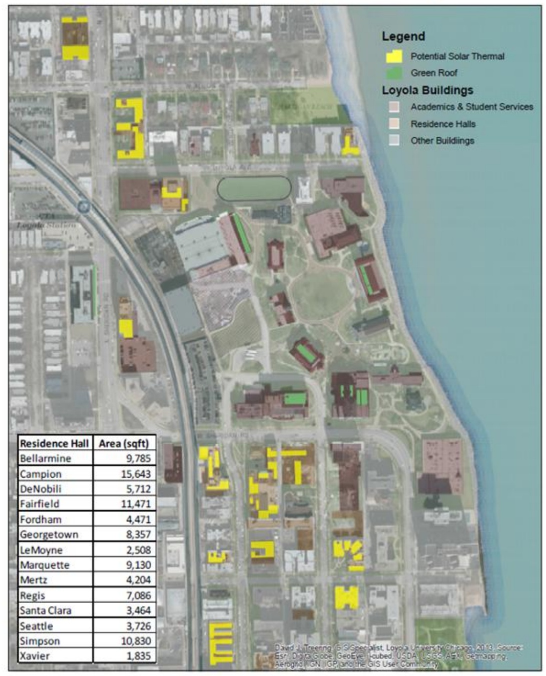
5/8/2014

# Loyola University Residence Hall Solar Thermal Feasibility Study

Loyola University enlisted Elara Energy Services to collaborate with students to prepare a residence hall solar thermal feasibility study. There are numerous items that should be considered when determining the feasibility of installing solar thermal for any building including:

- The amount of energy that can be harvested and associated energy cost savings
- The location(s) where the harvested energy can be used
- Understanding of existing site conditions
- Identification of the mechanical and electrical implementation costs

Potential Solar Thermal Roof Sites




In order to determine these items for each of the University's Lake Shore Campus residence halls, Elara collaborated with University students and faculty. All work on the Residence Hall Solar Thermal Feasibility Study was completed during the University's 2014 spring semester. This report was funded by Loyola's The Green Initiative Fund (TGIF), a sustainability fund for students, from students. Dana Buelsing, class of '14, was the project's student coordinator and led this effort on behalf of Loyola. Thank-you to the Institute of Environmental Sustainability, Residence Life, Facilities and the other students that assisted in making this project a success.

The following scope was completed as part of this collaborative study:

- Elara met with University students and discussed key concepts centered on data gathering and solar thermal design.
- Students, with the help of Elara, gathered and reviewed existing building drawings.
- Elara and University students conducted two site visits to review existing conditions and spot potential equipment locations. University students conducted the remaining 14 site visits with the help of facilities staff.
- Students gathered pertinent information including water and gas usage for each of the 16 residence halls.
- Elara reviewed the information gathered by the students and ranked the residence halls based on solar thermal feasibility.
- Elara evaluated the feasible buildings and calculated energy cost savings, implementation costs, and potential incentives.

## Data Gathering

The following is a summary of the data gathered for each of the residence halls being considered. Data was gathered from a combination of utility bills, site visits, existing drawings, and interviews with facilities staff. All data presented here is summarized in Table 1.

### A. Simpson Hall

Simpson Hall is a 5 story, year round residence hall with 417 beds and a dining hall. The available roof area for installing solar thermal panels is estimated approximately at 10,830 square feet which is ranked as the 3rd candidate among nineteen (16) residence halls. Simpson is also one of the largest water consumers among the residence halls. Simpson Hall has a clear sky and enough available mechanical space for associated equipment.

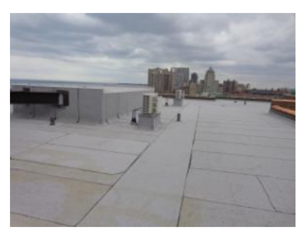
### B. Regis Hall

Regis hall is a 6 story, year round residence hall with 419 beds. The available roof area for installing solar thermal panels is estimated approximately at 7,090 square feet which is ranked as the 11th candidate among nineteen (16) residence halls. Regis Hall is one of the top five water consumers among the residence halls. Regis Center also has a clear sky and enough available mechanical space for associated equipment. There is no dining facility in Regis Hall.

### C. de Nobili Hall

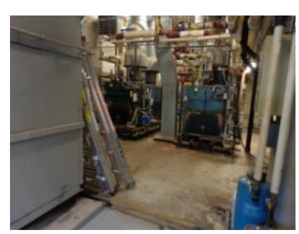
de Nobili Hall is a 5 story, year round residence hall with 200 beds and a dining hall. The available roof area for installing solar thermal panels is estimated approximately at 5,712 square feet which is ranked as the 9th candidate among nineteen (16) residence halls. de Nobili is estimated to be one of the top five water consumers among the residence halls due to the large dining hall on the first floor. de Nobili has a clear sky and enough available mechanical space for associated equipment.

### D. Santa Clara Hall



Santa Clara Hall is a 9 story, year round residence hall with 186 beds. The available roof area for installing solar thermal panels is estimated approximately at 3,464 square feet. Santa Clara Hall is ranked 9th among the 16 buildings in water consumption. Santa Clara Hall has a clear sky and enough available mechanical space for associated equipment. There is no dining facility in Santa Clara Hall.

