

Solar Hot Water Feasibility Analysis



Fairbank Center Pool

40 Fairbank Road
Sudbury, MA 01776

Prepared for:
Town of Sudbury, MA

Funded by:
Massachusetts Department of Energy Resources

Prepared by:
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1.0 INTRODUCTION

A solar hot water audit was performed on the Fairbank Center Pool located 40 Fairbank Road, Sudbury, MA through funding from the Massachusetts Department of Energy Resources (DOER). This report details the audit and associated analysis and the resulting feasibility of the potential project.

The solar hot water feasibility study of the Fairbank Center Pool was a result of a multi-site audit of the town owned facilities in Sudbury, Massachusetts.

The recommendations are based on estimated hot water flows, a single site review and a preliminary evaluation. The opinions of cost for the recommended upgrades are intended to be used for feasibility purposes only. For projects that are selected for further development, a dedicated water meter should be installed on the supply line to the hot water system and the hot water usage should be measured monthly for a period of two months. This information would be used in the final specification and detailed design of the hot water system. The selected projects should proceed to detailed design and evaluation followed by competitive bidding per the Massachusetts Procurement Guidelines. The resulting responses to the bid should be used for budget approval purposes. For more information see:

Office of the Inspector General, *Municipal, County, District, and Local Authority Procurement of Supplies, Services, and Real Property*, Publication No. CR-1520-170-200-09/06-IGO.

BACKGROUND

The Massachusetts Department of Energy Resources through its EAP program has awarded resources to municipalities throughout Massachusetts for energy audits of their facilities. As an additional service, identification of potential clean technologies such as solar hot water by the on-site energy consultants can result in a feasibility study of the potential implementation of the clean energy technology.

2.0 FACILITY DESCRIPTION & SITE ANALYSIS

The Fairbank Center Pool is located at 40 Fairbank Road, Sudbury, MA. The Fairbank Center in Sudbury, MA contains 28,076 interior square feet comprised of a senior center, school administrative offices, and recreation center. An 11,000 sf natatorium was added in 1987. This facility was originally constructed as a school in 1950. The single story building is now comprised of the original gymnasium, offices, multipurpose rooms, commercial kitchen, and the natatorium. The site area is owned by the town.

According to Mr. Tim Goulding, the aquatics director, the natatorium is open nearly 100 hours per week and hosts local club swim teams as well as school team. The Fairbank pool hosts numerous swim meets throughout the year. The pool facility is open from 5:30 am to 9:30 pm Monday through Thursday, 5:30 am to 7:00 pm Fridays, 6:30 am to 6:00 pm on Saturdays and 7:00 am to 4:00 pm on Sundays.

The natatorium consists of a 75' x 60' lap pool and a 25' by 40' dive pool. Both pools are always available and pool covers are not in use at the facility.

Locker rooms are off of the original school hallway adjacent to the pool and contain shower rooms as well as restroom facilities.

The facility's hot water demand is from restrooms, the kitchen, the shower areas adjacent to the pool, and the pool itself. The water heaters for the domestic hot water to the kitchen, the bathrooms, and the shower rooms are located in the original school boiler room down the hall from the pool. The pool water heater is located in a mechanical room.

Roof & Shading

There are some roof spaces to the north of the pool that are flat and may be able to accommodate a solar array. With the exception of the gym roof, most of these areas have existing roof mounted equipment that may make solar arrays on these roofs difficult.

The most promising location for a significant solar array is on the roof above the pool. This sloped roof is the original roof of the building. It is a low pitched roof with slopes (~20 degree) facing the southwest and the north east. The roof is a heavily ballasted rubber membrane that is now over twenty years old. The roof is supported by heavy laminated wood beams. There are no existing roof protrusions or adjacent structures, and it is assumed that the load of the solar array could be accommodated if the roof can be replaced in the near term with a non-ballasted system. The intent is to allow the structural capacity of the structure for ballasted roof can be substituted to support the array.

The roof of the pool is recommended as the best option for the proposed solar array. It is projected that most of the southwest facing roof would be required to support the solar array. Ballast removal with a roof replacement should relieve enough roof load so that the array can be mounted directly to the roof. The proposed solar array will require over 3800 square feet of roof surface area. This will encompass 80 percent of the available space on the south east facing roof. ***This means that it is likely that the roof would have to be replaced in order to install a solar hot water system.***

The structural design parameters were not found on the original construction documents so the amount of load that the roof was designed to accept is not known.

