# Sustainable Construction in Indian Country

## Energy Evaluation and Recommendations

### Kekyajek Odanek Elder Housing

August 6, 2012

### Pokagon Band of Potawatomi Indians Dowagiac, MI

U.S. Department of Housing and Urban Development | PD&R | Office of Native American Programs, Office of Public & Indian Housing

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# Executive Summary

The Pokagon Band of Potawatomi in Michigan constructed 20 single-family elder units in 2005 as part of an ongoing community master plan for Pokegnek Edawat Dowagiac. Key sustainable elements of this phase of the master plan included: dense deep-rooted vegetation, permeable pavement, clustering and placement of houses to preserve topography and existing vegetation, rain gardens, bioswales, and ENERGY STAR appliances. Each of the one-story single-family homes three bedrooms, a two car attached garage, and a screen porch. Three different floor plans were used for the 20 houses ranging in size from 1,962 to 2,593 square feet.

This report provides information and strategies on how to reduce the annual operation cost through load reduction and energy efficiency improvements. It compares a baseline analysis of the design by Wightman & Associates, Inc and the actual utility bill consumption and costs verses an analysis of proposed alterations to the homes suggested by the Sustainable Construction in Indian Country (SCinIC) team.

# 1. Analysis Approach

The basic approach used to develop this report involves several steps. First, initial information is collected from the client about the building's design, building usage, and utility data. Then a site visit is conducted where data and observations are recorded by the project SCinIC team.

A baseline energy model is constructed in computer modeling software that performs building energy simulations. The HVAC load design and analysis software e-QUEST version 3.64, was used to model the building. This modeled data is calibrated to match the actual building energy usage as shown by the utility bills and then used as a baseline for evaluating the energy cost reduction measures (ECRMs). The program calculates the amount of energy (and the resulting utility cost of that energy) the building is expected to use over an entire typical weather year. Model inputs are taken from information collected during the site visit and information provided by the client. The weather file for e-QUEST was taken from the Eau Claire, Michigan weather station.

Subsequently, the project SCinIC team performs computer analyses of the ECRMs. The baseline model is changed to reflect the implementation of theses ECRMs and the computer model generates the expected energy consumption and utility costs. When necessary, some ECRMs are evaluated outside of the modeling software using spreadsheet calculations.

# 2. Facility Description

Constructed in 2005, this 2,593 $ft^2$ single story single-family home is used as elder housing and is one of 20 similar houses. Each single-family home was constructed from 1 of 3 different plans ranging in size from 1,962 $ft^2$ to 2,593 $ft^2$. The largest of the plans was used for evaluation in this report. Each house has 3 bedrooms, 2 bathrooms, an attached two car garage, screen porch, living room, kitchen, dining area, laundry room, and basement.

*It is assumed that 6 people will be living in each unit (two people per bedroom). While occupancy is highly dependent on the individual lifestyles of the elders and what additional family members may be living with them, it is assumed that the elders living in the units will spend most of their time at home. Therefore it is assumed that the elders will primarily be in the units 80% of the time during the week (approximately 134 hours/week).*

## 2.1 Building Envelope

**Walls:** The typical wall construction from the inside to outside is 5/8" gypsum board, 2x6 wood stud construction at 16" on center with 5 ½" fiberglass batt insulation, vapor barrier, and ½" oriented strand board with #15 felt and vinyl siding. It is estimated that the wall assembly has a thermal resistance rating (R-value) of R-22.

**Roof:** The roof is gabled with a 8:12 slope. It is constructed with 2x6 pre-engineered trusses at 24" on center, covered in ½" CDX plywood, #15 felt, and light gray asphalt shingles. There is R-38 blown insulation above the ceiling.

**Floor:** The basement floor is a 4" reinforced concrete slab on 6 MIL Visqueen and granular fill compacted to 98 M.P.D. The main floor is 2x10 wood floor joists at 16" on center with ¾" plywood subfloor. The bedrooms and living room are carpeted. The dining area is hardwood, and the kitchen, foyer, mud room, laundry room, and bathrooms are sheet vinyl. The screen porch, garage, patio, and basement are sealed concrete.