### E. Fordham Hall



Fordham Hall is a 16 story, year round residence hall with 362 beds. Fordham has the 2nd highest water consumption of the 16 buildings and has substantial roof area for solar thermal panels. The building currently lacks mechanical space but was included because the existing domestic hot water heaters and storage tank are near the end of their useful life. Implementing a solar thermal system as part of a larger domestic hot water system replacement would take advantage of economies of scale and allow for consideration of space requirements for solar thermal equipment.

### F. Bellarmine Hall

Bellarmine Hall is a 5 story, year round residence hall with 300 beds. The available roof area for installing solar thermal panels is estimated approximately at 9,785 square feet. Bellarmine Hall is ranked 10th among the 16 buildings in water consumption (estimated). Bellarmine Hall has a clear sky but was eliminated from consideration after the site visit determined that there was not sufficient space for mechanical equipment.

### G. Campion Hall

Campion Hall is a school season only, 3 story residence hall with 304 beds. Campion Hall has significant roof area, mechanical space, and water usage but was eliminated from consideration due to no summer occupancy. Summer water use when the sun is strongest is critical for the design of a feasible solar thermal system.

### H. Canisius Hall

Canisius Hall is a school season only, 4 story residence hall with 70 beds. The building was eliminated from consideration due to limited mechanical space, relatively low water usage, no summer occupancy, and a large building blocking the southern exposure.

### I. Fairfield Hall

Fairfeild Hall is a school season only, 4 story residence hall with 201 beds. The building has a large water use and sufficient roof area but was eliminated from consideration due to no summer occupancy. Summer water use when the sun is strongest is critical for the design of a feasible solar thermal system.

### J. Georgetown Hall

Georgetown Hall is a school season only, 5 story residence hall with 122 beds. There is sufficient space for associated equipment and solar thermal panels, but the building has been eliminated from consideration due to lack of summer occupancy. Summer water use when the sun is strongest is critical for the design of a feasible solar thermal system.

### K. LeMoyne Hall

LeMoyne Hall is a school season only, 4 story residence hall with 71 beds. LeMoyne has relatively low water usage, no summer occupancy, and limited mechanical space, all of which eliminate it from consideration.

## L. Marquette South

Marquette South is a school season only, 5 story residence hall with 113 beds. Similar to Marquette Hall, this building was not considered for further study do to no summer occupancy, limited mechanical space, and shading from a building to the Southwest.

## M. Mertz Hall

Mertz Hall is a year round, 18 story residence hall with 665 beds. Mertz has by far the largest water consumption of the 16 buildings studied but lacks mechanical space and available roof area for solar panels. Therefore, Mertz Hall was eliminated from consideration.

## N. Messina Hall

Messina Hall is a school season only, 5 story residence hall with 124 beds. Low water use and no summer occupancy eliminate Messina Hall from consideration.

## O. San Francisco Hall

San Francisco Hall is a year round, 6 story residence hall with 410 beds. The building has high estimated water usage and plenty of roof area but has been eliminated due to the existing green roof which would have to be removed to add solar thermal panels.

## P. Spring Hill Hall

Spring Hill Hall is a year round, 6 story residence hall with 49 beds. This building has plenty of roof space, but no mechanical space and was therefore eliminated from further consideration.

## Ranking

Data gathering and analysis have revealed 5 residence halls that meet basic requirements to be a good fit for a solar thermal system. These basic requirements are as follows:

- The residence hall must have summer occupancy. A feasible solar thermal design needs to take advantage of the peak solar months in the summer.
- There must be adequate space for pumps, storage tanks, and other associated equipment for the solar thermal system.
- There must be adequate roof space for solar thermal panels.
- The roof must receive direct sunlight for the majority of the year. Adjacent buildings to the South that shade the building will significantly reduce solar thermal panel performance.

Residence halls that meet these 4 basic requirements are then ranked on a weighted scale by the combination of roof area and annual water use. For example, the building with the highest available roof area received 16 points with a 2x multiplier. The following table shows the results of this analysis with the weighting for roof area and water use in parenthesis:

**Table 1**

| Ranking | Building Name | Summer Use | Mechanical Space | Roof Space | Clear Sky | Usable Roof Area, $ft^2$ (2x) | Annual Water Usage, Million Gallons (1x) | Grade (%) |
|---|---|---|---|---|---|---|---|---|
| 1 | Simpson Center | Yes | Yes | Yes | Yes | 10,830 | 18.2 | 91% |
| 2 | Regis Hall | Yes | Yes | Yes | Yes | 7,086 | 9.6 | 73% |
| 3 | de Nobili | Yes | Yes | Yes | Yes | 5,712 | 14.2 | 69% |
| 4 | Fordham Hall | Yes | Yes* | Yes | Yes | 4,471 | 23.1 | 66% |
| 5 | Santa Clara Hall | Yes | Yes | Yes | Yes | 3,464 | 7.6 | 49% |
| 6 | Bellarmine | Yes | No | Yes | Yes | 9,785 | 6.9 | 0% |
| 7 | Campion Hall | No | Yes | Yes | Yes | 15,643 | 7.9 | 0% |
| 8 | Canisius Hall | No | No | Yes | No | 5,100 | 1.8 | 0% |
| 9 | Fairfield Hall | No | Yes | Yes | No | 11,471 | 8.2 | 0% |
| 10 | Georgetown Hall | No | Yes | Yes | Yes | 8,357 | 3.2 | 0% |
| 11 | LeMoyne Hall | No | No | Yes | Yes | 2,508 | 1.5 | 0% |
| 12 | Marquette South | No | --- | Yes | No | 8,854 | 3.2 | 0% |
| 13 | Mertz Hall | Yes | No | Yes | Yes | 4,204 | 38.4 | 0% |
| 14 | Messina Hall | No | --- | Yes | Yes | 6,900 | 1.2 | 0% |
| 15 | San Francisco Hall | Yes | Yes | No | Yes | 0 | 8.0 | 0% |
| 16 | Spring Hill Hall | Yes | No | Yes | No | 2,500 | 1.8 | 0% |

*Mechanical Space is dependent on a full domestic hot water and/or boiler replacement project.