Although there are many trees that surround this facility, trees that are growing close to the roof are to the northeast and will only cast a shadow on a small portion of the roof for a short period of time. Furthermore, these trees and all others on the property are owned and maintained by the town. The town would be responsible for trimming nearby trees so that full solar access can be maintained.



Pool roof with ballast



Pool decking and ceiling above the pool

Important Note: As noted previously, there is evidence to suggest that this roof *may* support the solar hot water panel loads. However, a structural analysis *must* be performed on the affected members before the project is to proceed to construction. It is recommended that this be done prior to, or as part of, the detailed design phase for this project.

Hot Water System

The domestic hot water heating is produced by two natural gas-fired 399,000 90 gallon domestic water heaters. These serve all of the facility restrooms as well as the pool showers with hot water set at 122 degree F. According to the aquatic director, 250 short-duration showers may be taken during the course of a busy day. An 80 gallon electric water heater serves the infrequent demand in the kitchen.

Two pool heaters operate independently to maintain different temperature set points for each of the pools. The smaller pool heater, rated at 511 MBH maintains the dive pool between 84 and 85 degrees F. The lap pool is maintained between 82 and 82.5 degrees by a separate 800 MBH pool heater. Flow through the heaters is through a bypass loop off of the main filtration loop.

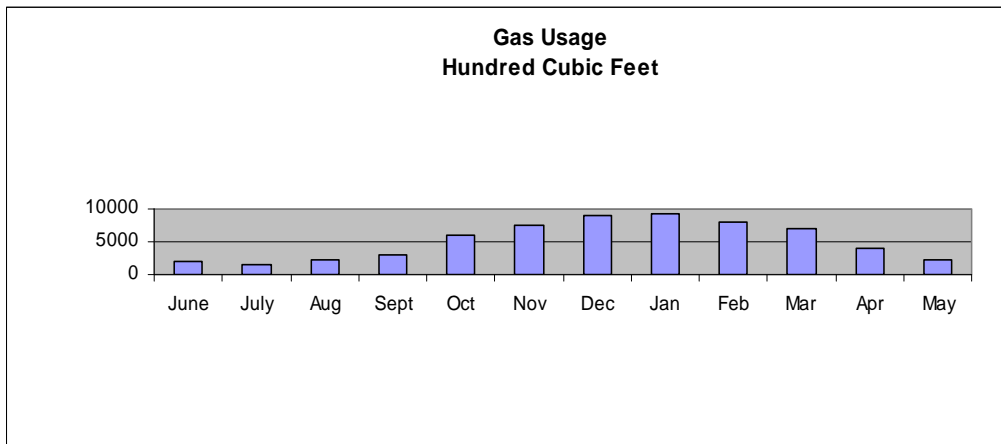


Existing pool heater and pool

Energy Profile

Fairbank Center Pool used 64,020 therms of natural gas during the most recent 12 month period of submitted gas usage.

| | | June | July | Aug | Sept | Oct | Nov | Dec | Jan | Feb | Mar | Apr | May | Total |
|-----|------|------|------|------|------|------|------|------|------|------|------|------|------|---------|
| Gas | FY07 | 2125 | 1620 | 2208 | 3113 | 5883 | 7567 | 8905 | 9267 | 7943 | 6958 | 4097 | 2276 | 152,894 |



A rate of \$1.60 per therm of natural gas and \$0.185/kwh for electricity was used for savings estimates in this report.

Estimated Hot Water Usage

One of the primary factors in sizing a solar hot water system is estimating the hot water usage. This is crucial so that the system can be properly sized to generate the appropriate amount of hot water. Too much hot water production can result in unused energy in the summertime and excess capital expended on a system too large for its demand.

Unfortunately, hot water is rarely metered and can be difficult to estimate due to the variation in usage (even within similar applications). In addition, hot water at the Fairbank Center Pool is generated for the domestic hot water including showers, by one system, and for pool water heating by a separate system. The largest hot water demand at Fairbank Center is for pool heating.

Indoor swimming pools lose heat from the surface of the pool due to evaporation. The rate of heat lost is directly proportional to the size of the surface exposed. Based on an exposed surface of 4300 square feet, it was calculated that approximately 2500 therms are required monthly to maintain the pool temperature.

