Sustainable Construction in Indian Country

Energy Evaluation and Recommendations

Kekyajek Odanek Phase 4:
Multi-unit Housing

August 6, 2012

Pokagon Band of Potawatomi Indians
Dowagiac, MI

PD&R
Office of Native American Programs
Office of Public & Indian Housing

U.S. Department of Housing and Urban Development | Office of Policy Development and Research

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Executive Summary

Figure 1: Sketch of Phase 4 of the Dowgiac Master Plan

The Pokagon Band of Potawatomi in Michigan are currently working on Phase 4 of a community master plan to provide multi-family housing on tribal government land in Pokegnk Edawat Dowagiac.[1] Construction is proposed to begin in the fall of 2012 and will consist of four new multi-family buildings. Each two-story 5,106 ft^2 multi-family building will have four individual apartments that comprise of two and three bedroom units. Two of the buildings will be used as a pilot project and will utilize a geothermal system while the other two buildings will utilize gas forced air furnaces.

This report provides information and strategies to reduce the annual operation cost through load reduction and energy efficiency improvements. It compares a baseline analysis of the current design by Nelson Design Group, LLC (NDG) verses an analysis of proposed alterations suggested by the Sustainable Construction in Indian Country (SCinIC) team to the building while maintaining the building footprint.

1.0 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, expected building usage, and project design goals.

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 expected building energy usage 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 provided by the client and the weather file for e-QUEST was taken from the weather station in Eau Claire, Michigan.

Subsequently, the project SCinIC team performs computer analyses of the ECRMs. The baseline model is changed to reflect the implementation of the ECRMs. The computer model estimates the energy consumption and utility costs using rate information derived from the utility analysis.

Finally, the estimated savings and additional costs of implementing ECRMs are evaluated in a life cycle cost analysis. This analysis assumes a twenty year life cycle and calculates the internal rate of return (IRR) and the net present value (NPV) of each ECRM and a package of ECRMs. IRR is essentially the annual yield on an equivalent investment. A project is a good investment if its IRR is greater than the rate of return that could be earned by an alternative investment (other projects, bonds, bank accounts, etc.). For public projects, the SCinIC team assumes 5 percent as the minimum acceptable rate of return. The NPV calculation uses a discount rate to find the present value of savings occurring at a future date. The discount rate is your minimum acceptable rate of return, or your time value of money. Again, SCinIC assumed 5 percent. Investments have a positive NPV when the IRR is greater than the discount rate. Therefore projects with IRR greater than the discount rate and a positive NPV are considered to be good investments and are recommended.

[1] For more information regarding the tribe's master plan, refer to the HUD Case Study "Sustainable Construction in Indian Country: Incorporating Sustainable Land and Water Strategies into a Master Plan."

2.0 Facility Description

Proposed to begin construction in the fall of 2012, this 5,106 ft^2 building is used as multi-family housing and comprises of four individual residential units. The two units on the ends of the building are

2-bedroom/2 bath, while the two units in the middle are 3-bedroom/2.5 bath. Each unit has a living room, kitchen, dining areas, and washer and dryer.

It is assumed that 4-6 people will be living in each unit (two people per bedroom). While occupancy is highly dependent on the individual lifestyles of the residents and what additional family members may be living with them, it is assumed that those living in the units will spend most of their time at home. Therefore it is assumed that the residents will primarily be in the units 80% of the time during the week (approximately 134 hours/week) and 20% of their time outside of the apartment.

Figure 2: Exterior of Pokagon duplex proposed by NDG

2.1 Building Envelope

Walls: Each unit is separated by a 2-hour fire rated wall. The typical wall construction from the inside to outside is 5/8” gypsum board, 2x6 wood frame construction with R-19 batt insulation, and an exterior insulation and finishing system (EIFS) finish on ¾” exterior foam board on ½” exterior gypsum board with 1 ½” (2x4) typical frieze. It is estimated that the wall assembly has a thermal resistance rating (R-value) of R-22.

Roof: The roof is hipped with a 7:12 slope. It is constructed with 2x6 wood rafters, is covered in light brown asphalt shingles, and has R-38 blown insulation above the ceiling providing the roof with a thermal resistance rating of R-38.