## Further Analysis

Five residence halls met the 4 basic requirements and moved on to further analysis. The solar thermal potential costs and savings were determined for each in the software, RETscreen. RETscreen is an excel based program developed by Natural Resources Canada, NASA, reep, UNEP, and GEF. This software was chosen because it is free and easily accessible for students to expand upon and recreate the results of this initial study. Screenshots from RETscreen for each of the five buildings can be found in Appendix 1.

The following table summarizes the results of the RETscreen analysis:

**Table 2**

| Rank | Building Name | Solar Heat Collected (Million BTU) | Storage Capacity (Gallons) | Solar Fraction | Annual Savings | Installed Cost | Potential Incentive | Simple Payback Without Incentives | Simple Payback W/Incentives |
|---|---|---|---|---|---|---|---|---|---|
| **1** | **Simpson Center** | 240.6 | 600 | 6% | $2,026 | $92,210 | $55,326 | 45.5 | 18.2 |
| **2** | **Regis Hall** | 234.7 | 600 | 10% | $2,208 | $92,210 | $55,326 | 41.8 | 16.7 |
| **3** | **de Nobili** | 95.2 | 200 | 8% | $801 | $36,884 | $22,130 | 46.0 | 18.4 |
| **4** | **Fordham*** | 240.6 | 600 | 12% | $2,026 | $92,210 | $55,326 | 45.5 | 18.2 |
| **5** | **Santa Clara Hall** | 77.6 | 200 | 12% | $653 | $30,737 | $18,442 | 47.1 | 18.8 |

*Implementation cost savings may be realized due to reduced water heater capacity and economies of scale as part of a larger domestic hot water and/or boiler project.

Some of the initial decisions and assumptions made to complete the analysis are as follows:

- Alternate Energy Technologies MSC-40 collector was used for all 5 buildings.
- Storage was based on 200 gallon tanks, the largest able to fit through a standard doorway.
- The number of collectors was determined by optimizing installed cost while keeping in mind roof area. Due to a high load to roof area ratio, high solar fractions could not be achieved.
- The number of tanks was based on 1 gallon of storage per ft² which was determined once it was known that the solar fraction was low. A low solar fraction means that we will be able to more directly use the water as it is heated and that storage is less important.
- Collector slope was fixed at 35° from horizontal. This was decided after it was determined we would be getting low solar fractions and very high summer gain would not be wasted.

Each of the buildings found an optimal simple payback around 10% solar fraction. This is due to the reduced cost of storage and the high use of summer peak sun. Incentives are based on a Illinois Clean Energy Community Foundation (ICECF) solar thermal grant that provides up to 60% of the installed cost.

## Results

As can be seen from the above table, incentives are crucial to achieving a feasible project. Additional savings could be made by ordering equipment direct and/or reusing existing storage tanks. Furthermore, economies of scale could be accomplished by installing solar thermal systems when replacing existing domestic hot water equipment.

## Potential Next Steps

This initial study has separated 5 buildings from the 16 residence halls studied that show potential for a solar thermal system. By design, this study was cursory in nature and therefore further investigations should be done to evaluate which of the 5 remaining buildings present the best opportunity and the fasted return on investment. Once available roof and mechanical space and verified, more detailed solar thermal analysis and implementation costs can be developed. If it is decided to proceed further with any of the buildings, detailed engineering and construction documents can be completed.

# Appendix 1

## RETScreen Energy Model - Heating project

### Heating project

| | | | | | |
|---|---|---|---|---|---|
| Technology | | Solar water heater | | | |
| **Load characteristics** | | | | | |
| Application | | ○ Swimming pool | | | |
| | | ⊙ Hot water | | | |

| | Unit | Base case | Proposed case |
|---|---|---|---|
| Load type | | Apartment | |
| Number of units | Unit | 407 | |
| Occupancy rate | % | 100% | |
| Daily hot water use - estimated | gal/d | 18,219 | |
| Daily hot water use | gal/d | 16,424 | 16,424 |
| Temperature | °F | 135 | 135 |
| Operating days per week | d | 7 | 7 |

☐ **Percent of month used**

| | Unit | Base case | Proposed case | Energy saved | Incremental initial costs |
|---|---|---|---|---|---|
| Supply temperature method | | Formula | | | |
| Water temperature - minimum | °F | 41.2 | | | |
| Water temperature - maximum | °F | 58.7 | | | |
| Heating | million Btu | 4,254.2 | 4,254.2 | 0% | |

**Resource assessment**

| | | |
|---|---|---|
| Solar tracking mode | | Fixed |
| Slope | ° | 35.0 |
| Azimuth | ° | 0.0 |