**Windows:** All windows have 7/8" insulated glazing, insect screen, and grilles.

## 2.2 HVAC

The current NDG proposal of the building places all HVAC equipment in the basement. *Assumptions were made according to the following heating/cooling design schedule detailed in the plans:*

**Heating/Cooling:** *Provide a 93 high efficiency gas forced air furnace with humidifier, a-coil, and electronic air filter and condenser system to be sized and designed with all controls to maintain the following conditions: 72 degrees (F) inside temperature at 0 degrees (F) outside and wind velocity of 15 MPH; 75 degrees (F) inside temperature at 95 degrees (F) outside in the summer. System to be controlled by low voltage thermostat with subbase including fan switch. Furnace to have a variable speed motor. Outdoor condenser to be high efficiency type with 2 speed motor. System to have outlets in all rooms and high returns located as required. Returns from all rooms except the kitchen, laundry and bathrooms. All trunk, risers, runs and returns to be completely sealed in aluminum, galvanized steel or composite ducts. If ducts cut through house plate, contractor is to supply and install a steel plate, 1/8" thick by 3 ½" wide with 4 nails. All ducts in outside wall and unconditioned areas to be insulated. All risers to have balancing dampers. Use canvas connectors at furnace.*

**Ventilation:** Ventilation air will be provided by infiltration. Each bathroom also has an exhaust fan rated at 80 CFM.

## 2.3 Domestic Hot Water

Design calls for a 40 gallon high efficiency natural gas water heater (Lochinvar ETN 040-4) with vent through roof and bird screen.

## 2.4 Lighting

When day-lighting from the windows is insufficient, lighting in the building is provided by incandescent light fixtures throughout the house, a 4' T8 in the laundry room, 3' T8s above the sinks in the bathrooms, and from the ceiling fans with incandescent fixtures in the living room and screen porch.

Assumed lighting power density for the base model was 0.80 W/ft$^2$ using a 60 W incandescent lamp in each fixture (including recessed can lights and ceiling fans) throughout the house, and a 4' 32 W T8 and 3' 25 W T8 linear fixture with rapid start electronic ballast in the laundry room and bathrooms respectively.

## 2.5 Additional Plug Loads

Additional plug loads in the building include typical residential appliances such as task lighting, TVs, washer and dryer, and standard kitchen equipment (refrigerators, stove, and microwaves).

# 3. Energy Consumption and Analysis

## 3.1 Utility Consumption Benchmarking

Utility data was provided for 6 of the 20 elder houses for the 2011 calendar year. Of these 6 sets of data, two were for the same floor plan that was chosen to evaluate for this report. The Pokagon receive their electricity through COOP Electric and it is delivered at an estimated rate of $0.12 per kWh. Their natural gas is supplied by SEMCO Energy at an estimated rate of $0.71 per therm. These rates include meter fees and taxes. The estimated annual energy use intensity (EUI) of the first elder home is 69 kBtu/ft$^2$/yr and the estimated annual energy cost intensity (ECI) is $1.20 /ft$^2$. For home 2 the EUI is 67 kBtu/ft$^2$/yr and the ECI is $0.99 /ft$^2$. These two values can be used to benchmark the energy performance of the current housing against similar buildings.

**Utility Consumption Analysis Home 1**

| Average Annual Consumption | | | Annual Costs | | Average Unit Cost | |
|---|---|---|---|---|---|---|
| Electricity | 13,797 | kWh | $ 1,656 | 74% | $0.12 | $/kWh |
| Natural Gas | 819 | therms | $ 586 | 26% | $0.71 | $/therm |
| | | Total: | **$ 2,241** | | | |
| Total Conditioned Area | 1,873 | ft$^2$ | | | | |
| Electricity Use Intensity | 7 | kWh/ft$^2$/yr | **Natural Gas Use Intensity** | | 0.44 | Therms/ft$^2$/yr |
| Energy Use Intensity | **69** | **kBtu/ft$^2$/yr** | **Energy Cost Intensity** | | **$ 1.20** | **$/ft$^2$/yr** |
| ***Electricity is provided by COOP Electric and natural gas is supplied by SEMCO Energy*** | | | | | | |