Floor: The first floor is a 4” reinforced concrete slab on grade with no insulation. *It is assumed that the first floor and the bedrooms on the second floor will have carpet.*

Windows: *It is assumed that the windows on the North façade are to be clear, double-pane in a vinyl frame and the windows on the South façade are to be double-pane, low-E with a vinyl frame in order to reflect the sun in the summer months.*

2.2 HVAC

The current Nelson Design Group proposal of the building places all HVAC equipment in the attic. *Since information regarding the types of mechanical systems used in the building was not available, the following assumptions have been made and are based on code analysis and Energy Star ratings.*

Heating/Cooling: Each unit will have its own dedicated split heating and cooling system. It is assumed that the *gas-forced air furnace has an Annual Fuel Utilization Efficiency (AFUE) of 95% and the condensing unit has a cooling efficiency of EER 14.5 according to the drawings,* ceiling fans are specified in the great room and in each bedroom. These fixtures will help reduce stratification. *It is also assumed that standard programmable thermostats shall be installed in each apartment to allow occupants to adjust the thermostat to their preferred comfort level.*

Ventilation: Since supplemental ventilation is not typically provided for residential buildings, it is assumed that ventilation air will be provided by infiltration. Each bathroom also has an exhaust fan rated at 90 CFM.

2.3 Domestic Hot Water

It is assumed that a standard efficiency 40-gallon gas domestic water heater will be used to provide hot water to each apartment (160 gallons total). An ENERGY STAR rated unit of this size is estimated to have an energy factor of 0.67, use approximately 224 therms per year and have a 68.0-gallon first hour rating. In the e-Quest model, it was assumed that each person would use approximately 10 gallons/day.

2.4 Lighting

Lighting in the building is provided by a 2'x4' fluorescent light in the kitchen, incandescent light fixtures throughout the apartment, and from incandescent light fixtures attached to the ceiling fans in the great room and bedrooms.

For Units #1 and 4, we assumed for the base model a lighting power density of 1.77 W/ft^2 using a 60 W incandescent lamp in each fixture (including recessed can lights and ceiling fans) throughout the apartment, and a 4-foot 32 W T-8 linear fixture with rapid start electronic ballast in the kitchen.

For Units #2 and 3, we assumed for the base model a lighting power density of 2.33 W/ft^2 using a 60 W incandescent lamp in each fixture (including recessed can lights and ceiling fans) throughout the apartment, and a 4-foot 32 W T-8 linear fluorescent light fixture with rapid start electronic ballast in the kitchen.

2.5 Additional Plug Loads

Additional plug loads in the building include typical residential appliances such as task lighting, TVs, washer, dryer and standard kitchen equipment (refrigerators, stove, and microwaves). It was assumed that an electric stove and natural gas dryer was installed in each apartment. In the e-Quest model it was assumed that each unit would do approximately 2 loads of laundry per week.

3. Energy Consumption and Analysis

3.1 Utility Consumption Benchmarking

Since these units are new construction, annual utility data was not available. However, using the estimated kWh from the e-Quest energy model, the following analysis was performed.

According to the utility data from the existing single-family homes located near the proposed site for elder housing, the Pokagon receive its electricity through COOP Electric and is delivered at an estimated rate of $0.12 per kWh and its natural gas is supplied by SEMCO Energy at an estimated rate of $0.71 per therm. These rates include meter fees and taxes.

Table 1 shows the estimated annual utility consumption for the NDG building design while Figure 3 shows the estimated energy consumption breakdown for each month. The estimated annual energy use intensity (EUI) of the proposed design for a new multi-family housing building is 60 kBtu/ft^2 and the estimated annual energy cost intensity (ECI) is $1.12 /ft^2. These two values can be used to benchmark the energy performance of the current NDG proposal of the units against similar buildings.[2]

