# Green Homes

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## Abstract

We performed a payback period analysis on options to make a house more energy efficient. We examined photovoltaics, appliances, solar hot water, geothermal heat, windows, and insulation to determine which versions of each was the most efficient and cost effective for an average Massachusetts home. We found that the majority of these technologies are feasible. The exceptions to this are Icynene insulation and photovoltaic panels which require additional subsidies in order to become affordable in residential building.

## Background

In the current market it is difficult for contractors and home owners to use energy efficient products. This occurs because the initial investment is so expensive that many home owners do not have the money to purchase the system. It would be more cost effective for the contractor to install these systems when the houses are being built, but it would raise the selling price of the home making it harder to sell. As a result green building needs a push from the government to make it a more appealing option.

### Methods/Process

**Heating Load:**
To determine the heating load of the house we calculated the energy lost due to each of the three components: the walls, the ceiling, and the windows. The sum of the numbers gives the total energy lost. This is converted into gallons of oil burned using 82% efficiency and then into dollars using the price per gallon of oil.

**Insulation/Windows:**
To determine the payback period of the insulation we computed the energy lost per hour using the formula:
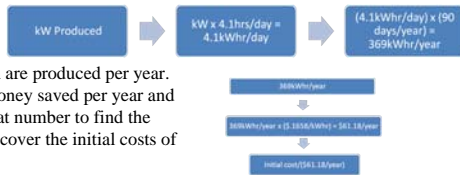
$$BTU = \frac{hr \cdot {}^{\circ}F \cdot ft^2}{R \cdot x}$$

This was then converted into the operating cost per year using the number of BTU's/gal and the price of oil. The payback period was calculated with the formula:

$$\frac{Cost\ of\ Upgrade - Cost\ of\ Standard}{Operating\ Cost\ of\ Standard - Operating\ Cost\ of\ Upgrade}$$

**Photovoltaics:**
In order to calculate the payback period of photovoltaics we first had to find how many kWh are produced per year. Then find the amount of money saved per year and divide the initial cost by that number to find the number of years it takes to cover the initial costs of the system.

kW Produced → kW x 4.1hrs/day = 4.1kWhr/day → (4.1kWhr/day) x (90 days/year) = 369kWhr/year

369kWhr/year

369kWhr/year x ($.1658/kWhr) = $61.18/year

Initial cost/($61.18/year)

**Appliances:**
When dealing with the cost benefit analysis of appliances we used a worksheet from the energy star website in which we plugged in the price of electricity($.1658) and we were then told how much money was saved over the lifetime of the appliance and how many years it would take to pay off the initial cost.

**Geothermal:**
To establish the payback period for a geothermal heat pump, we first determined the initial cost of both a geothermal system and a conventional oil-fired system. This we added to the rates of usage for each heating system to create linear equations. By plotting these, we then found the points at which the geothermal intersected with the conventional heating. These intersection points correspond to the time that is required for the geothermal heat pump to pay itself off.

**Solar Hot Water:**
Like the geothermal heating, solar hot water is found by first find the initial cost of each system and adding it to its yearly cost. Using these equations we plotted the lines and determined the intersection points. The intersection points correspond to the time at which solar hot water becomes cumulatively cheaper than conventional water heating.

## Results

### Insulation/Windows:

The following tables show the payback periods for wall insulation and for windows.

| Type | Operating Cost / Year | Capital Cost | Payback Period |
|---|---|---|---|
| 2X4 Fiberglass | $2,162.83 | $1,157.83 | -- |
| 2X6 Fiberglass | $961.26 | $1,480.80 | 0.27 years |
| 2X6 Cellulose | $815.77 | $1,532.00 | 0.28 years |
| 2X6 Icynene | $838.43 | $16,647.60 | 11.70 years |

| Type | Operating Cost / Year | Capital Cost | Payback Period |
|---|---|---|---|
| Clear | $901.30 | $4,663.68 | -- |
| Low-E | $643.78 | $5,190.72 | 2.05 years |
| Low-E/Argon | $570.21 | $5,527.68 | 2.61 years |

### Photovoltaics:

Photovoltaic Systems can be expensive and take a while to break even. However, if you are planning on living in the same home for a while PV can be a viable option, especially if you have the funds available. Subsidies are a good resource when installing a photovoltaics system because they can help carry some of the burden of the original cost.