**Utility Consumption Analysis Home 2**

| Average Annual Consumption | | | Annual Costs | | Average Unit Cost | |
|---|---|---|---|---|---|---|
| Electricity | 10,056 | kWh | $ 1,207 | 65% | $0.12 | $/kWh |
| Natural Gas | 913 | therms | $ 653 | 35% | $0.71 | $/therm |
| | | Total: | **$ 1,859** | | | |
| Total Conditioned Area | 1,873 | ft$^2$ | | | | |
| Electricity Use Intensity | 5 | kWh/ft$^2$/yr | **Natural Gas Use Intensity** | | 0.49 | Therms/ft$^2$/yr |
| Energy Use Intensity | **67** | **kBtu/ft$^2$/yr** | **Energy Cost Intensity** | | **$ 0.99** | **$/ft$^2$/yr** |
| ***Electricity is provided by COOP Electric and natural gas is supplied by SEMCO Energy*** | | | | | | |

## 3.2 Energy Consumption Profiles

The SCinIC team analyzed one year of electric and gas data provided by the client. The utility data covers the months from January 2011 through December 2011. The home was then modeled using the closest weather station, Eau Claire, Michigan, which recorded 6,215 heating degree days and 801 cooling degree days. Degree days are indicative of the duration and intensity of the heating and cooling seasons and are used in this analysis to track how electricity and gas usage correspond to seasonal weather changes.

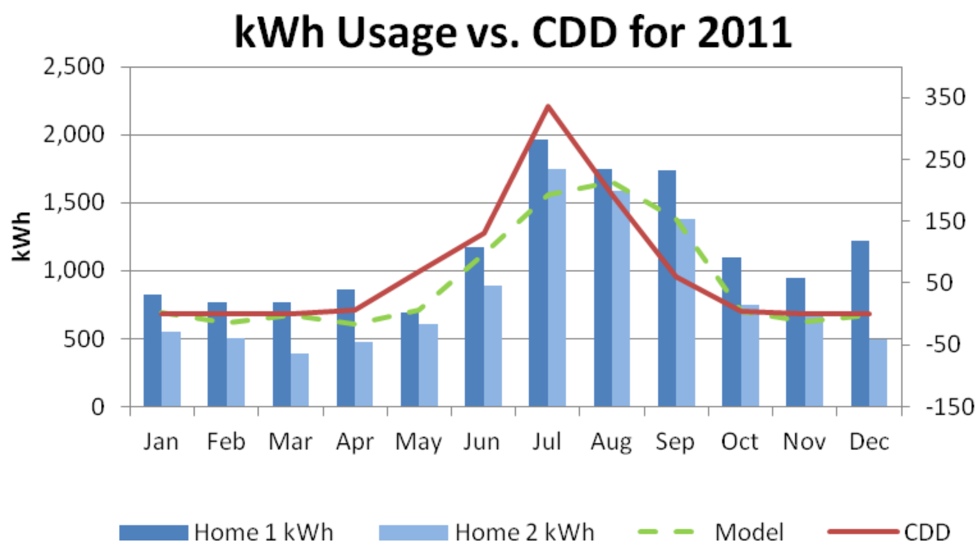



**Figure 1. Electricity Consumption vs. Cooling Degree Days**

Figure 1 compares the Pokagon elder home's electricity usage with cooling degree days and the modeled electricity usage. Electricity is used for lighting, cooling, plug loads, and fans and pumps. The base electrical load for Home 1 is approximately 800 kWh per month and it is about 600 kWh per month for Home 2. The homes use this amount of electricity regardless of weather. The graph shows that additional electricity use does correspond with the cooling degree days except for the additional use in September which could be attributed to a delayed change in seasons, and a spike in December for Home 1 which could be from humidification or space heating. The difference in usage for the two homes is attributed to the difference in occupancy patterns. The modeled electricity use comes within 14 percent (average of home 1 & home 2) of the metered annual electricity use.