Estimated Annual Consumption			**Annual Costs**		**Average Unit Cost**	
Electricity	37,110	kWh	$ 4,453	78%	$0.12	$/kWh
Natural Gas	1,816	therms	$ 1,290	22%	$0.71	$/therm
		Total:	**$ 5,743**			
Total Facilities Area	5,106	ft^2				
Electricity Use Intensity	7	kWh/ft^2/yr	**Natural Gas Use Intensity**		0.36	Therms/ft^2/yr
Energy Use Intensity	**60**	**kBtu/ft^2/yr**	**Energy Cost Intensity**		**$ 1.12**	**$/ft^2/yr**
Electricity is provided by COOP Electric and natural gas is supplied by SEMCO Energy						

Table 1: Estimated Annual Utility Consumption for the NDG building design

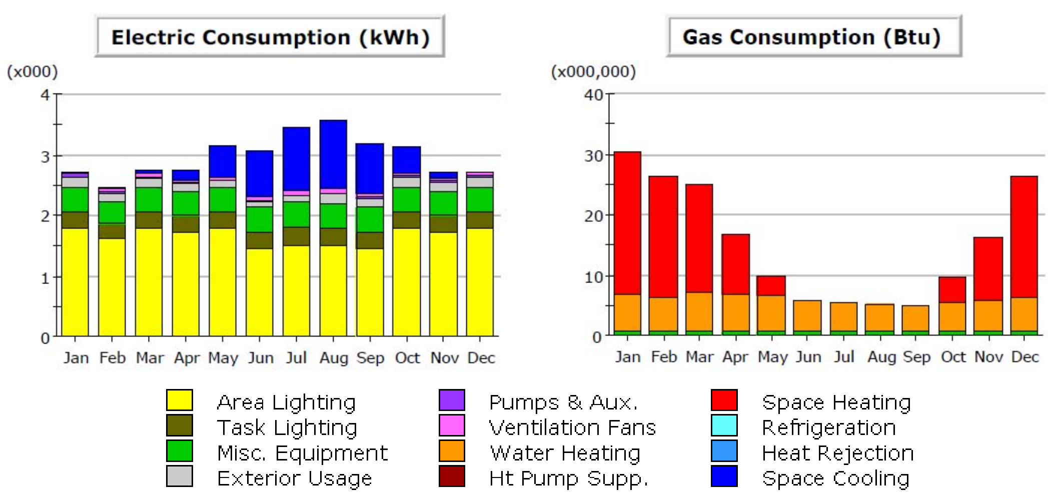


Figure 3: Estimated Annual Utility Consumption for the NDG building design

[2] The Energy Use Intensity (EUI) is measured in kBtu which is a common energy unit used in benchmarking and allows for comparing different fuel sources. The higher the EUI, the less efficient the building is.

3.2 Energy Consumption Profiles

The SCinIC team analyzed the 2011 calendar year of electric and gas data in the energy model using the closest weather station, Eau Claire, Michigan, which recorded 6,215 heating degree days and 801 cooling degree days.[3] 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.

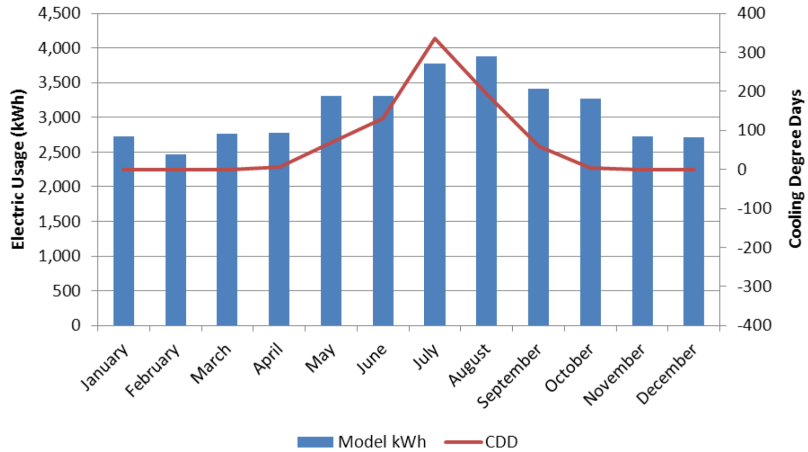


Figure 4: Electricity Consumption for 4 units vs. Cooling Degree Days

Figure 4 compares the NDG current building design's modeled electricity usage with cooling degree days. Electricity is used for lighting, cooling, plug loads, and fans and pumps. The base electrical load for the building is approximately 2,250 kWh per month. The graph shows that additional electricity use corresponds with the cooling degree days.

