Energy Audit

Sudbury Town Hall

322 Concord Road
Sudbury, MA 01776

Prepared for:
Massachusetts Department of Energy Resources

Energy Audit Program

Prepared by:

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Executive Summary

The Massachusetts Department of Energy Resources contracted with Facility Energy Consultants, LLC, (FEC) to conduct an energy audit of the subject property, Sudbury Town Hall, located at 322 Concord Road, Sudbury, Massachusetts 01776. The audit consisted of a building evaluation aimed at 1) assessing the overall energy usage efficiency of the building and its on-site systems, 2) identifying potential energy areas of improvement in these systems based on a maximum of a 15 year payback period, and 3) where applicable, proposing "clean energy" alternatives to the current systems where future energy savings could be realized. Included as part of the audit was a review of the building's construction features, its historical energy costs, discussions with the local utilities concerning the property's energy usage, and discussions with the prime energy equipment suppliers/manufactures for the purpose of determining more efficient alternatives. The energy audit site visit was performed on June 17, 2009.

1.1 General Description of Building

The Sudbury Town Hall is a 2-story building which reportedly contains 12,789 interior square feet. The building was reportedly originally constructed around 1930. A small subsequent addition was completed in the 1940s. The original building includes a large multi-purpose room on the first floor and a large room above with a high ceiling, stage, and balcony. Some town offices are located in the first floor addition.

The HVAC system has not been upgraded recently and no significant energy improvements were reported or observed.

Mr. Jim Kelly served as the on-site representative for the energy audit.

1.2 ECM Table

FEC has identified 3 Energy Conservation Measures (ECMs) for this property. The following table summarizes these ECMs in terms of description, the initial investment required to implement these ECMs and their impact on energy and cost savings.

Proposed ECMs			Effect on connected electrical load (kW)	Annual Energy Usage								Annual Reduction in Greenhouse Gas (CO_2) Emissions (Tons)	Annual Savings
#	Description	Installed Cost		Existing			Savings with ECM			% Reduction			
				KWh	MMBTU		KWh	MMBTU					
					Primary Fuel	Backup Fuel		Primary Fuel	Backup Fuel	KWh	MMBTU		
1	Install Attic Insulation	$ 3,500			1348.5			154.1			11.43%	8.17	$ 2,312
2	Insulate Steam Pipes	$ 3,800			1348.5			68.8			5.10%	3.65	$ 1,032
3	Increase Radiator Output	$ 1,350	4.5	1800	1348.5		1800	-7.8		100%	-0.58%	0.35	$ 171
	Total:	$ 8,650		42572	1348.5		1800	215.1		4.2%	16.0%	12.16	$ 3,515

1.3 Financial Summary

If these ECMs are implemented, the Sudbury Town Hall can potentially save approximately $3,515 per year with an investment of $8,650.

1.4 Clean Tech

There currently does not appear to be clean technology opportunities available at the Sudbury Town Hall.

2 Introduction

Through the Energy Audit Program (EAP) offered by the Commonwealth of Massachusetts, Department of Energy Resources (DOER), technical assistance is provided to cities, towns, regional school districts and wastewater districts to identify capital improvements to reduce energy costs.

The purpose of this audit report is to provide the program participant with a list of energy conservation projects, their costs and estimated energy savings. This information may be used to support a future application to DOER's Energy Conservation Improvement Program, support performance contracting or justify a municipal bond funded improvement program. EAP is a state funded grant program that provides funds for energy conserving capital improvements.

The approach taken in this audit included a thorough walk-through of the buildings and associated systems and equipment, including both process systems and building systems. The major areas covered in the audit included the building envelope, electrical systems, HVAC systems, lighting systems and operational and maintenance procedures. Another element of the audit is an initial interview and ongoing consultation with operational and maintenance personnel as well as building occupants. This approach is critical to the quality of the audit process, since the input of building personnel is invaluable to the effort to obtain accurate information required for the audit

Facility Energy Consultants, LLC, (FEC) is pleased to submit this Energy Audit for the subject property. Our services have been performed in accordance with the scope of services and terms and conditions in FEC's contract with the Massachusetts Department of Energy Resources dated January 26. 2009.