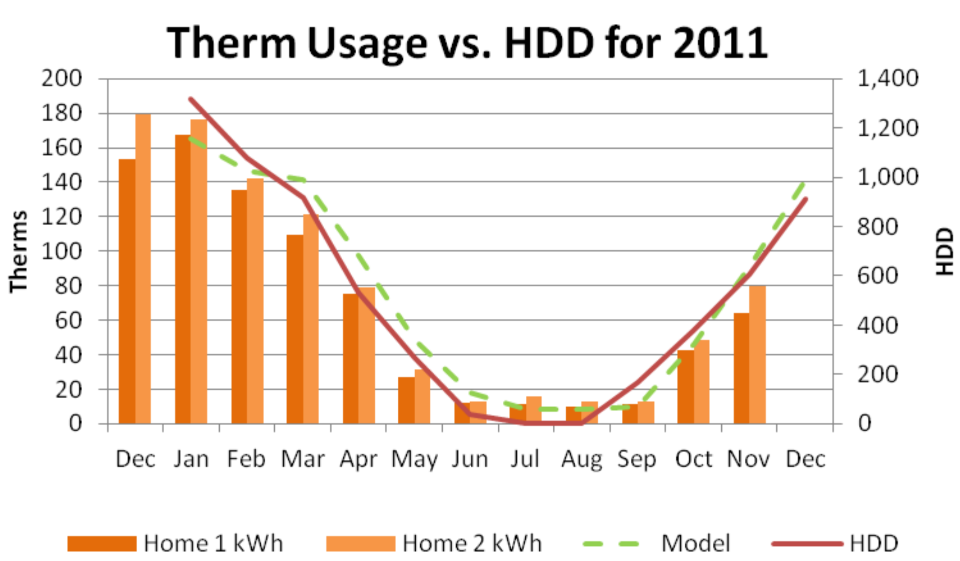



**Figure 2. Gas Consumption vs. Heating Degree Days**

Figure 2 compares the building's natural gas usage with heating degree days and the modeled gas usage. Natural gas is used for the furnace and domestic hot water. The homes' gas use does follow the heating degree days. The base natural gas consumption is simply the amount of gas used to provide domestic hot water. The modeled gas use comes within 6 percent of the metered annual use and is acceptable for the purposes of this report.

## 3.3 Breakdown of Energy Consumption

Using the modeled energy data, an energy consumption profile was created for the Pokagon Elder Housing. Figure 3 shows the energy consumption breakdown for the homes. The largest category of energy usage is space heating. The second largest consumer is miscellaneous loads (including plug loads, humidification, and space heating), and then lighting.

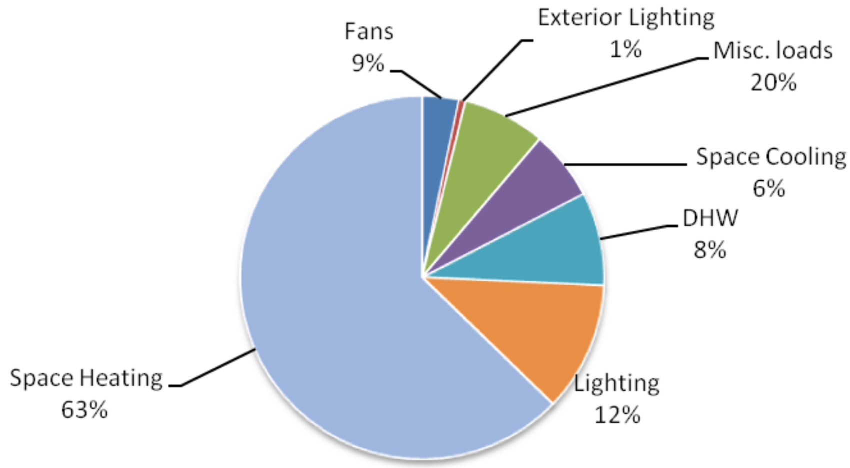



**Figure 3. Energy Consumption Breakdown**

The energy cost breakdown is illustrated in Figure 4. When energy consumption is translated to energy cost, the most costly operational categories are revealed: (1) Space Heating, (2) Lighting, (3) Miscellaneous loads. These are the first areas that should be targeted for energy savings.