The second largest demand for hot water at the school is for showers associated with swimming. Based on the daily pool use, the flow rate of the showerheads and the duration of a typical shower, it is estimated that showers consume approximately 100 therms per month.

Combined restroom and kitchen consumption are likely much less on a percentage basis and becomes irrelevant to the study.

The study needed to calculate the hot water demands of the pool and then consider adding the shower load to size the system. Because the HVAC system operates in a limited capacity in the summer and no natural gas is used for heat in the cooling season, it can be assumed that natural gas consumption in the summer should be used only to heat the pool and water for showers. Monthly consumption for the months of June, July, and August for 2007 and 2008 averaged 2000 therms*. Based on the estimated required consumption of the pool and calculating the assumed efficiency of the pool water heater, it is estimated that the pool water heater would consume 1900 therms per month and the showers would account for about 100 therms per month. This serves as a reasonability check and suggests that our calculated pool demand is somewhat higher, but a reasonable assumption. We decided to split the difference between the actual monthly summer heat demanded calculation and the demand calculated based on surface area. Monthly pool heating demand is assumed to be 2200 therms per month and domestic hot water consumption is assumed to be 100 therms.

It should be noted that there is significant month to month variation in consumption which is likely due to the actual days of consumption used on each billing period. The average of the consumption in summer months of the past two years was calculated to even out the variation.

3.0 SOLAR HOT WATER SYSTEM

Based on the data gathered and the calculated pool water heating demand, a solar collection system can be specified.

The RET Screen[®] software (rev 4) was used for the modeling of system performance and to determine equipment sizes. Originally, the model, based on evaporation calculations, output a hot water demand of approximately 2500 therms per month for pool heating only. Hot water demand calculated from actual summertime use resulted in total consumption of 2000 therms per month including showers. Based on this, the output of the baseline consumption of the sum of the showers and pool heaters was assumed to be 2000 therms per month. The total pool surface areas were adjusted from 4300 square feet to 3800 square feet in the model so that the calculated system consumption matched this assumption.

The detailed results and assumptions used in the analysis are in Appendix A. In summary, the recommended equipment sizes would include:

- 3825 square feet of collector area (for the cost estimate, 130 Stiebel Eltron Sol 25 collectors with associated mounting hardware were used)
- 4000 gallons of thermal storage with heat exchanger
- A \$25,000 allowance for locating the storage tank has also been added to the cost model. The ideal location for the hot water tank is adjacent to the pool in the pool equipment room. Based on our observations, there is not sufficient space for a tank of this size in the existing room. Two options were considered. One was locating the tank in the existing HVAC boiler room where there is sufficient space but additional piping would be required. The other option is to bump out the existing wall of the mechanical space adjacent to the pool to accommodate the tank. It is expected that either option will cost approximately \$25,000 to implement.

Other system components: circulator pump, expansion tank, pressure relief valve, feed water valve, backflow valve, strainer, automatic heat dump valve, balancing valve(s), boiler drains, air separator, air purge vents, thermowells, thermocouples, differential controller, pressure & temperature gages, and all associated pipes, manual valves and fittings. This closed loop system would need to be plumbed to the existing boiler. It is assumed that cost saving associated with a simplified array mounting system will be offset by the cost of additional piping to both water heaters.

The opinion of total capital cost for this system, including engineering, labor, and installation is \$365,978.00*. Calculations were based on assumed utility costs of \$0.185 per kWh and \$1.60 per gallon therm of natural gas; in addition, an annual energy escalation rate of 4% was used. These variables resulted in a project with financial viability in a seventeen year time frame. The project's cash flow becomes positive at 18. See Appendix B.

This analysis assumes that no "clean energy" incentives are provided to offset project costs, but natural gas consumption will be reduced by 1160 therms per year which correlates to an annual carbon emissions reduction of 61.5 metric tons.

Solar hot water systems tend to have long lives if properly maintained and have relatively low maintenance costs over the life of the system.

*The reality of municipal construction requires a very high level of detailed design, procurement and construction oversight. While these efforts and costs vary with project size, there is a certain minimum 'fixed cost' to performing a municipal project. Additionally, the municipal procurement process (designed around creating a fair and competitive environment) often results in moderately higher construction costs on these projects as compared to the private market.