The conclusions, recommendations, and financial implications presented in this report are based on a brief review of available drawings, interviews with key personnel who have a working knowledge of this property, our site observations, and our experience on similar projects. Observations were made by a trained professional or professionals but there may be energy conservation opportunities at the facility that were not readily accessible, not visible or which were inadvertently overlooked. Additional energy conservation measures may develop with time that were not evident at the time of this audit.

Recommendations presented in this report are conceptual in nature and are not intended to serve as a scope of work for implementation. Additional assessment and preparation of construction drawings may be required in order to develop a formal scope of work and to develop actual implementation budgets.

Opinions of probable capital costs are intended only to provide an order of magnitude or scale of the recommendations and were prepared, without developing a formal scope of work. The Opinions of Probable Costs were based on a combination of sources including published sources of cost data such as R.S. Means, discussions with the site contact(s) and others identified in this report and our experience with other projects. Actual costs will be dependant upon many factors that are beyond FEC's control including but not limited to the quality of the type and design of the remedy/replacement, quality of the materials and installation, manufacturer and type of equipment or system selected, field conditions, the extent of work performed at any one time, whether items are purchased individually or under a master purchase contract, and other factors. Additionally, bids for work can vary widely (e.g., 50-percent to 200-percent of the mean bid). If any of the opinions of probable capital costs presented herein are considered critical in making decisions about the Subject Property, FEC recommends that formal scopes of work be developed and quotations be obtained from contractors or suppliers, prior to making a final decision on the property.

3 Facility Description

The Sudbury Town Hall is a 2-story building which reportedly contains 12,789 interior square feet. The building was reportedly originally constructed around 1930. A small subsequent addition was completed in the 1940s. The original building includes a large multi-purpose room on the first floor and a large room above with a high ceiling, stage, and balcony. Some town offices are located in the first floor addition.

The large first floor multi-purpose room is primarily used for the Board of Selectmen and other town government meetings approximately four times a week. Otherwise, this room is unoccupied. The large upstairs room is currently used to house the operations and artifacts of the Sudbury Historical Society.

The building is typically open from 8:00 am to 4:00 pm Monday-Friday and is also open occasionally in the evenings for town government meetings. We estimate that the building is at least occupied for around 2,080-hours per year. A total of six to seven town employees have offices within this building.

The building is of poured concrete foundation walls with assumed interior brick and wood framing. The roof is pitched, covered with asphalt shingles and supported by steel trusses. The first floor windows are double-pane insulated units. The second floor windows are the original single-pane, double-hung, wood-framed windows. There are multiple entrances with both wood and insulated steel doors. One exterior door, installed subsequent to the original construction, provides direct access to the multi-purpose room space.

The original building does not have air conditioning and the multi-purpose room is only heated to 65 degrees when not being occupied. The historical society space on the second floor is not heated.

Heating is provided by a Weil-McLain steam boiler located in a basement mechanical room. The boiler is rated at 1,703 MBH and supplies steam to radiators and radiating pipes throughout the original building. Condensate is returned by gravity and traps throughout the building to a condensate pump in the boiler room. Condensate is collected in a tank before returning to the boiler. The boiler also supplies steam to a heat exchanger that heats water for circulation to the1940s addition. Boiler control is by pressure demand only. Original building HVAC control is by thermostat only. Mr. Art Richard, the building supervisor, manually adjusts the temperature of the multi-purpose room in anticipation of events.

The 1940s addition is supplied by a hot water loop from the stem to water heat exchanger located in the boiler room. Temperature control is by a thermostat inside the office space. Air conditioning to these offices is provided by a three ton roof-top package unit, and conditioned air is delivered to the space by ductwork in the ceiling of the addition.

Domestic hot water is supplied to the offices by a 2.5-gallon electric water heater located underneath the restroom sink serving the offices. At the other end of the building is a 20-gallon electric water heater located under the front steps that serves both restrooms off of the multi-purpose room as well as a mop sink in the men’s restroom.

