usage between a ñwarmò winter and a ñcoldò winter.

Utility Data - Sample Metrics and Calculations

Electric, natural gas, and heating oil usage data needs to be converted to a common value for comparison. The common unit used in energy analysis is the British thermal unit (BTU). The following is a list of the conversion rates:

- One gallon of oil provides 140,000 BTUs of energy
- One therm of natural gas provides 100,000 BTUs of energy
- One kWh (kilowatt hour) of electricity provides 3,412 BTUs of energy

Oil Usage

Delivery Date	Days of Heat	Gallons	$/gallon	Degree Days	BTUs Consumed*	BTUs / HDD
2/18/2010	12	323.2	2.769	443.50	45,248,000	102,024.8
2/27/2010	9	175.8	2.749	254.10	24,612,000	96,859.5

**One gallon of oil provides 140,000 BTUs of energy*

Natural Gas Usage

Read Date	Days of Heat	Meter Reading	Therms Used	Degree Days	BTUs Consumed*	BTUs / HDD
1/23/2013		761				
3/27/2013	63	1523	762	2186.4	76,200,000	34,852

**One therm of natural gas provides 100,000 BTUs of energy*

Electrical Usage

	KWh		CDD		KWh/CDD		BTUs / CDD	
	2010	2012	2010	2012	2010	2012	2010	2012
May	5080	4423	63	60	80.6	73.7	275,007	251,464
Jun	5418	4642	122	128	44.4	36.3	151,492	123,855

**One kWh of electricity provides 3,412 BTUs of energy*

Heating Degree Days - Sample Metrics and Calculations

Regional variations in temperature required the data to be normalized so that properties across New England, say in Rhode Island and in Maine, could be compared on equal standing regardless of the local climate. The standard in energy analysis is to identify how many BTUs were used per Heating Degree Days (HDD) and Cooling Degree Days (CDD).

In brief, a Degree Day is calculated using the average temperature from a local weather station. For each degree that the average temperature was below 65° on a given day, one HDD is added. For each degree that the average temperature was above 65° on a given day, one CDD is added. Thus, a day when the average temperature was 30° results in 35 HDD.

Obtained from a weather monitoring station near the building being analyzed.

2/6/2010	45.9
2/7/2010	43.7
2/8/2010	39.9
2/9/2010	37.2
2/10/2010	35.1
2/11/2010	32.6
2/12/2010	36.1
2/13/2010	36.9
2/14/2010	32.8
2/15/2010	32.9
2/16/2010	35.5
2/17/2010	34.9
Total Degree Days for the period	443.5

<u>Air Leakage</u>

Air leakage is calculated with a blower door, which is a mechanical tool used to physically change the pressure differential between spaces. Blower doors are expensive and not typically owned by a homeowner or organization, but they are one of the more important tools used by an energy auditor. They use large fans to pull air out of a space with a goal of creating a pressure differential of 50 Pa (Pascal, a measure of pressure) between the interior and exterior areas. As nature abhors a vacuum, the outside air (which is now at a higher pressure) seeks to balance the pressure differential and will rush back into the space through every available nook and cranny.

Once a blower door is set up, software configured with the system should be used to evaluate the ñleakinessò of the building. This is done by simultaneously measuring the air flow through the fan and its effect on the pressure differential.

- CFM50: This is the airflow (in Cubic Feet per Minute) needed to create a change in building pressure of 50 Pascals. CFM50 is the most commonly used measure of building airtightness. The lower the CFM50, the better the reading.
- ACH at 50 Pa: The Air Changes per Hour (ACH at 50 Pa) is another commonly used measure of building airtightness. ACH at 50 Pa is the number of complete air changes that will occur in one hour with a 50 Pascal pressure being applied uniformly across the building envelope. ACH at 50 Pa is a metric used to adjust (or normalize) the leakage rate by the size (volume) of the building.

Once the leakage rate is established, the software can also provide an estimate of the cumulative size of all the small leaking openings. This Equivalent Leakage Area (EqLA) measurement is the area of a sharp edged opening that would leak as much as all the buildingôs holes put together with a 10 Pa pressure applied.

<u>Blower Door Test - Sample Metrics and Calculations</u>

The following calculations were derived from testing related to window conservation efforts undertaken by Historic New England. The goal was to determine how much air leakage was decreased through traditional preservation-related repairs to the windows.