4.0 RECOMMENDATIONS

Based on the site investigations and the initial analysis performed in this study, the Fairbank Center Pool appears to be a good candidate to host a solar hot water system. Positive contributing factors include:

- Consistent and significant hot water demand from the pool
- Potential of structural capacity for the solar array (more extensive evaluation is needed prior to project development)
- Sufficient unshaded roof area for collectors

The economics of this project are positive. The operational savings yield a positive cash flow prior to year 18 of the project. It is recommended that a solar hot water project for the Fairbank Center Pool be pursued, particularly if government incentives are available to defray some of the initial cost and shorten the simple payback of the project or fuel costs escalate at a rate higher than predicted.

5.0 SOLAR HOT WATER FATAL FLAW ANALYSIS FOR THE SUDBURY FIRE STATION

Other than municipal indoor pools, another potential use of solar hot water are town facilities with significant shower loads. Often, the highest shower loads in a location is that from the municipal fire department. Sudbury's fire department was analyzed as a potential site of a solar hot water system to meet its shower load.

The following factors are critical to the feasibility of a solar hot water system. A fatal flaw analysis is a quick overview of these parameters to determine if further study is warranted.

Demand:

Is there sufficient hot water demanded at regular intervals to justify a system?
Is the demand year round?

Analysis: Fatal Flaw

The hot water demand at the Sudbury Fire Department is year round but low with some occasional spikes in demand (when returning from a fire). The hot water demand is not significant or consistent.

System Configuration:

Is there enough sunlight at the site?
Are there any structural limitations to mounting a solar array in a suitable location?

Analysis:

There appears to be roof space available with little shading and it appears that the roof structure may support an array.

Conclusion: The hot water demand at the Sudbury Fire department is not sufficient to consider this as a potential location for solar hot water.



RETScreen® International

www.retscreen.net

Clean Energy Project Analysis Software

Project information

[See project database](#)

| | |
|-------------------------|-------------------------------------|
| Project name | Fairbank Center Pool |
| Project location | 40 Fairbank Road, Sudbury, MA |
| Prepared for | MassDOER |
| Prepared by | Russell Friend PE |
| Project type | Heating |
| Technology | Solar water heater |
| Analysis type | Method 2 |
| Heating value reference | Higher heating value (HHV) |
| Show settings | <input checked="" type="checkbox"/> |
| Language - Langue | English - Anglais |
| User manual | English - Anglais |
| Currency | \$ |
| Units | Imperial units |

Site reference conditions

[Select climate data location](#)

| | |
|-----------------------|-------------------------------------|
| Climate data location | Boston |
| Show data | <input checked="" type="checkbox"/> |

| | Unit | Climate data location | Project location |
|-----------------------------|------|-----------------------|------------------|
| Latitude | °N | 42.4 | 42.4 |
| Longitude | °E | -71.0 | -71.0 |
| Elevation | m | 5 | 5 |
| Heating design temperature | °C | -10.9 | |
| Cooling design temperature | °C | 30.9 | |
| Earth temperature amplitude | °C | 21.4 | |

| Month | Air temperature | Relative humidity | Daily solar radiation - horizontal | Atmospheric pressure | Wind speed | Earth temperature | Heating degree-days | Cooling degree-days |
|---------------|-----------------|-------------------|------------------------------------|----------------------|------------|-------------------|---------------------|---------------------|
| | °C | % | kWh/m ² /d | kPa | m/s | °C | °C-d | °C-d |
| January | -1.8 | 62.3% | 1.86 | 101.5 | 6.2 | -5.6 | 614 | 0 |
| February | -1.0 | 62.0% | 2.71 | 101.5 | 6.2 | -3.7 | 532 | 0 |
| March | 3.4 | 63.2% | 3.74 | 101.4 | 6.1 | 1.5 | 453 | 0 |
| April | 8.5 | 63.0% | 4.71 | 101.3 | 6.0 | 8.1 | 285 | 0 |
| May | 14.2 | 66.7% | 5.63 | 101.4 | 5.5 | 14.8 | 118 | 130 |
| June | 19.6 | 68.5% | 6.12 | 101.3 | 5.2 | 20.4 | 0 | 288 |
| July | 22.8 | 68.5% | 6.06 | 101.4 | 5.0 | 23.0 | 0 | 397 |
| August | 21.9 | 70.8% | 5.35 | 101.5 | 4.8 | 21.7 | 0 | 369 |
| September | 17.8 | 71.8% | 4.27 | 101.7 | 5.1 | 17.2 | 6 | 234 |
| October | 12.2 | 68.5% | 3.01 | 101.7 | 5.4 | 10.1 | 180 | 68 |
| November | 7.0 | 67.4% | 1.89 | 101.6 | 5.8 | 3.8 | 330 | 0 |
| December | 0.8 | 65.5% | 1.53 | 101.6 | 6.1 | -2.3 | 533 | 0 |
| Annual | 10.5 | 66.5% | 3.91 | 101.5 | 5.6 | 9.2 | 3,051 | 1,486 |
| Measured at | m | | | | 10.0 | 0.0 | | |