The interior lighting of commonly used spaces is primarily supplied by energy efficient T8 florescent fixtures with electronic ballasts.

4 Energy Usage Analysis and Benchmarking

4.1 Usage Analysis

The following table summarizes the basic energy rates and FY08 energy cost expenditure data that formed the basis for many of the calculations in this report.

Utility	Provider	Rates	FY08 Expenditures
Electric	NSTAR	$ 0.160/kWh	$6,829.00
Gas	NGRID	$1.76/therm	$23,676.00
#2 Oil	NA	NA	NA
Water & Sewer		NA	NA
Propane Gas		NA	NA
TOTALS			**$ 30,505.00**

The following table lists the building's area and its total energy and cost indices. The total energy index is a measure of energy intensity, or annual energy usage per square foot of building area. Similarly, the energy cost index is a measure of annual energy costs per square foot of building area.

Heated Area (SF)	Total Annual Cost Of Energy ($)	Energy Cost Index $/SF-Year	Total Energy Index (KBTU/SF-YR)
12,798	$ 30,505	$2.39	117

4.2 Benchmarking in Energy Star

Benchmarking has been employed in order to make determinations of the relative energy efficiency of this facility. FEC, in cooperation with the Massachusetts Department of Energy Resources, is using the Portfolio Manager tool developed by the Federal EPA. The Portfolio Manager tool allows the input of historic utility data of a facility to be compared to normalized data of a large database of buildings of its peers.

Energy Star has compiled a database of some facility types sufficient to allow energy use comparisons.

The energy use metric (energy intensity) of KBTU/SF/yr was used as a general guide to determine the efficiency of this facility. Sudbury Town Hall's energy intensity is 117 KBTU/SF/YR with an energy cost of $2.39 per square foot. Both of these figures are high. Based on this, it was determined that this facility should be audited for potential energy savings measures.

After adjustment of some building assumptions, this building rated in the 33rd percentile for energy efficiency against Energy Star's Office Building database.

The results generated by Portfolio Manager related to this facility are displayed below in section 4.3.

4.3 Statement of Energy Performance

Energy Performance Comparison

	Evaluation Periods		Comparisons		
Performance Metrics	**Current** (Ending Date 06/30/2008)	**Baseline** (Ending Date 06/30/2008)	**Rating of 75**	**Target**	**National Average**
Energy Performance Rating	33	33	75	N/A	50
Energy Intensity					
Site (kBtu/ft2)	117	117	72	N/A	98
Source (kBtu/ft2)	148	148	92	N/A	124
Energy Cost					
$/year	$ 30,506.00	$ 30,506.00	$ 18,904.32	N/A	$ 25,561.83
$/ft2/year	$ 2.39	$ 2.39	$ 1.48	N/A	$ 2.00
Greenhouse Gas Emissions					
$MtCO_2e$/year	90	90	56	N/A	75
$kgCO_2e$/ft2/year	7	7	4	N/A	6

5 Energy Conservation Measures

FEC has identified 3 Energy Conservation Measures (ECMs) for this property. The following table summarizes these ECMs in terms of description, the initial investment required to implement these ECMs and their impact on energy and cost savings.

Proposed ECMs			Effect on connected electrical load (kW)	Annual Energy Usage								Annual Reduction in Greenhouse Gas (CO_2) Emissions (Tons)	Annual Savings
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	Total:	$ 8,650		42572	1348.5		1800	215.1		4.2%	16.0%	12.16	$ 3,515

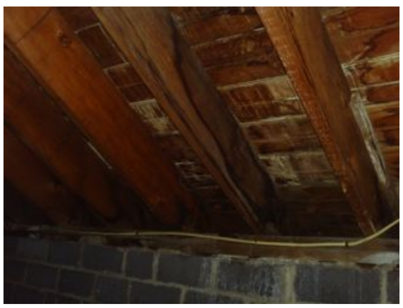
If these ECMs are implemented, the Sudbury Town Hall can potentially save approximately $3,515 per year with an investment of $8,650.