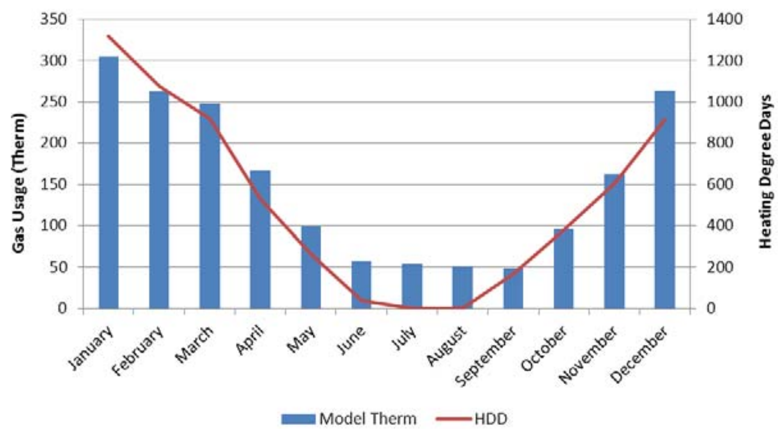


Figure 5: Natural Gas Consumption for 4 units vs. Heating Degree Days

Figure 5 compares the NDG current building design's modeled natural gas usage with heating degree days. Natural gas is used for the furnace, domestic hot water, and laundry dryer. The building's gas use follows the heating degree days. The base natural gas consumption for most residential buildings is simply the amount of gas used to provide domestic hot water. Although the gas usage in the summer

[3] This climate data came from: http://www.weatherdatadepot.com/

months may seem high, this multi-family building equates to approximately 50 therms per month, which is roughly 12.5 therms per apartment and is comparable to a Pokagon single-family elder home.[4]

3.3 Breakdown of Energy Consumption

Using the modeled energy data, an energy consumption profile was created for the Pokagon Elder Housing units. Figure 6 shows the energy consumption breakdown for the building. When energy consumption is broken down, the building uses the most energy in the following categories: (1) space heating, (2) lighting, (3) DHW.

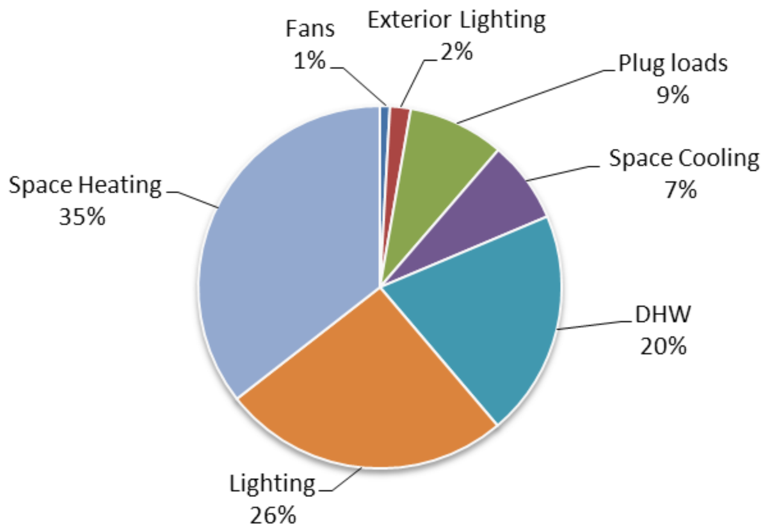


Figure 6: Energy Consumption Breakdown

The energy cost breakdown is illustrated in Figure 7. When energy consumption is translated to energy cost, the most costly operational categories are revealed: (1) Lighting, (2) Space Heating. These are the first areas that should be targeted for energy savings.