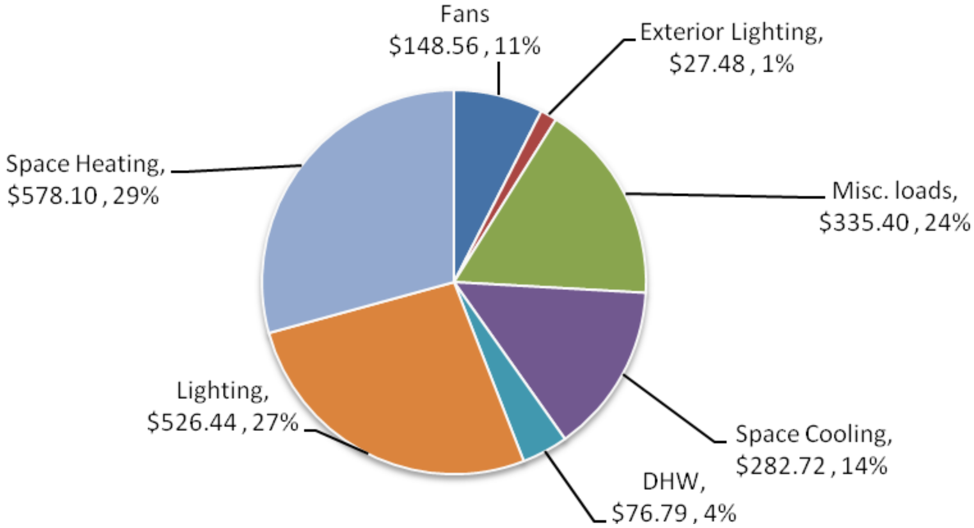



**Figure 4. Energy Cost Breakdown**

# 4. Energy Cost Reduction Measures

Energy conservation is best achieved through a multifaceted approach that involves load reduction, efficiency improvements, and renewable generation.  Addressing any one of these pathways will save energy.

Load reduction, whether no cost or low cost, should be the first step.  Load reduction involves managing energy consumption by simply turning things off when not needed or implementing control systems to help manage unnecessary energy use.  Examples of load reduction include using nighttime thermostat setbacks or turning off lights in well-lit areas on sunny days to reduce lighting loads.  Envelope upgrades such as adding insulation or window shades can result in load reduction but usually require large capital expenditures.

Energy efficiency improvements should be considered next.  While typically more expnsive than load reduction, energy efficiency improvements are more cost effective than implementing renewable energy generation.  Efficiency improvements involve replacing old or failing systems with modern technologies which perform the same function while consuming less energy.  Examples of energy efficiency improvements include installing boilers with greater heating efficiency improvements include installing boilers with greater heating efficiencies or installing lighting with increased luminous efficacy.

The final step is energy generation.  This step offsets a portion of the remaining energy consumption with onsite energy generation.  Onsite energy generation is purposefully recommended after load reduction and efficiency improvements.  Accomplishing the first two steps makes it possible to install lower capacity, therefore less expensive, generation systems.

The following sections of the report address load reduction and efficiency improvements because these measures will be the easiest and most cost effective options.

## 4.1 ECRM 1: Lighting Upgrade

The current lighting in the homes is provided by incandescent light fixtures throughout the house, a 4' T8 in the laundry room, 3' T8s above the sinks in the bathrooms, and from the ceiling fans with incandescent fixtures in the living room and screen porch. This calculates to a lighting power density of 0.80 $W/ft^2$ using a 60 W incandescent lamp in each fixture (including recessed can lights and ceiling fans) throughout the house, and a 4' 32 W T8 and 3' 25 W T8 linear fixture in the laundry room and bathrooms respectively. By replacing the 60 W incandescent lamps with 13 W CFLs and using a 28 W T8 instead of the 32 W T8 in the 4' fluorescent fixture, 2,695 kWh may be saved annually resulting in an annual cost savings of $299. This lifespan of lighting is calculated at 5 years. The replacement of the incandescent lamps with CFLs will pay back in under a year, so implementation of this measure is highly recommended.

**Table 1: Lighting Upgrade Energy Savings**

| ECRM 1: Lighting Upgrade | | | | | | |
|---|---|---|---|---|---|---|
| Annual Energy Savings | | | | Economic Analysis | | |
| kWh | Therms | Cost | % Energy | Investment | IRR[1] | NPV[2] |
| 2,695 | -34 | $299 | 72% | $165 | 180% | $1,077 |

## 4.2 ECRM 2: Geothermal System

The purpose of a geothermal system is to reduce the use of traditional energy sources. This system uses the temperature of the earth to moderate the temperature of water which is pumped through the structure. When analyzed in the e-Quest model, the following results indicate this measure should be implemented only if fuel switching is the goal as the measure will not pay off in its lifetime (20 years).

**Table 2: Geothermal System Energy Savings**

| ECRM 2: Geothermal System | | | | | | |
|---|---|---|---|---|---|---|
| Annual Energy Savings | | | | Economic Analysis | | |
| kWh | Therms | Cost | % Energy | Investment | IRR | NPV |
| -2,043 | 711 | $266 | 50% | $25,000 | -12% | -$20,652 |

## 4.3 ECRM 3: Photovoltaic Array

The purpose of a photovoltaic array is to reduce the use of traditional energy sources. This system captures solar energy and converts it to electricity for use in the home which cuts down on the amount of energy that must be purchased from the utility company. When analyzed using the PV Watts calculator, the following results indicate that a 4.0 kW array in the South Bend, IN area will produce 4,490 kWh annually. The investment cost is calculated with the 30% ($8,400) federal/state tax credit.