5.1 ECM Discussion

FEC has identified 3 Recommended Energy Conservation Measures (ECMs) for this property. The following paragraphs describe each of these ECMs along with the initial annual energy savings and payback period for each ECM.

There are many building systems and spaces at the Bedford Town Hall that will require attention and investment in the near term in order for the building to continue to serve its intended function. The ECMs listed here are recommended for energy savings; however, the long term plan of the building and its components should be considered as some ECMs may be better implemented within the scope of a renovation project.

5.1.1 Install Attic Insulation



No attic insulation

Only the first floor of the town hall is used on a regular basis. There is typically no heat supplied to the second floor. There is no insulation in any of the spaces above the heated lower level.

There is more than one option for the location of the insulating layer. Since the first floor is the only space that is currently insulated, the insulation could be installed between the two floors. Another option is to insulate above the second floor. This would make the most sense if it anticipated that the second floor of this building may be used for more than storage at some point in the future. A third option would be to insulate between the rafters either with conventional insulation which would require venting or spray-in foam insulation. The best option would best be chosen with regards to the building's future.

Recommendation: Insulation is recommended. For the sake of this calculation, R-19 fiberglass insulation will be installed above the second floor ceiling at the level of the bottom of the steel roof trusses.

R-19 insulation was analyzed versus using R-30 insulation. Since the first floor is heated to only 65 degrees most of the time, R-19 insulation is sufficient. If the space is intended to be occupied for regular business hours and a higher set temperature is desired, R-30 may be a better choice.

Cost to implement	$3,500	Est. annual cost savings	$2,312	Payback period	1.5 years

5.1.2 Install Insulation on Steam and Condensate Return Piping

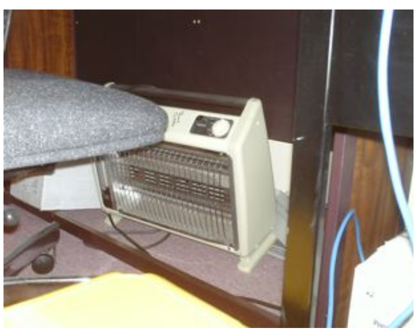
Condensate return tank and uninsulated steam piping

Steam piping in the area around the boiler was observed to be missing insulation. Steam piping at the end of the steam loops at the crawl spaces below the steps to the second floor of the original building was observed to be without insulation. All observed condensate return piping was observed to be without insulation. These pipes are in unconditioned spaces. Most of the heat that is dissipated through these uninsulated pipes will not contribute to building heat.

Recommendation: Steam, hot water, and condensate return piping should be insulated particularly if it runs through spaces that are not conditioned as the heat lost does not contribute to building heating. It is recommended that uninsulated steam, hot water, and condensate piping be insulated.

Cost to implement	$3,800	Est. annual cost savings	$1,032.00	Payback period	3.7 years

5.1.3 Increase Radiator Output



Electric space heater

Some of the office workers are uncomfortably cold in the winter. In order to maintain comfort, they use electric space heaters. Electric heat is expensive. It would be more cost effective to use the central hot water loop to provide additional heating to cold spaces in the building.

Airflow across a radiator can increase its output. Small fan units can be added to or near radiators to increase their heat output. Even more heat can be generated by installing a cabinet heater on the steam or water loop. The only electric required for these type heaters is the electric to run the small fan motor.

Recommendation: It is recommended that small fan units be located in cold areas of the office in lieu of electric space heaters.

Cost to implement	$1,350	Est. annual cost savings	$171.00	Payback period	7.9 years

5.2 Other ECMs Considered

The steam boiler in the Town Hall is old, and steam systems in small buildings are difficult to maintain well. Although the Town Hall's steam system seemed to be well maintained, the level of maintenance required to keep all of the traps functioning and keep water quality high requires more maintenance time than should be required for a smaller building. A typical solution is to convert the existing steam system to a hot water system. Often the condensate return lines are large enough to accept this change to serve as the hot water return. However, if pipes are old or in poor condition, it is probably best to replace them at the time of the conversion. FEC estimates that a system conversion at the Town Hall would cost around $250,000 which would include replacement of all of the piping and a new condensing boiler. Although this would likely save $5,000 to $6,000 dollars annually from a reduction in natural gas consumption, it does not return the investment on energy efficiency alone. The boiler system will require replacement at some point and this conversion should be considered at that time.