☐ **Show data**

**Solar water heater**

| | | | | | |
|---|---|---|---|---|---|
| Type | Glazed | | | $ 92,210 | *See technical note* |
| Manufacturer | Alternate Energy Technologies | | | | *See product database* |
| Model | Morning Star MSC-40 | | | | |
| Gross area per solar collector | m² | 3.92 | | | |
| Aperture area per solar collector | m² | 3.58 | | | |
| Fr (tau alpha) coefficient | | 0.71 | | | |
| Fr UL coefficient | (W/m²)/°C | 4.91 | | | |
| Temperature coefficient for Fr UL | (W/m²)/°C² | 0.000 | | | |
| Number of collectors | | 30 | 242 | | |
| Solar collector area | m² | 117.48 | | | |
| Capacity | kW | 75.18 | | | |
| Miscellaneous losses | % | 5.0% | | | |

**Balance of system & miscellaneous**

| | | |
|---|---|---|
| Storage | | Yes |
| Storage capacity / solar collector area | gal/ft² | 1 |
| Storage capacity | gal | 578.0 |
| Heat exchanger | yes/no | Yes |
| Heat exchanger efficiency | % | 80.0% |
| Miscellaneous losses | % | 5.0% |
| Pump power / solar collector area | W/m² | 12.00 |
| Electricity rate | $/kWh | 0.072 |

**Summary**

| | | |
|---|---|---|
| Electricity - pump | MWh | 2.9 |
| Heating delivered | million Btu | 240.6 |
| Solar fraction | % | 6% |

**Heating system**

| | | Base case | Proposed case | | |
|---|---|---|---|---|---|
| ☐ Project verification | | | | | |
| Fuel type | | Natural gas - therm | Natural gas - therm | | |
| Seasonal efficiency | | 95% | 95% | | |
| Fuel consumption - annual | therm | 44,781.2 | 42,248.8 | therm | |
| Fuel rate | $/therm | 0.800 | 0.800 | $/therm | |
| Fuel cost | $ | 35,825 | 33,799 | | |

## ☑ Emission Analysis

| Base case electricity system (Baseline) | | GHG emission factor (excl. T&D) | T&D losses | GHG emission factor |
|---|---|---|---|---|
| Country - region | Fuel type | tCO2/MWh | % | tCO2/MWh |
| United States of America | All types | 0.522 | 8.0% | 0.568 |

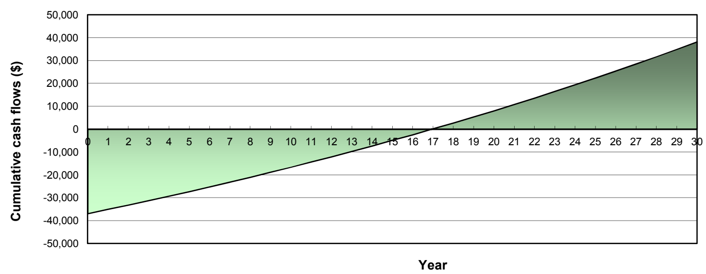
| GHG emission | | | | | |
|---|---|---|---|---|---|
| Base case | tCO2 | 234.9 | | | |
| Proposed case | tCO2 | 223.3 | | | |
| **Gross annual GHG emission reduction** | tCO2 | 11.6 | | | |
| GHG credits transaction fee | % | | | | |
| **Net annual GHG emission reduction** | tCO2 | 11.6 | is equivalent to | 2.1 | Cars & light trucks not used |

| GHG reduction income | | |
|---|---|---|
| GHG reduction credit rate | $/tCO2 | |

## Financial Analysis

| Financial parameters | | | |
|---|---|---|---|
| Inflation rate | % | 2.0% | |
| Project life | yr | 30 | |
| Debt ratio | % | | |
| **Initial costs** | | | |
| Heating system | $ | 92,210 | 100.0% |
| Other | $ | | 0.0% |
| **Total initial costs** | $ | 92,210 | 100.0% |
| **Incentives and grants** | $ | 55,326 | 60.0% |
| **Annual costs and debt payments** | | | |
| O&M (savings) costs | $ | | |
| Fuel cost - proposed case | $ | 34,011 | |
| Other | $ | | |
| **Total annual costs** | $ | 34,011 | |
| **Annual savings and income** | | | |
| Fuel cost - base case | $ | 35,825 | |
| Other | $ | | |
| **Total annual savings and income** | $ | 35,825 | |
| **Financial viability** | | | |
| Pre-tax IRR - assets | % | 4.8% | |
| Simple payback | yr | 20.3 | |
| Equity payback | yr | 16.9 | |

**Cumulative cash flows graph**



**RETScreen Energy Model - Heating project**

**Heating project**

| | | | |
|---|---|---|---|
| Technology | | Solar water heater | |
| **Load characteristics** | | | |
| Application | | ○ Swimming pool | |
| | | ⊙ Hot water | |

| | Unit | Base case | Proposed case |
|---|---|---|---|
| Load type | | Apartment | |
| Number of units | Unit | 419 | |
| Occupancy rate | % | 100% | |
| Daily hot water use - estimated | gal/d | 18,756 | |
| Daily hot water use | gal/d | 8,663 | 8,663 |
| Temperature | °F | 135 | 135 |
| Operating days per week | d | 7 | 7 |

☐ **Percent of month used**

| | | |
|---|---|---|
| Supply temperature method | | Formula |
| Water temperature - minimum | °F | 41.2 |
| Water temperature - maximum | °F | 58.7 |

| | Unit | Base case | Proposed case | Energy saved | Incremental initial costs |
|---|---|---|---|---|---|
| Heating | million Btu | 2,243.9 | 2,243.9 | 0% | |