[Complete Energy Model sheet](#)

RETScreen Energy Model - Heating project

| Heating project | | | | | |
|--|---|---|---|--------------|---------------------------|
| Technology | | | | | |
| Solar water heater | | | | | |
| Load characteristics | | | | | |
| Application | <input checked="" type="checkbox"/> Swimming pool <input type="checkbox"/> Hot water | | | | |
| Type | Unit | Base case | Proposed case | | |
| Area | ft ² | Indoor 3800.0 | 3800.0 | | |
| Cover use | h/d | 0.0 | 0.0 | | |
| Temperature | °F | 81.0 | 81.0 | | |
| Makeup water | %/w | 2% | 2% | | |
| <input type="checkbox"/> Percent of month used | | | | | |
| Supply temperature method | Formula | | | | |
| Water temperature - minimum | °F | 43.2 | | | |
| Water temperature - maximum | °F | 58.7 | | | |
| Heating | Unit | Base case | Proposed case | Energy saved | Incremental initial costs |
| | million Btu | 1,991.1 | 1,991.1 | 0% | |
| Resource assessment | | | | | |
| Solar tracking mode | Fixed | | | | |
| Slope | 15.0 | | | | |
| Azimuth | 45.0 | | | | |
| <input checked="" type="checkbox"/> Show data | | | | | |
| | Month | Daily solar radiation - horizontal kWh/m ² /d | Daily solar radiation - tilted kWh/m ² /d | | |
| | January | 1.86 | 2.34 | | |
| | February | 2.71 | 3.15 | | |
| | March | 3.74 | 4.08 | | |
| | April | 4.71 | 4.89 | | |
| | May | 5.63 | 5.67 | | |
| | June | 6.12 | 6.09 | | |
| | July | 6.06 | 6.05 | | |
| | August | 5.35 | 5.49 | | |
| | September | 4.27 | 4.56 | | |
| | October | 3.01 | 3.42 | | |
| | November | 1.89 | 2.28 | | |
| | December | 1.53 | 1.90 | | |
| | Annual | 3.91 | 4.17 | | |
| Annual solar radiation - horizontal | MWh/m ² | 1.43 | | | |
| Annual solar radiation - tilted | MWh/m ² | 1.52 | | | |
| Solar water heater | | | | | |
| Type | Glazed | | | | |
| Manufacturer | Stiebel Eltron | | | | |
| Model | SOL 25 Plus | | | | |
| Gross area per solar collector | ft ² | 29.42 | | | |
| Aperture area per solar collector | ft ² | 26.69 | | | |
| Fr (tau alpha) coefficient | | 0.72 | | | |
| Fr UL coefficient | (W/m ²)/°C | 3.96 | | | |
| Temperature coefficient for Fr UL | (W/m ²)/°C ² | 0 | | | |
| Number of collectors | | 130 | 130 | | |
| Solar collector area | ft ² | 3824.6 | | | |
| Capacity | kW | 225.64 | | | |
| Miscellaneous losses | % | 5.0% | | | |
| Balance of system & miscellaneous | | | | | |
| Heat exchanger | yes/no | Yes | | | |
| Heat exchanger efficiency | % | 95.0% | | | |
| Miscellaneous losses | % | 5.0% | | | |
| Pump power / solar collector area | W/m ² | 8.00 | | | |
| Electricity rate | \$/kWh | 0.185 | | | |
| Summary | | | | | |
| Electricity - pump | MWh | 7.6 | | | |
| Heating delivered | million Btu | 956.9 | | | |
| Solar fraction | % | 48% | | | |
| Heating system | | | | | |
| <input type="checkbox"/> Project verification | | | | | |
| Fuel type | Base case | Proposed case | | | |
| Seasonal efficiency | Natural gas - therm | Natural gas - therm | | | |
| Fuel consumption - annual | therm | 23,989.5 | 12,461.1 | therm | |
| Fuel rate | \$/therm | 1.600 | 1.600 | \$/therm | |
| Fuel cost | \$ | 38,383 | 19,938 | | |