The A/C rooftop package unit was considered for replacement with a more efficient unit. Energy savings does not justify this upgrade with a simple payback period less than the anticipated life of a new unit.

The second floor windows are the original single-pane double-hung windows. Since the second floor of the building is currently not heated, there is very little benefit to upgrading these windows at this time. If this becomes usable heated space in the future, it can be expected that quality replacement windows will return the investment in energy savings in approximately 15 to 20 years.

The door that directly accesses the first floor multi-purpose room was designed for handicapped accessibility. Based on conversations with building management, the door gets frequent use during town government meetings. This can be uncomfortable as there is no vestibule to trap the heat loss. Because the radiant heat in this space takes a long time to recover to the temperature set point, the room will remain uncomfortable for a period. A full vestibule enclosure could be constructed outside of the building, but it may be better to encourage those who don't need the accessibility feature to use the main entrance with its vestibule.

The condensate return tank would also benefit from insulation, but the cost of this work and the return was below the threshold for consideration as a general ECM.

6 Operational and Maintenance Analysis

The quality of the maintenance and operation of the facility's energy systems has a direct effect on its overall energy efficiency. Energy efficiency needs to be a consideration when implementing facility modifications, equipment replacements, and general corrective actions. The following is a list of activities that should be performed as part of the routine maintenance program for the property. These actions, which have been divided into specific and general recommendations, will insure that the energy conservation measures identified in this report will remain effective. The following general recommendations should be continued or implemented.

Building Envelope

1. Caulking and weather stripping is functional and effective.
2. Holes are patched in the building envelope.
3. Cracked or fogged windowpanes are repaired.
4. Automatic door closing mechanisms are functional.
5. Interior vestibule doors are closed.

Heating and Cooling

6. Temperature settings are reduced in unoccupied areas and set points are seasonally adjusted.
7. Steam condensate return traps are checked regularly and repaired and replaced as needed.
8. Equipment is inspected for worn or damaged parts.
9. Heating is uniform throughout the designated areas.
10. Evaporator and condenser coils in AC equipment are clean.

Domestic Hot Water

11. Domestic hot water heater temperature is set to the minimum temperature required.
12. All hot water piping is insulated and not leaking.
13. Tank-type water heaters are flushed as required.

Lighting

14. Only energy efficient replacement lamps are used and in-stock.
15. Lighting fixture reflective surfaces and translucent covers are clean.
16. Walls are clean and bright.
17. Timers and/or photocells are operating correctly on exterior lighting.

Miscellaneous

18. Refrigerator and freezer doors close and seal correctly.
19. Office/computer equipment is either in the "sleep" or off mode when not used.

7 Clean Technology Opportunities

The Commonwealth of Massachusetts is dedicated to promoting clean energy as an alternative to traditional sources of energy. As such, the DOER and other agencies have developed a number of programs to promote the use of clean energy sources by potentially providing technical assistance and/or financial incentives based on project feasibility. A brief discussion of the various programs is provided below, along with specific projects that may be appropriate for the respective technologies.

Solar

Through the Commonwealth Solar Program[1], rebates are offered to encourage the installation of solar photovoltaic (PV) power by homeowners, businesses and municipalities. The rebate program is designed to help defray the costs that are associated with the installation of eligible systems from 20% - 60%. Rebate applications have been available since January 23, 2008. Incentives are greater for projects on public buildings and those that incorporate products manufactured in Massachusetts. The rebates are available for systems that will be directly owned by the applicant, as well as those financed through a third-party ownership model that takes advantage of federal and state tax credits. A total of $68 million is available over the next four years. The following table provides the initial rebate levels:

Non-Residential Rebates for Incremental Capacity ($/Watt)				
Incremental Capacity	**First:** **1 to 25 kW**	**Next:** **> 25 to 100 kW**	**Next:** **> 100 kW to 200 kW**	**Next:** **> 200 kW to 500 kW**
Base Incentive	$3.15	$3.00	$2.00	$1.40
PLUS: Additions to Base Incentives				
Massachusetts Manufactured System	$0.15	$0.15	$0.15	$0.15
Public Building	$1.00	$1.00	$1.00	$1.00

Third-Party PV Financing Resources

MTC and DOER encourage applicants to explore various options for financing their PV project. One such option is known as Third-Party Financing. With Third-Party Financing, the PV system is owned and operated by an entity that is separate from the building owner or the PV installer. The Third-Party Financing entity has sufficient financial capital to pay for the entire installation and to maintain and operate the system over its lifetime. In return, the building owner, or “host” site, signs a long term contract agreeing to purchase all the power produced by the PV system.

Third-Party Financing is a way to install a large PV array with little or no up-front capital expense from the building owner or “host” site. This type of financing may be most applicable to entities such as non-profits or public buildings. The Third-Party PV Owner can utilize the substantial tax incentives available for PV projects, along with rebates and other incentives, plus the sale of the electricity from the PV array to finance the PV project.

Solar Hot Water

The State supports the use of solar hot water systems and the payback periods are generally attractive for buildings with high water usage. Systems are generally composed of solar thermal collectors, a fluid system to move the heat from the collector to its point of usage, and a reservoir or tank for heat storage and subsequent use. The systems may be used to heat water for home or business use, for swimming pools, underfloor heating or as an energy input for space heating and cooling and industrial applications. Attractive applications for town buildings and facilities may include municipal pools, schools especially with summer locker room or kitchen usage, fire stations, and public housing facilities. On a periodic basis, the DOER accepts grant applications for solar hot water systems.

[1] Web site: www.commonwealthsolar.org

Solar at Sudbury Town Hall
Solar PV at Sudbury Town Hall is not recommended. Even given available incentive programs, a solar photovoltaic will not achieve a justified simple payback.

The current domestic hot water demand is relatively low. For this reason, a solar hot water feasibility study is not recommended for this facility.

Wind

The Massachusetts Renewable Energy Trust's (MRET) Commonwealth Wind initiative will provide an overarching framework to expand investments for wind energy installations in Massachusetts and help the Commonwealth meet Governor Deval Patrick's 2000 MW by 2020 wind goals as well as the Renewable Portfolio Standard (RPS). MRET will formally launch Commonwealth Wind during the summer of 2009 and additional details on the program will be available then. The three types of projects listed below would qualify for technical and/or financial assistance:

- Commercial scale projects that primarily serve wholesale markets
- Community-scale projects in the 100 kW to approximately2 MW range where the project sponsor and primary beneficiary is a private company or organization, a municipality, or a government agency, and
- Small-scale projects under 100 kW serving residential, small commercial or institutional buildings.

Wind at Sudbury Town Hall
Based on the wind map of Massachusetts provided by the U.S. Department of Energy, Sudbury is located in a Class 1 or 2 wind region. A Class 1 wind is defined as wind power rated at 0-200 watts/square meter at a height of 50 feet. Class 2 wind is defined as wind power rated at 200 to 300 watts/square meter. These are the lowest wind power designation and regions with a Class 1 and 2 designations are typically not recommended for wind energy projects. A Massachusetts wind resource map can be found at the following web site: http://www.windpoweringamerica.gov/maps_template.asp?stateab=ma

Wood Pellet Fueled Heating

On a periodic basis, the DOER accepts grant applications for wood pellet fueled heating systems[2], which burn pellets made from renewable sources of energy such as compacted sawdust, wood chips, bark and agricultural crop waste. Funding is available to cities, towns, regional school districts, as well as water and wastewater districts. A maximum of $50,000 per project is available for installation; however, applicants may propose greater grant requests, which will be considered based on the merits of the project and available funding. A total of $525,000 is available for this program. The grantee is responsible for repaying 30% of the funds granted within one year of the completed installation.