**Resource assessment**

| | | |
|---|---|---|
| Solar tracking mode | | Fixed |
| Slope | ° | 35.0 |
| Azimuth | ° | 0.0 |

☐ **Show data**

**Solar water heater**

| | | | | | |
|---|---|---|---|---|---|
| Type | Glazed | | | $ 92,210 | *See technical note* |
| Manufacturer | Alternate Energy Technologies | | | | *See product database* |
| Model | Morning Star MSC-40 | | | | |
| Gross area per solar collector | m² | 3.92 | | | |
| Aperture area per solar collector | m² | 3.58 | | | |
| Fr (tau alpha) coefficient | | 0.71 | | | |
| Fr UL coefficient | (W/m²)/°C | 4.91 | | | |
| Temperature coefficient for Fr UL | (W/m²)/°C² | 0.000 | | | |
| Number of collectors | | 30 | 128 | | |
| Solar collector area | m² | 117.48 | | | |
| Capacity | kW | 75.18 | | | |
| Miscellaneous losses | % | 5.0% | | | |

**Balance of system & miscellaneous**

| | | |
|---|---|---|
| Storage | | Yes |
| Storage capacity / solar collector area | gal/ft² | 1 |
| Storage capacity | gal | 578.0 |
| Heat exchanger | yes/no | Yes |
| Heat exchanger efficiency | % | 80.0% |
| Miscellaneous losses | % | 5.0% |
| Pump power / solar collector area | W/m² | 12.00 |
| Electricity rate | $/kWh | 0.072 |

**Summary**

| | | |
|---|---|---|
| Electricity - pump | MWh | 2.9 |
| Heating delivered | million Btu | 234.7 |
| Solar fraction | % | 10% |

**Heating system**

| | | Base case | Proposed case | | |
|---|---|---|---|---|---|
| ☐ Project verification | | | | | |
| Fuel type | | Natural gas - therm | Natural gas - therm | | |
| Seasonal efficiency | | 85% | 85% | | |
| Fuel consumption - annual | therm | 26,399.1 | 23,638.2 | therm | |
| Fuel rate | $/therm | 0.800 | 0.800 | $/therm | |
| Fuel cost | $ | 21,119 | 18,911 | | |

## ☑ Emission Analysis

| Base case electricity system (Baseline) Country - region | Fuel type | GHG emission factor (excl. T&D) tCO2/MWh | T&D losses % | GHG emission factor tCO2/MWh |
|---|---|---|---|---|
| United States of America | All types | 0.522 | 8.0% | 0.568 |

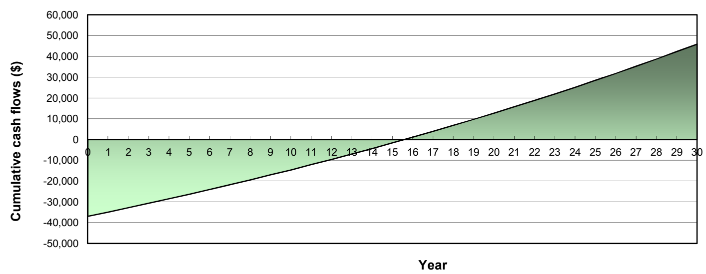
| GHG emission | | | | | |
|---|---|---|---|---|---|
| Base case | tCO2 | 138.5 | | | |
| Proposed case | tCO2 | 125.6 | | | |
| **Gross annual GHG emission reduction** | tCO2 | 12.9 | | | |
| GHG credits transaction fee | % | | | | |
| **Net annual GHG emission reduction** | tCO2 | 12.9 | is equivalent to | 2.4 | Cars & light trucks not used |

| GHG reduction income | | |
|---|---|---|
| GHG reduction credit rate | $/tCO2 | |

## Financial Analysis

| Financial parameters | | | |
|---|---|---|---|
| Inflation rate | % | 2.0% | |
| Project life | yr | 30 | |
| Debt ratio | % | | |
| **Initial costs** | | | |
| Heating system | $ | 92,210 | 100.0% |
| Other | $ | | 0.0% |
| **Total initial costs** | $ | 92,210 | 100.0% |
| **Incentives and grants** | $ | 55,326 | 60.0% |
| **Annual costs and debt payments** | | | |
| O&M (savings) costs | $ | | |
| Fuel cost - proposed case | $ | 19,117 | |
| Other | $ | | |
| **Total annual costs** | $ | 19,117 | |
| **Annual savings and income** | | | |
| Fuel cost - base case | $ | 21,119 | |
| Other | $ | | |
| **Total annual savings and income** | $ | 21,119 | |
| **Financial viability** | | | |
| Pre-tax IRR - assets | % | 5.6% | |
| Simple payback | yr | 18.4 | |
| Equity payback | yr | 15.6 | |

**Cumulative cash flows graph**



**RETScreen Energy Model - Heating project**

**Heating project**

| | | | | | |
|---|---|---|---|---|---|
| Technology | | Solar water heater | | | |
| **Load characteristics** | | | | | |
| Application | | ○ Swimming pool | | | |
| | | ⊙ Hot water | | | |

| | Unit | Base case | Proposed case |
|---|---|---|---|
| Load type | | Apartment | |
| Number of units | Unit | 200 | |
| Occupancy rate | % | 100% | |
| Daily hot water use - estimated | gal/d | 8,953 | |
| Daily hot water use | gal/d | 4,675 | 4,675 |
| Temperature | °F | 135 | 135 |
| Operating days per week | d | 7 | 7 |