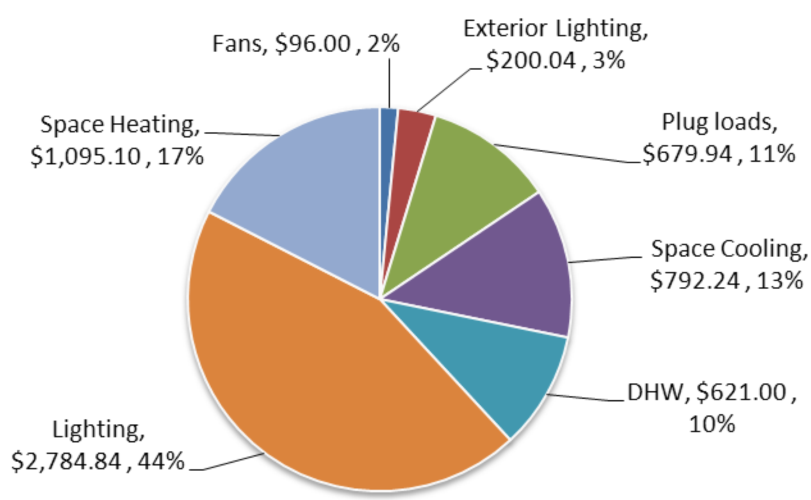


Figure 7: Energy Cost Breakdown

[4] See report *Energy Evaluations and Recommendations: Pokagon Elder Housing*.

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 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 upgrading windows can result in load reduction but usually require large capital expenditures.

Energy efficiency improvements should be considered next. While typically more expensive 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 or installing lighting with increased luminous efficacy.

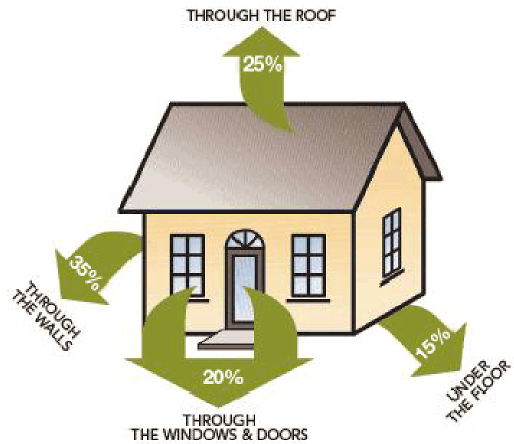


Figure 8: A diagram showing where energy loss occurs in a residential building.

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.

As Figure 8 shows, 35% of a residence's energy loss occurs through the walls, 25% through the roof, 20% through leaks around windows and doors, and 15% under the floor. In order to help create a tighter building, reduce energy loss, and increase energy efficiency, the SCinIC team generated a baseline model in e-Quest based on the NDG design and compared it with the following scenarios:

- Baseline (with HVAC moved into the building)
- Attic Insulation (with HVAC remaining in the attic)
- Geothermal system (with HVAC in the attic)
- Geothermal system (with HVAC moved into the building)
- Upgraded windows (triple pane with low-E where appropriate)
- Additional windows (double-pane with low-E where appropriate)
- Lighting upgrade with CFLs
- Insulate the slab foundation

The following sections of the report address these load reduction and efficiency improvements and compares their annual energy and cost savings.