### Appliances:

The following table shows the payback period for the appliances we investigated.

Data compiled from Energy Star.

| Appliance Payback Period | | |
|---|---|---|
| Appliance | Money Saved | Payback Period |
| Ceiling fans | $ 243.00 | 0.80 |
| Central AC | $ 253.00 | 2.80 |
| CFLs | $ 123.00 | 0.00 |
| Clothes washers | $ 157.02 | 4.28 |
| Computers | $ 62.00 | 0.00 |
| Copiers | $ 311.00 | 0.00 |
| Dehumidifiers | $ 136.00 | 0.00 |
| Dishwashers | $ 125.00 | 0.00 |
| Fax | $ 99.00 | 0.00 |
| Furnaces (gas) | $ 2,090.00 | 18.00 |
| Lighting fixtures | $ 171.00 | 1.70 |
| Monitors | $ 59.00 | 0.00 |
| Printer | $ 132.00 | 0.00 |
| Programmable thermostats | $ 2,339.00 | 0.30 |
| Refrigerators | $ 89.00 | 2.50 |
| VCRs | $ 36.00 | 0.00 |

### Geothermal:

The 75 percent efficiency makes a great deal of difference over the 50 percent efficiency. It is also evident that once equalization of the cost of solar heating and conventional water heating occurs, the savings are rapid and easily noticeable.

| | Payback Period | Cost at time of Intersection |
|---|---|---|
| Closed Loop | 3.852 years | $17,206.42 |
| Open Loop | 6.036 years | $2,6263.14 |

### Solar Hot Water:

This chart shows the cost of geothermal and conventional oil heating versus time. It also show the intersection points of geothermal with conventional heating. These points signify the break even points, after which the geothermal system will have paid itself off.
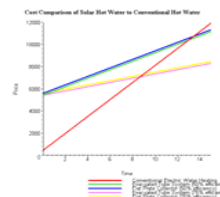
## Conclusions/Recommendations

### Insulation/Windows:
- Use low-e glass with Argon
- Use 2x6 cellulose wall
- Use cellulose insulation in the ceiling

### Photovoltaics:

Photovoltaics are not feasible in the short term. However, given their entire lifespan they will likely pay for themselves.

### Appliances:
Four Groups:
- Instant payback
- Three year payback
- Five year payback
- 20 year payback.

| | Payback Period | Appliances | Lifetime Savings |
|---|---|---|---|
| Group 1 | 0 years | computers, copiers, etc. | $1,083 |
| Group 2 | 3 years | Ceiling fans, Lighting fixtures, etc. | $4,178 |
| Group 3 | 5 years | Washing machines | $4,335.02 |
| Group 4 | 20 years | Furnaces | $6,425 |

### Geothermal:

Both open and closed loop systems work. Open loop pays back more quickly but closed loop can be used in more settings. The preferable technology depends on the setting.

### Solar Hot Water:

While flat plate collectors are slightly less expensive than the evacuated tube we do not recommend them. Evacuated tube systems have a better chance of reaching the ideal 75 percent efficiency in New England climate. Therefore, the slightly higher initial price is a worthy expense.

| | Payback Period | Cost at time of Intersection |
|---|---|---|
| Flat Plate Collector (50 % efficiency) | 12.988 years | $10,392.80 |
| Evacuated Tube System (50% efficiency) | 13.431 years | $10,732.80 |
| Flat Plate Collector (75 % efficiency) | 8.658 years | $7,075.08 |
| Evacuated Tube System (75% efficiency) | 8.954 years | $7,301.75 |

### Recommendations:
- Remove or increase caps on subsidies
- Require energy star appliances
- R-value of greater than 19 is achievable

## Acknowledgments

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