[See technical note](#)
[See product database](#)

RETScreen Cost Analysis - Heating project

| Settings | | | | |
|--|---|-------------|------|--|
| <input checked="" type="checkbox"/> Method 1 | <input checked="" type="checkbox"/> Notes/Range | Notes/Range | None | |
| <input type="checkbox"/> Method 2 | <input type="checkbox"/> Second currency | | | |
| | <input type="checkbox"/> Cost allocation | | | |

| Initial costs (credits) | Unit | Quantity | Unit cost | Amount | Relative costs |
|--|---------|------------|------------|------------|----------------|
| Feasibility study | | | | | |
| Feasibility study | cost | 0 | \$ - | \$ - | |
| Sub-total: | | | | \$ - | 0.0% |
| Development | | | | | |
| Development | cost | 0 | \$ 6,000 | \$ - | |
| Sub-total: | | | | \$ - | 0.0% |
| Engineering | | | | | |
| Engineering | cost | 1 | \$ 30,000 | \$ 30,000 | |
| Sub-total: | | | | \$ 30,000 | 8.2% |
| Heating system | | | | | |
| Solar water heater | | | | \$ - | |
| User-defined | cost | 1 | \$ 285,000 | \$ 285,000 | |
| Water tank accomodation | cost | 1 | \$ 25,000 | \$ 25,000 | |
| Sub-total: | | | | \$ 310,000 | 84.7% |
| Balance of system & miscellaneous | | | | | |
| Spare parts | % | 3.0% | \$ 285,000 | \$ 8,550 | |
| Transportation | project | | | \$ - | |
| Training & commissioning | p-d | | | \$ - | |
| User-defined | cost | | | \$ - | |
| Contingencies | % | 5.0% | \$ 348,550 | \$ 17,428 | |
| Interest during construction | 0.00% | 0 month(s) | \$ 365,978 | \$ - | |
| Sub-total: | | | | \$ 25,978 | 7.1% |
| Total initial costs | | | | \$ 365,978 | 100.0% |

| Annual costs (credits) | Unit | Quantity | Unit cost | Amount |
|----------------------------------|---------|----------|------------|-----------|
| O&M | | | | |
| Parts & labour | project | 1 | \$ 2,000 | \$ 2,000 |
| User-defined | cost | | | \$ - |
| Contingencies | % | | \$ 2,000 | \$ - |
| Sub-total: | | | | \$ 2,000 |
| Fuel cost - proposed case | | | | |
| Natural gas | therm | 12,461 | \$ 1.600 | \$ 19,938 |
| Electricity | MWh | 8 | \$ 185.000 | \$ 1,414 |
| Sub-total: | | | | \$ 21,352 |

| Annual savings | Unit | Quantity | Unit cost | Amount |
|------------------------------|-------|----------|-----------|-----------|
| Fuel cost - base case | | | | |
| Natural gas | therm | 23,989 | \$ 1.600 | \$ 38,383 |
| Sub-total: | | | | \$ 38,383 |

| Periodic costs (credits) | Unit | Year | Unit cost | Amount |
|--------------------------|------|------|-----------|-----------|
| User-defined | cost | 15 | \$ 28,500 | \$ 28,500 |
| | | 30 | \$ 28,500 | \$ 28,500 |
| End of project life | cost | | | \$ - |