Wood Pellet Heating for Sudbury Town Hall

Biofuels are typically attractive alternatives as a heating fuel in locations where wood pellets are available in bulk, the heating demand is sufficient to justify the investment, and when heating fuels with a greater cost than natural gas are the only alternatives. Sudbury does not meet this profile and biofuel heating is not recommended as a cost effective alternative.

7.1 Recommended Clean Energy Projects for Sudbury Town Hall

Based on this audit, and due to its location, Sudbury Town Hall does not currently exhibit a building profile that would lend itself to implementation of these clean technologies.

[2] http://www.mass.gov/Eoca/docs/doer/pub_info/doer_pellet_guidebook.pdf

8 Other Considerations

In addition to the actions recommended in Section 6 of this report, the following recommendations should also be considered.

No other recommendations have been identified.

9 Appendices

ECM Calculations

Install Attic Insulation

Step 1 Obtain total cost of installing selected type of insulation.

	a	R-13 add'l insulation (total labor & material costs):	R19 $.5/sf	$3,500	$
	b	R-30 add'l insulation (total labor & material costs):	R30 $.8/sf	$5,000	$
	c	R-42 add'l insulation (total labor & material costs):			$

d Incremental cost of adding R-30 insulation vs. R-13 insulation:

1b: $5,000 - 1a: $3,500 = $1,500 $

e Incremental cost of adding R-30 insulation vs. R-13 insulation:

1c: 0.00 - 1b: ___ = ___ $

Step 2 Transfer the following information from the Survey:

4-8	**a**	Heating degree-day zone:		2.30	DDZ
4-34	**b**	Attic area:		5,000	sq. ft.
4-35	**c**	Existing insulation level:		0	inches
4-35	**d**	Existing insulation type:			
	e	Existing insulation R-value (use Table 1):		2	R
5-9	**f**	Cost of heating fuel:	Gas:	1.5	$/therm
			Oil:	N/A	$/gal
			Electric:	0.16	$/kWh
			Propane:	NA	$/gal

Step 3 Obtain the following savings factors from Table 2:

Table 2	**a**	R-13 add'l insulation:	
Table 2	**b**	R-30 add'l insulation:	0.143
Table 2	**c**	R-42 add'l insulation:	

Step 4 Estimate annual energy savings:

a R-13 add'l insulation:

2a: 2.30 x 2b: 5,000 x 3a: 0.13 = 1541.00 /yr

b R-30 add'l insulation:

2a: 2.30 x 2b: 5,000 x 3b: 0.01 = 104 /yr

c R-42 add'l insulation:

2a: 1.74 x 2b: 35,000 x 3c: 0.00 = 0.00 /yr

Step 5 Calculate annual cost savings:

a R-13 add'l insulation:

4a: 1541.00 x 2f: 1.50 = 2311.50 $/yr

b R-30 add'l insulation:

4b: 104 x 2f: 1.50 = $155 $/yr

c R-42 add'l insulation:

4c: 0.00 x 2f: ___ = 0.00 $/yr

Step 6 Calculate payback period:

a R-13 add'l insulation:

1a: 3500.00 / 5a: 2311.50 = 1.51 yrs

b R-30 add'l insulation:

1d: $5,000 / 5b: $155 = 32.2 yrs

c R-42 add'l insulation:

1e: ___ / 5c: 0.00 = 0.00 yrs

Table 1: R-value vs. Thickness for Typical Attic Insulation Materials

Thickness (inches)	**R-Value** Batt Fiberglass	Dry Cellulose	Loose Fill Fiberglass
0	1.6	1.6	1.6
1	3	4	3
2	7	7	5
3	10	11	8
4	13	14	10
5	17	18	13
6	19	21	15
7	23	25	18
8	26	28	20
9	30	32	23
10	33	35	25
11	36	39	28
12	40	42	30