☐ **Percent of month used**

| | Unit | Base case | Proposed case | Energy saved | Incremental initial costs |
|---|---|---|---|---|---|
| Supply temperature method | | Formula | | | |
| Water temperature - minimum | °F | 41.2 | | | |
| Water temperature - maximum | °F | 58.7 | | | |
| Heating | million Btu | 1,210.9 | 1,210.9 | 0% | |

| | | |
|---|---|---|
| **Resource assessment** | | |
| Solar tracking mode | | Fixed |
| Slope | ° | 35.0 |
| Azimuth | ° | 0.0 |

☐ **Show data**

| | | | | |
|---|---|---|---|---|
| **Solar water heater** | | | | |
| Type | | Glazed | | $ 36,884 |
| Manufacturer | | Alternate Energy Technologies | | |
| Model | | Morning Star MSC-40 | | |
| Gross area per solar collector | m² | 3.92 | | |
| Aperture area per solar collector | m² | 3.58 | | |
| Fr (tau alpha) coefficient | | 0.71 | | |
| Fr UL coefficient | (W/m²)/°C | 4.91 | | |
| Temperature coefficient for Fr UL | (W/m²)/°C² | 0.000 | | |
| Number of collectors | | 12 | 69 | |
| Solar collector area | m² | 46.99 | | |
| Capacity | kW | 30.07 | | |
| Miscellaneous losses | % | 5.0% | | |

*See technical note*
*See product database*

| | | |
|---|---|---|
| **Balance of system & miscellaneous** | | |
| Storage | | Yes |
| Storage capacity / solar collector area | gal/ft² | 1 |
| Storage capacity | gal | 231.2 |
| Heat exchanger | yes/no | Yes |
| Heat exchanger efficiency | % | 80.0% |
| Miscellaneous losses | % | 5.0% |
| Pump power / solar collector area | W/m² | 12.00 |
| Electricity rate | $/kWh | 0.072 |
| **Summary** | | |
| Electricity - pump | MWh | 1.2 |
| Heating delivered | million Btu | 95.2 |
| Solar fraction | % | 8% |

**Heating system**

| ☐ Project verification | | Base case | Proposed case | | |
|---|---|---|---|---|---|
| Fuel type | | Natural gas - therm | Natural gas - therm | | |
| Seasonal efficiency | | 95% | 95% | | |
| Fuel consumption - annual | therm | 12,746.7 | 11,745.0 | therm | |
| Fuel rate | $/therm | 0.800 | 0.800 | $/therm | |
| Fuel cost | $ | 10,197 | 9,396 | | |

## ☑ Emission Analysis

| Base case electricity system (Baseline) Country - region | Fuel type | GHG emission factor (excl. T&D) tCO2/MWh | T&D losses % | GHG emission factor tCO2/MWh |
|---|---|---|---|---|
| United States of America | All types | 0.522 | 8.0% | 0.568 |

| GHG emission | | | | | |
|---|---|---|---|---|---|
| Base case | tCO2 | 66.9 | | | |
| Proposed case | tCO2 | 62.3 | | | |
| **Gross annual GHG emission reduction** | tCO2 | 4.6 | | | |
| GHG credits transaction fee | % | | | | |
| **Net annual GHG emission reduction** | tCO2 | 4.6 | is equivalent to | 0.8 | Cars & light trucks not used |

**GHG reduction income**

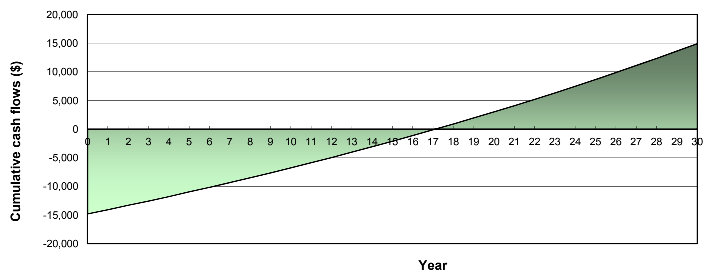
| | | |
|---|---|---|
| GHG reduction credit rate | $/tCO2 | |

## Financial Analysis

**Financial parameters**

| | | | |
|---|---|---|---|
| Inflation rate | % | 2.0% | |
| Project life | yr | 30 | |
| Debt ratio | % | | |
| **Initial costs** | | | |
| Heating system | $ | 36,884 | 100.0% |
| Other | $ | | 0.0% |
| **Total initial costs** | $ | 36,884 | 100.0% |
| **Incentives and grants** | $ | 22,131 | 60.0% |
| **Annual costs and debt payments** | | | |
| O&M (savings) costs | $ | | |
| Fuel cost - proposed case | $ | 9,480 | |
| Other | $ | | |
| **Total annual costs** | $ | 9,480 | |
| **Annual savings and income** | | | |
| Fuel cost - base case | $ | 10,197 | |
| Other | $ | | |
| **Total annual savings and income** | $ | 10,197 | |
| **Financial viability** | | | |
| Pre-tax IRR - assets | % | 4.7% | |
| Simple payback | yr | 20.6 | |
| Equity payback | yr | 17.1 | |