RETScreen Financial Analysis - Heating project

| Financial parameters | | | |
|---|----|--|------|
| General | | | |
| Fuel cost escalation rate | % | | 4.0% |
| Inflation rate | % | | 3.0% |
| Discount rate | % | | 0.0% |
| Project life | yr | | 35 |
| Finance | | | |
| Incentives and grants | \$ | | 0 |
| Debt ratio | % | | 0.0% |
| Income tax analysis <input type="checkbox"/> | | | |

| Annual income | | | |
|---|---------|-------|--|
| Electricity export income | | | |
| GHG reduction income <input type="checkbox"/> | | | |
| Net GHG reduction | tCO2/yr | 59 | |
| Net GHG reduction - 35 yrs | tCO2 | 2,060 | |
| Customer premium income (rebate) <input type="checkbox"/> | | | |
| Other income (cost) <input type="checkbox"/> | | | |
| Clean Energy (CE) production income <input type="checkbox"/> | | | |

| Project costs and savings/income summary | | | |
|--|---------------|-----------|----------------|
| Initial costs | | | |
| Engineering | 8.2% | \$ | 30,000 |
| Heating system | 84.7% | \$ | 310,000 |
| Balance of system & misc. | 7.1% | \$ | 25,978 |
| Total initial costs | 100.0% | \$ | 365,978 |
| Annual costs and debt payments | | | |
| O&M | | \$ | 2,000 |
| Fuel cost - proposed case | | \$ | 21,352 |
| Total annual costs | | \$ | 23,352 |
| Periodic costs (credits) | | | |
| User-defined - 15 yrs | | \$ | 28,500 |
| | | \$ | 28,500 |
| Annual savings and income | | | |
| Fuel cost - base case | | \$ | 38,383 |
| Total annual savings and income | | \$ | 38,383 |

| Financial viability | | | |
|---------------------------|---------|--|---------|
| Pre-tax IRR - equity | % | | 5.6% |
| Pre-tax IRR - assets | % | | 5.6% |
| After-tax IRR - equity | % | | 5.6% |
| After-tax IRR - assets | % | | 5.6% |
| Simple payback | yr | | 24.3 |
| Equity payback | yr | | 18.1 |
| Net Present Value (NPV) | \$ | | 631,258 |
| Annual life cycle savings | \$/yr | | 18,036 |
| Benefit-Cost (B-C) ratio | | | 2.72 |
| GHG reduction cost | \$/tCO2 | | (306) |

| Yearly cash flows | | | | |
|-------------------|----------|-----------|------------|----|
| Year | Pre-tax | After-tax | Cumulative | |
| # | \$ | \$ | \$ | \$ |
| 0 | -365,978 | -365,978 | -365,978 | |
| 1 | 15,652 | 15,652 | -350,325 | |
| 2 | 16,299 | 16,299 | -334,026 | |
| 3 | 16,972 | 16,972 | -317,054 | |
| 4 | 17,673 | 17,673 | -299,382 | |
| 5 | 18,402 | 18,402 | -280,979 | |
| 6 | 19,162 | 19,162 | -261,818 | |
| 7 | 19,952 | 19,952 | -241,866 | |
| 8 | 20,775 | 20,775 | -221,091 | |
| 9 | 21,631 | 21,631 | -199,461 | |
| 10 | 22,522 | 22,522 | -176,938 | |
| 11 | 23,450 | 23,450 | -153,488 | |
| 12 | 24,416 | 24,416 | -129,073 | |
| 13 | 25,421 | 25,421 | -103,652 | |
| 14 | 26,467 | 26,467 | -77,185 | |
| 15 | -16,846 | -16,846 | -94,031 | |
| 16 | 28,689 | 28,689 | -65,342 | |
| 17 | 29,869 | 29,869 | -35,473 | |
| 18 | 31,097 | 31,097 | -4,376 | |
| 19 | 32,375 | 32,375 | 27,998 | |
| 20 | 33,705 | 33,705 | 61,703 | |
| 21 | 35,089 | 35,089 | 96,792 | |
| 22 | 36,530 | 36,530 | 133,322 | |
| 23 | 38,029 | 38,029 | 171,351 | |
| 24 | 39,590 | 39,590 | 210,941 | |
| 25 | 41,214 | 41,214 | 252,155 | |
| 26 | 42,905 | 42,905 | 295,060 | |
| 27 | 44,664 | 44,664 | 339,724 | |
| 28 | 46,495 | 46,495 | 386,219 | |
| 29 | 48,401 | 48,401 | 434,620 | |
| 30 | -87,970 | -87,970 | 346,649 | |
| 31 | 52,448 | 52,448 | 399,097 | |
| 32 | 54,595 | 54,595 | 453,692 | |
| 33 | 56,831 | 56,831 | 510,523 | |
| 34 | 59,157 | 59,157 | 569,680 | |
| 35 | 61,578 | 61,578 | 631,258 | |