Insulate Steam Pipes

Step 1	Obtain total cost of insulating steam and hot water pipes								
								3800	$
Step 2	Transfer the following information from the Survey:								
4-45		Heat distribution type (steam or hot water):							
4-48	**a**	Linear feet of uninsulated 3/4" diameter pipe:						540	ft.
4-48	**b**	Linear feet of uninsulated 1" diameter pipe:						#REF!	ft.
4-48	**c**	Linear feet of uninsulated 1-1/2" diameter pipe:						#REF!	ft.
4-48	**d**	Linear feet of uninsulated 2" diameter pipe:						#REF!	ft.
4-48	**e**	Linear feet of uninsulated 3" diameter pipe:						100	ft.
4-48	**f**	Linear feet of uninsulated 4" diameter pipe:						#REF!	ft.
4-48	**g**	Linear feet of uninsulated 6" diameter pipe:						#REF!	ft.
5-9	**h**	Cost of heating fuel:					Gas:	1.5	$/therm
							Oil:	#REF!	$/gal
							Propane:		$/gal
Step 3	Obtain the following value from Table 1:								
Table 1	Savings factors for heat distribution type								
Table 1	**a**	3/4" diameter pipe:						1.25	
Table 1	**b**	1" diameter pipe:							
Table 1	**c**	1-1/2" diameter pipe:							
Table 1	**d**	2" diameter pipe:							
Table 1	**e**	3" diameter pipe:						7.08	
Table 1	**f**	4" diameter pipe:							
Table 1	**g**	6" diameter pipe:							
Step 4	Estimate annual energy savings due to conduction losses:								
	a	3/4" diameter pipe:	2a		3a				
			0.00	x	1.25	=		0	/yr
	b	1" diameter pipe:	2b		3b				
			#REF!	x	0.00	=		#REF!	/yr
	c	1-1/2" diameter pipe:	2c		3c				
			100.00	x	1.57	=		157	/yr
	d	2" diameter pipe:	2d		3d				
			#REF!	x	0.00	=		#REF!	/yr
	e	3" diameter pipe:	2e		3e				
			100.00	x	5.31	=		531	/yr
	f	4" diameter pipe:	2f		3f				
			#REF!	x	0.00	=		#REF!	/yr
	g	6" diameter pipe:	2g		3g				
			#REF!	x	0.00	=		#REF!	/yr
	h	Total (add all results):						688	
Step 5	Calculate annual cost savings:								
			4h		2h				
			688.00	x	1.50	=		1032	$/yr
Step 6	Calculate your payback period:								
			1		5				
			3800.00	/	1032.00	=		3.7	yrs

Table 1: Savings Factors for Insulating Pipes

Heat Distribution Type	Pipe Size	Fuel Type: Gas	Oil	Propane
Hot water	3/4"	1.02	0.73	1.11
	1"	1.28	0.91	1.40
	1-1/2"	2.10	1.50	2.29
	2"	2.58	1.84	2.82
	3"	3.76	2.69	4.10
	4"	4.74	3.39	5.23
	6"	6.82	4.87	7.45
Steam	3/4"	2.16	1.54	2.36
	1"	2.68	1.91	2.93
	1-1/2"	3.96	2.83	4.32
	2"	4.90	3.50	5.35
	3"	7.08	5.06	7.73
	4"	8.96	6.40	9.78
	6"	13.12	9.37	14.32

Savings factors assume pipes are hot 2,000 hours per year. Actual savings will differ in warmer and cooler climates. Derated to 1500 hrs per year for this analysis

Increase Radiator Output

				Rates		
Electric heater wattage		1.5	kW		0.16	$/kWh
Annual run time/heater		400	hrs		1.5	$/therm
Number of heaters		3				
Annual energy consumption of heaters		1800				
Cost of electrical consumption	$	288.00				
Cost of installation of small air handlers	$	450.00	ea*	Total cost	**$**	**1,350.00**
Energy consumption of heaters		5200	BTUH			
Total Energy Consumption		78	therm			
Cost of additional energy consumption	$	117.00				
Annual savings = cost of electric consumption - cost of hot water =				**$**	**171.00**	
Capital cost = $150/unit and $300/unit for installation			Simpe Payback =			7.9