[1] Internal Rate of Return: Rate of return on investment for project
[2] Net Present Value: Shows project earns this amount more or less than the desired rate of return (5%)

Even with the tax credit, the calculator shows that this array would not pay back within the photovoltaics 25 year lifespan.

**Table 3: Photovoltaic Array Energy Savings**

| ECRM 3: Photovoltaic Array | | | | | | |
|---|---|---|---|---|---|---|
| Annual Energy Savings | | | | Economic Analysis | | |
| kWh | Therms | Cost | % Energy | Investment | IRR | NPV |
| 4,490 | | $539 | 38% | $19,600 | -3% | -$11,434 |

## 4.4 ECRM 4: Additional Attic/Ceiling Insulation

By adding attic/ceiling insulation to at least R38, heating and cooling losses may be minimized. The calculations below use $1.20/ sq. ft. for insulation and labor. If this cost could be reduced to $0.90/sq. ft. the additional insulation would pay for itself within its 20 year lifespan.

**Table 4: Additional Attic/Ceiling Insulation Energy Savings**

| ECRM 3: Attic/Ceiling Insulation | | | | | | |
|---|---|---|---|---|---|---|
| Annual Energy Savings | | | | Economic Analysis | | |
| kWh | Therms | Cost | % Energy | Investment | IRR | NPV |
| 56 | 159 | $119 | 7% | $3,112 | -2% | -$1,548 |

# 5. Additional Energy Reduction Measures

## 5.1 Install Low Flow Fixtures

Although stormwater and domestic water management was not addressed as part of the building energy analysis, a large amount of savings can be achieved by reducing the amount of hot water used on a daily basis. Research shows that along with energy, access to fresh, clean water is also becoming a dwindling resource and shortages in certain areas of the United States are already causing water to be the next leading concern. Reducing water consumption will not only save water, but it will reduce natural gas use by reducing hot water use.

Low-flow showerheads and aerators are inexpensive, simple to install, and save hot water heating costs. Recommended are low flow showerheads (1.6 GPM or less), faucet aerators (1.0 GPM or less) and kitchen sink aerators (1.8 GPM or less). Some faucet aerators will reduce flow to 0.5 GPM.

## 5.2 Develop an Energy Management Strategy

Organizations that adopt and practice an energy management strategy are rewarded with lower energy use. These plans are very effective and are considered low cost. The United States Green Building Council (USGBC) recommends using an energy management plan to save 10% of energy use. The SCinIC team recommends this plan to the Pokagon community. Here are the steps that describe an energy management strategy offered by ENERGY STAR.

1) **Make a Commitment:** Recognize that the economic, environmental, political, and social impacts of energy consumption are sufficient motivation to change our energy use patterns.

2) **Assess performance:** Make a personalized accounting of energy use and costs. Benchmark your site by comparing its energy performance with similar sites.

3) **Set Goals:** Review your objectives and constraints. Establish priorities and set measurable goals with target dates.

4) **Create an Action Plan:** Define the technical steps. Apply proven methods to increase energy efficiency or get specialized guidance. Assign roles and resources. Consider rolling savings from earlier efforts into future, more complex initiatives.

5) **Implement Action Plan:** Install equipment and change operational procedures. Establish a maintenance schedule. Train equipment operators and building occupants on the changes. Track and monitor conditions.

6) **Evaluate Progress:** Compare current performance to established goals. Understand what worked well in order to identify best practices. Adjust procedures, goals, and schedule the next evaluation.