**Cumulative cash flows graph**



## RETScreen Energy Model - Heating project

**Heating project**

| | | | | | |
|---|---|---|---|---|---|
| Technology | | Solar water heater | | | |
| **Load characteristics** | | | | | |
| Application | | ○ Swimming pool | | | |
| | | ⊙ Hot water | | | |

| | Unit | Base case | Proposed case |
|---|---|---|---|
| Load type | | Apartment | |
| Number of units | Unit | 362 | |
| Occupancy rate | % | 100% | |
| Daily hot water use - estimated | gal/d | 16,205 | |
| Daily hot water use | gal/d | 7,609 | 7,609 |
| Temperature | °F | 135 | 135 |
| Operating days per week | d | 7 | 7 |

☐ **Percent of month used**

| | | |
|---|---|---|
| Supply temperature method | | Formula |
| Water temperature - minimum | °F | 41.2 |
| Water temperature - maximum | °F | 58.7 |

| | Unit | Base case | Proposed case | Energy saved | Incremental initial costs |
|---|---|---|---|---|---|
| Heating | million Btu | 1,970.9 | 1,970.9 | 0% | |

**Resource assessment**

| | | |
|---|---|---|
| Solar tracking mode | | Fixed |
| Slope | ° | 35.0 |
| Azimuth | ° | 0.0 |

☐ **Show data**

**Solar water heater**

| | | | | |
|---|---|---|---|---|
| Type | Glazed | | | $ 92,210 |
| Manufacturer | Alternate Energy Technologies | | | |
| Model | Morning Star MSC-40 | | | |
| Gross area per solar collector | m² | 3.92 | | |
| Aperture area per solar collector | m² | 3.58 | | |
| Fr (tau alpha) coefficient | | 0.71 | | |
| Fr UL coefficient | (W/m²)/°C | 4.91 | | |
| Temperature coefficient for Fr UL | (W/m²)/°C² | 0.000 | | |
| Number of collectors | | 30 | 112 | |
| Solar collector area | m² | 117.48 | | |
| Capacity | kW | 75.18 | | |
| Miscellaneous losses | % | 5.0% | | |

*See technical note*
*See product database*

**Balance of system & miscellaneous**

| | | |
|---|---|---|
| Storage | | Yes |
| Storage capacity / solar collector area | gal/ft² | 1 |
| Storage capacity | gal | 578.0 |
| Heat exchanger | yes/no | Yes |
| Heat exchanger efficiency | % | 80.0% |
| Miscellaneous losses | % | 5.0% |
| Pump power / solar collector area | W/m² | 12.00 |
| Electricity rate | $/kWh | 0.072 |

**Summary**

| | | |
|---|---|---|
| Electricity - pump | MWh | 2.8 |
| Heating delivered | million Btu | 233.0 |
| Solar fraction | % | 12% |

**Heating system**

| ☐ Project verification | | Base case | Proposed case | | |
|---|---|---|---|---|---|
| Fuel type | | Natural gas - therm | Natural gas - therm | | |
| Seasonal efficiency | | 95% | 95% | | |
| Fuel consumption - annual | therm | 20,746.5 | 18,294.1 | therm | |
| Fuel rate | $/therm | 0.800 | 0.800 | $/therm | |
| Fuel cost | $ | 16,597 | 14,635 | | |

**☑ Emission Analysis**

**Base case electricity system (Baseline)**

| **Country - region** | **Fuel type** | **GHG emission factor (excl. T&D) tCO2/MWh** | **T&D losses %** | **GHG emission factor tCO2/MWh** |
|---|---|---|---|---|
| United States of America | All types | 0.522 | 8.0% | 0.568 |

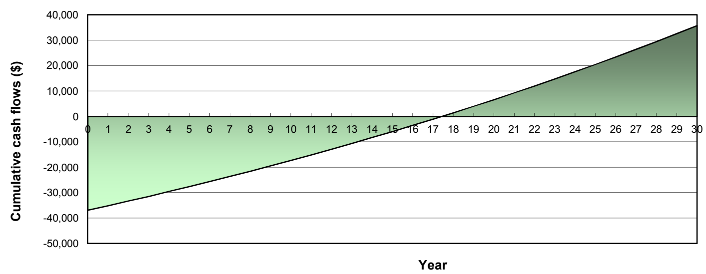
| **GHG emission** | | | | | |
|---|---|---|---|---|---|
| Base case | tCO2 | 108.8 | | | |
| Proposed case | tCO2 | 97.6 | | | |
| **Gross annual GHG emission reduction** | tCO2 | 11.2 | | | |
| GHG credits transaction fee | % | | | | |
| **Net annual GHG emission reduction** | tCO2 | 11.2 | is equivalent to | 2.1 | Cars & light trucks not used |

| **GHG reduction income** | | |
|---|---|---|
| GHG reduction credit rate | $/tCO2 | |

**Financial Analysis**

| **Financial parameters** | | | |
|---|---|---|---|
| Inflation rate | % | 2.0% | |
| Project life | yr | 30 | |
| Debt ratio | % | | |
| **Initial costs** | | | |
| Heating system | $ | 92,210 | 100.0% |
| Other | $ | | 0.0% |
| **Total initial costs** | $ | 92,210 | 100.0% |
| **Incentives and grants** | $ | 55,326 | 60.0% |
| **Annual costs and debt payments** | | | |
| O&M (savings) costs | $ | | |
| Fuel cost - proposed case | $ | 14,840 | |
| Other | $ | | |
| **Total annual costs** | $ | 14,840 | |
| **Annual savings and income** | | | |
| Fuel cost - base case | $ | 16,597 | |
| Other | $ | | |
| **Total annual savings and income** | $ | 16,597 | |
| **Financial viability** | | | |
| Pre-tax IRR - assets | % | 4.5% | |
| Simple payback | yr | 21.0 | |
| Equity payback | yr | 17.4 | |