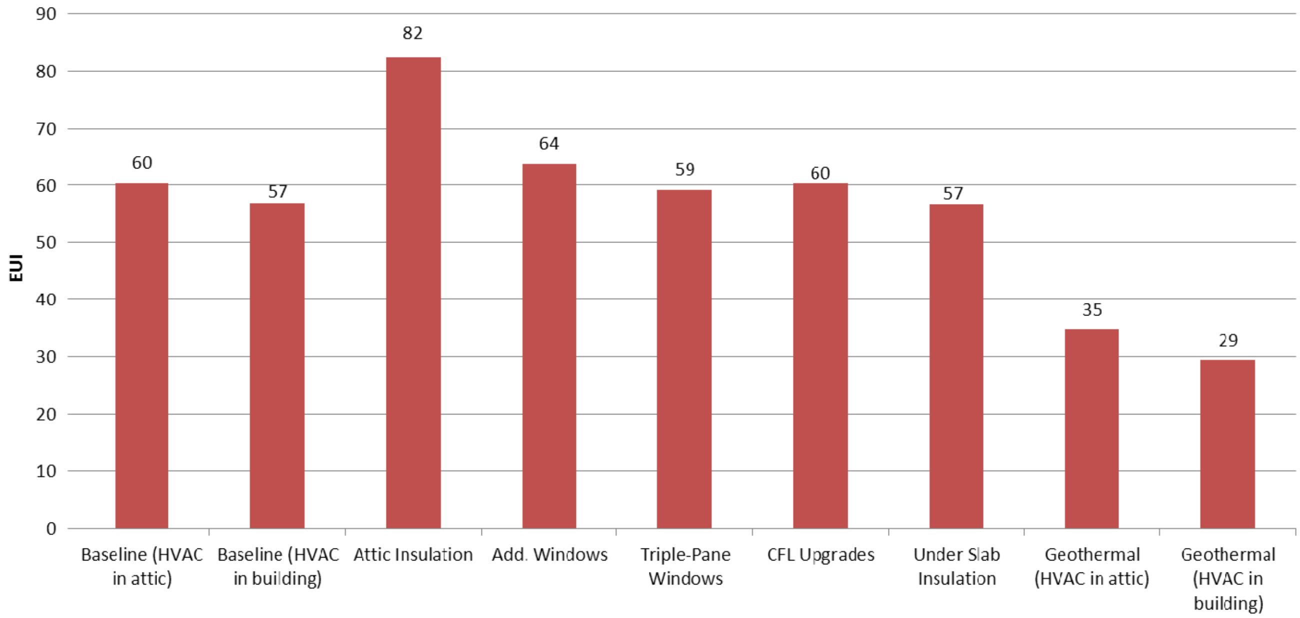


Figure 9: Annual Energy Use Comparison

Figure 9 compares the annual energy use for each scenario modeled in e-Quest to the baseline model described earlier in this report. It shows that transforming the attic into a conditioned space in which to place the HVAC equipment by placing insulation in the attic instead of the ceiling uses the most energy, whereas implementing a geothermal system with the HVAC equipment inside of the building (already conditioned space) would use the least amount of energy over the course of a year. Changing the lighting fixtures to have CFL bulbs instead of incandescent would save roughly 5% of the annual energy costs.