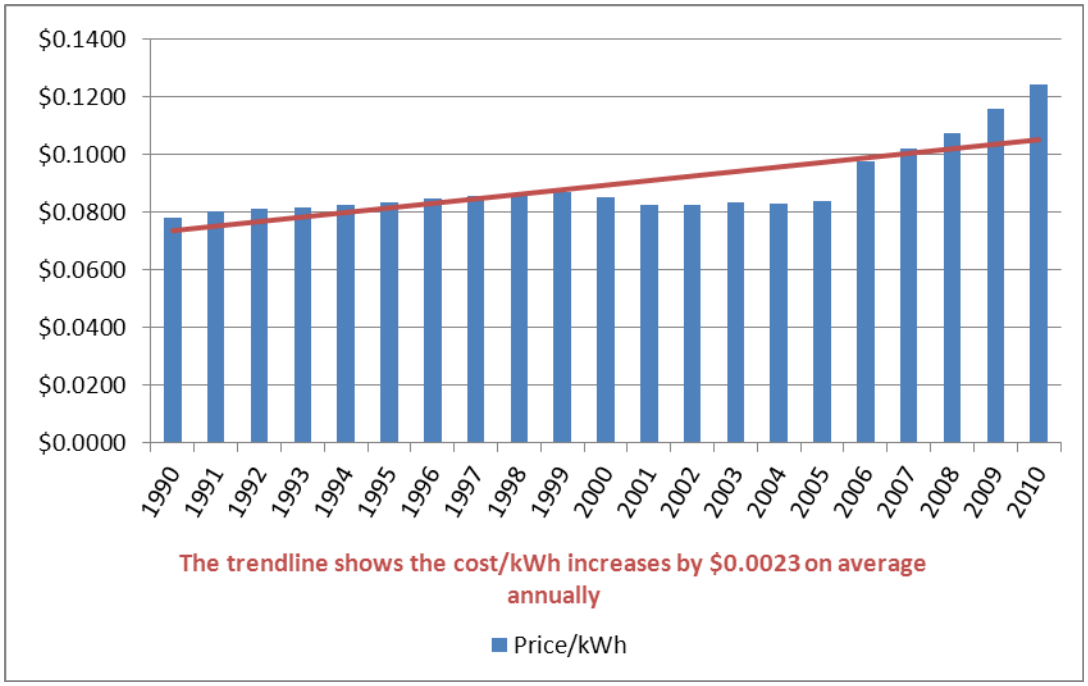
7) **Recognize Achievements:** Provide internal recognition for the efforts and achievement of individuals, teams, and facilities. Seek external recognition from government agencies, media, or third party organizations.

   The quickest, easiest, and cheapest way to reduce loads during peak hours is to ensure that lights and equipment are turned off whenever they are not required. This could be achieved by developing better occupancy habits by the residents. Savings can also be achieved by changing the thermostat settings to minimum cooling during the peak day time. Thermostat should be set to 78 °F for occupied zones.

# 6. Conclusions and Recommendations

In summary, this report provides information and strategies on how to reduce the annual operation cost through load reduction and energy efficiency improvements. Table 5 includes a summary of the quantified results. These results also include calculations using the annual rate of inflation on electricity costs for Michigan. The cost/kWh increases on average by $0.0023 each year[3] as shown in Figure 5 below.

**Figure 5: Michigan Average Cost/kWh by Year**




[3] http://www.eia.gov/electricity/data/state

**Table 5: Summary of ECRMs**

| Annual Energy Savings | | | | | Economic Analysis | | | | Study Period |
|---|---|---|---|---|---|---|---|---|---|
| **ECRM** | **kWh** | **Therms** | **Cost** | **% Energy** | **Investment** | **IRR** | **NPV** | **SP[4]** | |
| **Lighting** | 2,695 | -34 | $299 | 72% | $165 | 180% | $1,077 | 0.55 | 5 |
| *with inflation* | | | $316 | | | 190% | $1,144 | 0.52 | |
| **Geothermal** | -2,043 | 711 | $266 | 50% | $25,000 | -12% | -$20,652 | 93.98 | 20 |
| *with inflation* | | | $411 | | | -9% | -$18,931 | 60.83 | |
| **Photovoltaics** | 4,490 | | $539 | 38% | $19,600 | -3% | -$11,434 | 36.36 | 25 |
| *with inflation* | | | $618 | | | -2% | -$10,371 | 31.72 | |
| **Attic/Ceiling Insulation** | 56 | 159 | $119 | 7% | $3,112 | -2% | -$1,548 | 26.09 | 20 |
| *with inflation* | | | $120 | | | -2% | -$1,541 | 25.96 | |
| **Total:** | **5,198** | **836** | | | **$47,877** | | | | |

[4] Simple Payback: The number of years it will take the savings of the project to payback the initial investment. If this number exceeds the lifespan of the measure (study period), it is not recommended for implementation.