Before conservation of windows:

Date	CFM @ 50	ACH	CFM/ft2	EqLA (sqin)
3/13/2011	1620	23.8	3.91	184
3/13/2011	1682	24.38	4.06	186.6
3/13/2011	1666	24.14	4.02	208.1

Average effective opening size: 192.9 square inches
Average air changes per hour: 24.1
Airflow needed to create 50 Pa pressure differential: 1656 cubic feet/minute

After conservation of windows:

5/20/2011	1513	21.93	3.66	175
5/20/2011	1540	22.33	3.72	171.6

Average effective opening size: 173.3 square inches
Average air changes per hour: 22.1

Airflow needed to create 50 Pa pressure differential: 1527 cubic feet/minute

(1-(Effective opening after results / before results))*100 = % change after treatment

(1-(173.3/192.9))*100 = 10% decrease in air infiltration
due to window conservation treatment

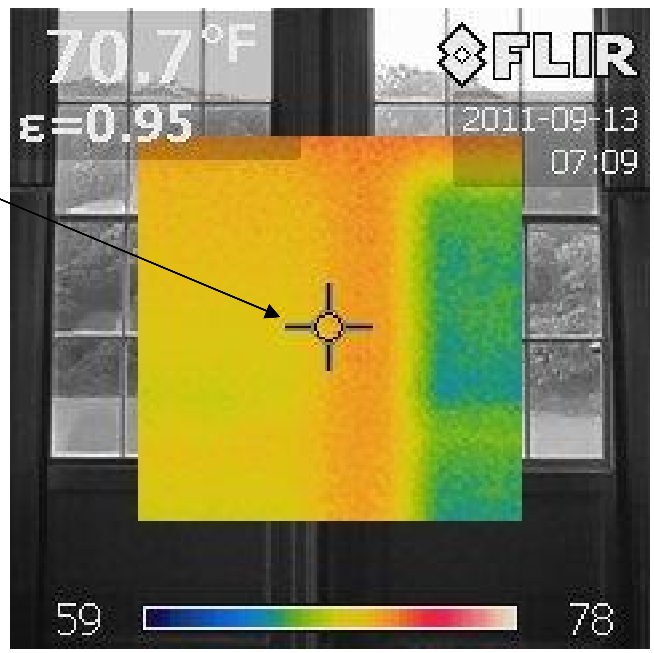
Calculations taken before and after the window repair work show that the work reduced air leakage by 10%.

<u>Thermal Imaging</u>
Thermal imaging measures surface temperatures using an infrared camera. This tool detects radiation in the infrared range. The amount of radiation emitted by an object is proportional to the temperature radiating from the object. Thus, images record the temperature variations of the object ï the building's surface, windows, water pipes, electrical wires, etc. The colors range from white for very hot regions to black for very cold areas. When used for house assessments, the colors tend to range from red (warm) through yellow to blue (cool). The color differences provide a quick picture of general temperature ranges ï even when the differences in temperature of an object vary by less than 20 degrees.

Temperature at this point is 70.7°F

IR image overlaid on black and white image shows impact of interior storm window on the left and no interior storm window on the right.

The blue on the right reflects the cold glass when the exterior temperature is lower than the room temperature.



Thermographic scans are commonly used while a blower door test is running. The blower door helps exaggerate air leaking through defects in the building shell. When outside temperatures are 30+ degrees cooler than indoor temperatures, the cool air can be seen to visually ñwashò blue across an otherwise yellow or red surface as it enters the building. The imagery provides a very visible reference point for air leakage.

<u>Smoke Pencil/Puffer Sticks</u>

Much more economical than an infrared camera, a smoke pencil releases a non-toxic colored vapor that looks like a puff of smoke. This device can be used to locate air leaks by identifying wind currents within a room.

<u>HERS Rating</u>

An energy audit will generally analyze utility usage, calculate air leakage, provide methods for energy conservation improvements and sometimes a HERS Index rating. A home energy rating system (HERS) rating is an analysis of a home's projected energy efficiency in comparison to a "reference homeò. The energy auditor will analyze different components of a building system ï walls, insulation, windows, heating and cooling systems, and appliances ï and give grades. The grades are converted into a metric that can then be compared to those of other homes. The lower a home's HERS Index, the more energy efficient it is. As historic homes were not built to current efficiency codes and HERS analysis can only truly be applied to modern construction, the real value of this rating for a historic home is somewhat moot.