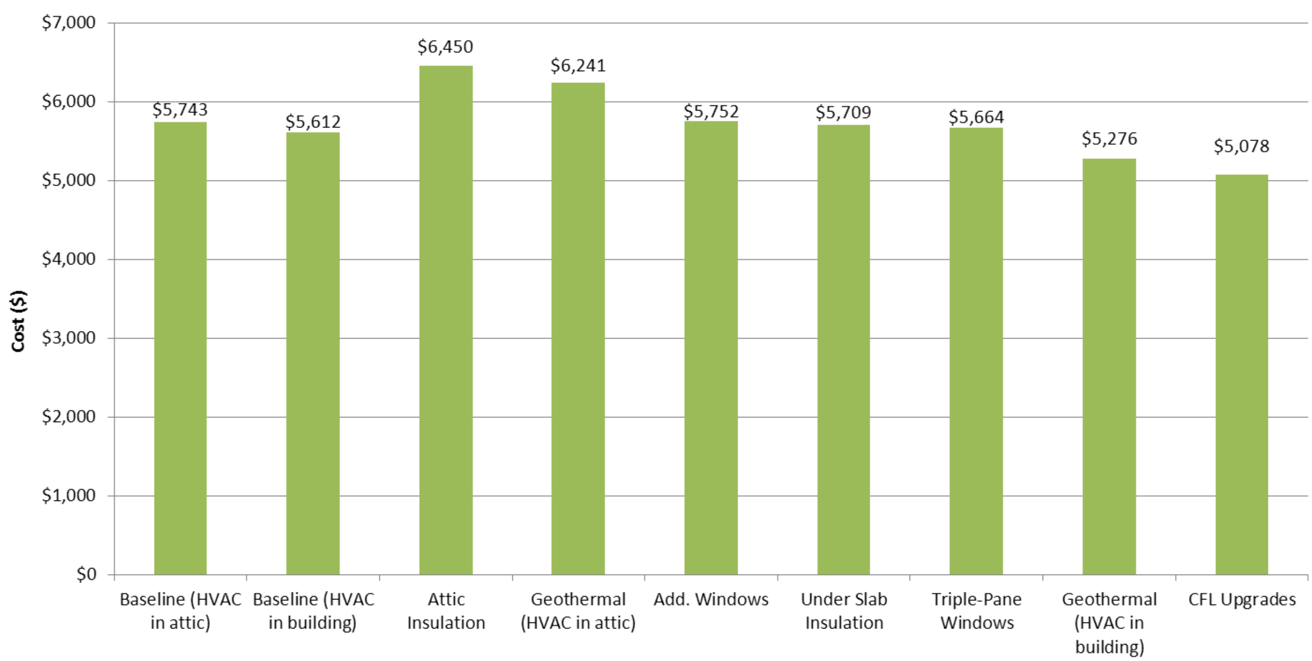


Figure 10: Annual Energy Cost Comparison

Figure 10 compares the annual energy cost for each scenario modeled in e-Quest to the baseline model as described earlier in the report. It shows that adding insulation in the attic (instead of the ceiling of the second floor) would increase the annual energy costs, whereas upgrading the lighting to CFL bulbs would provide the greatest annual energy cost savings.

4.1 ECRM 1: Moving HVAC inside the building

The first recommendation by the SCinIC team, is to move the HVAC equipment to the inside of the building. As mentioned earlier in this report, the current NDG design for the multi-family duplexes mentions that all HVAC equipment will be placed in the attic space of the building. According to the architectural plans, the attic space is considered an unconditioned space. Placing ducts in a vented, unconditioned attic is a bad idea for several reasons.

Figure 11: Image of duct work in an attic.

First, solar energy is absorbed by the roof, heating the roof sheathing and causing the underside of the sheathing and the roof framing to become hot. These surfaces then radiate heat downward toward the attic floor. Second, the outside surface of the ductwork exchanges energy with the air in the attic space, causing energy to be lost. Third, when return ducts leak, the air that is sucked into the ducts feeds into the HVAC air handler, which then has to use extra energy to cool this warmer air.[5] Leaky duct work also allows the air meant to condition the interior spaces to instead go into the attic and out with the attic ventilation. Maintenance and replacement or upgrading of the system will also be more difficult to accomplish because of its challenging location, resulting in higher labor costs.

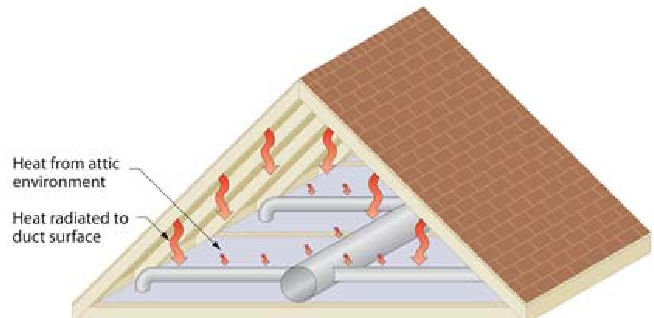


Figure 12: Diagram showing heat radiation in an attic space.

Therefore, even though the most efficient HVAC equipment may be used and the ductwork may be installed properly (which is rare), studies show that merely having the equipment located in the attic reduces the HVAC system efficiency by about 20%.[6] When the baseline was modeled in e-Quest, this energy loss was taken into account with the split heating and cooling system by assuming that the gas-forced air furnace had an AFUE of 75% and the condensing unit has a cooling efficiency of SEER 11.6. The first ECRM modeled in e-Quest was to show the energy savings of moving the HVAC system into the building in order to maintain the split system's full efficiency level of an AFUE of 95% and SEER 14.5. The results in Table 2 show that by moving the HVAC equipment to the inside of the building will save 6% of the building's total energy consumption and an annual $131 in utility bills. This analysis was based on the investment cost being equal or slightly less than the cost of installing the HVAC system in the attic resulting in an immediate payback.