**Cumulative cash flows graph**



**RETScreen Energy Model - Heating project**

**Heating project**

| | | | | | |
|---|---|---|---|---|---|
| Technology | | **Solar water heater** | | | |
| **Load characteristics** | | | | | |
| Application | | ○ Swimming pool | | | |
| | | ⊙ Hot water | | | |
| | **Unit** | **Base case** | **Proposed case** | | |
| Load type | | Apartment | | | |
| Number of units | Unit | 186 | | | |
| Occupancy rate | % | 100% | | | |
| Daily hot water use - estimated | gal/d | 8,326 | | | |
| Daily hot water use | gal/d | 2,511 | 2,511 | | |
| Temperature | °F | 135 | 135 | | |
| Operating days per week | d | 7 | 7 | | |
| ☐ **Percent of month used** | | | | | |
| Supply temperature method | | Formula | | | |
| Water temperature - minimum | °F | 41.2 | | | |
| Water temperature - maximum | °F | 58.7 | | | |
| | **Unit** | **Base case** | **Proposed case** | **Energy saved** | **Incremental initial costs** |
| Heating | million Btu | 650.4 | 650.4 | 0% | |
| **Resource assessment** | | | | | |
| Solar tracking mode | | Fixed | | | |
| Slope | ° | 35.0 | | | |
| Azimuth | ° | 0.0 | | | |
| ☐ **Show data** | | | | | |
| **Solar water heater** | | | | | |
| Type | | Glazed | | | $ 30,737 |
| Manufacturer | | Alternate Energy Technologies | | | |
| Model | | Morning Star MSC-40 | | | |
| Gross area per solar collector | m² | 3.92 | | | |
| Aperture area per solar collector | m² | 3.58 | | | |
| Fr (tau alpha) coefficient | | 0.71 | | | |
| Fr UL coefficient | (W/m²)/°C | 4.91 | | | |
| Temperature coefficient for Fr UL | (W/m²)/°C² | 0.000 | | | |
| Number of collectors | | 10 | 37 | | |
| Solar collector area | m² | 39.16 | | | |
| Capacity | kW | 25.06 | | | |
| Miscellaneous losses | % | 5.0% | | | |
| **Balance of system & miscellaneous** | | | | | |
| Storage | | Yes | | | |
| Storage capacity / solar collector area | gal/ft² | 1 | | | |
| Storage capacity | gal | 192.7 | | | |
| Heat exchanger | yes/no | Yes | | | |
| Heat exchanger efficiency | % | 80.0% | | | |
| Miscellaneous losses | % | 5.0% | | | |
| Pump power / solar collector area | W/m² | 12.00 | | | |
| Electricity rate | $/kWh | 0.072 | | | |
| **Summary** | | | | | |
| Electricity - pump | MWh | 0.9 | | | |
| Heating delivered | million Btu | 77.6 | | | |
| Solar fraction | % | 12% | | | |
| **Heating system** | | | | | |
| ☐ Project verification | | **Base case** | **Proposed case** | | |
| Fuel type | | Natural gas - therm | Natural gas - therm | | |
| Seasonal efficiency | | 95% | 95% | | |
| Fuel consumption - annual | therm | 6,846.4 | 6,029.5 | therm | |
| Fuel rate | $/therm | 0.800 | 0.800 | $/therm | |
| Fuel cost | $ | 5,477 | 4,824 | | |

*See technical note*

*See product database*

## ☑ Emission Analysis

| Base case electricity system (Baseline) | | GHG emission factor (excl. T&D) | T&D losses | GHG emission factor |
|---|---|---|---|---|
| Country - region | Fuel type | tCO2/MWh | % | tCO2/MWh |
| United States of America | All types | 0.522 | 8.0% | 0.568 |

| GHG emission | | | | | |
|---|---|---|---|---|---|
| Base case | tCO2 | 35.9 | | | |
| Proposed case | tCO2 | 32.2 | | | |
| **Gross annual GHG emission reduction** | tCO2 | 3.7 | | | |
| GHG credits transaction fee | % | | | | |
| **Net annual GHG emission reduction** | tCO2 | 3.7 | is equivalent to | 0.7 | Cars & light trucks not used |

| GHG reduction income | | |
|---|---|---|
| GHG reduction credit rate | $/tCO2 | |

## Financial Analysis

| Financial parameters | | | |
|---|---|---|---|
| Inflation rate | % | 2.0% | |
| Project life | yr | 30 | |
| Debt ratio | % | | |
| **Initial costs** | | | |
| Heating system | $ | 30,737 | 100.0% |
| Other | $ | | 0.0% |
| **Total initial costs** | $ | 30,737 | 100.0% |
| **Incentives and grants** | $ | 18,442 | 60.0% |
| **Annual costs and debt payments** | | | |
| O&M (savings) costs | $ | | |
| Fuel cost - proposed case | $ | 4,892 | |
| Other | $ | | |
| **Total annual costs** | $ | 4,892 | |
| **Annual savings and income** | | | |
| Fuel cost - base case | $ | 5,477 | |
| Other | $ | | |
| **Total annual savings and income** | $ | 5,477 | |
| **Financial viability** | | | |
| Pre-tax IRR - assets | % | 4.5% | |
| Simple payback | yr | 21.0 | |
| Equity payback | yr | 17.4 | |

**Cumulative cash flows graph**