Baseline (HVAC in the attic)						
Annual Energy Consumption						
kWh		Therms		Cost		
37,110		1,816		5,743		
ECRM 1: Baseline (HVAC inside the building)						
Annual Energy Savings				Economic Analysis		
kWh	Therms	Cost	% Energy	Investment	IRR	NPV
0	184	$131	6%	$0	N/A	$1,553

Table 2: Moving the HVAC system inside the building Energy Savings

[5] http://ornl.gov/sci/ees/etsd/btric/RadiantBarrier/rb2.shtml

[6] *Ducts in the Attic? What Were They Thinking?* by David Roberts and Jon Winkler

4.2 ECRM 2: Attic Insulation (with HVAC remaining in the attic)

Buildings lose roughly 25% of the building's energy through the roof. Attics are often one of the easiest places in a house to insulate and can result in large energy savings for the building. However, this energy savings can be lost by placing HVAC in the attic which reduces system efficiency by about 20%.[7] Therefore although properly insulating and air sealing an attic will help reduce energy bills, it is still recommended that the HVAC equipment be moved to somewhere inside of the building.

Figure 13: Example of blown insulation.

The current architectural plans call for HVAC in the attic and R-38 blown insulation in the ceiling level of the conditioned apartment spaces instead of being at the roof line for the building. These conditions were used to model the baseline in e-Quest, and were then compared to a second ECRM that moved the line of insulation from the ceiling level to the roof while keeping the HVAC system in the attic. Figure 14 illustrates this description of moving the thermal envelope.[8] Using the 2012 International Energy Conservation Code guidelines, it was assumed that a minimum of R-38 Batt insulation would be installed in the roof line, which would allow for heating and cooling losses to be minimized.

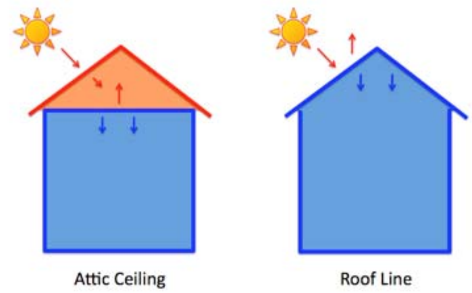


Figure 14: Moving the thermal envelope from the attic ceiling to the roof line.

The results in Table 3 show that by moving the line of insulation from the ceiling level to the roof level with the HVAC equipment in the attic would save 950 kWh of electricity, but increase the building's gas consumption to heat the building, resulting in an annual increase of $708 in utilities. Therefore the building would be 36% less efficient. By moving the building's thermal envelope from the attic ceiling to the roof line, some of the energy used to heat and cool the apartment units below is allowed to actually creep back into the attic, therefore helping to keep the attic cooler in the summer and warmer in the winter. Thus the attic becomes an inadvertently conditioned space.

ECRM 2: Attic Insulation (with HVAC remaining in the attic)						
Annual Energy Savings				Economic Analysis		
kWh	Therms	Cost	% Energy	Investment	IRR	NPV
950	-1,157	-$708	-36%	$3,240	N/A	-$13,650

Table 3: Additional Attic/Ceiling Insulation Energy Savings

The calculations above use an investment cost of $1.20/ sq. ft. for insulation and labor. The IRR and NPV analysis were based on a 20 year study period. The results indicate a negative return of investment. Therefore, it is recommended that the building keeps the insulation at the ceiling level and move the HVAC system out of the attic and into somewhere inside of the building.

4.3 ECRM 3: Geothermal System (HVAC in attic VS HVAC in the building)

The Pokagon are currently planning on implementing a geothermal heating and cooling system in two of the four new multi-family buildings as part of a pilot project, while the other two buildings will utilize gas forced air furnaces.

[7] *Ducts in the Attic? What Were They Thinking?* by David Roberts and Jon Winkler
[8] http://greencomplianceplus.markenglisharchitects.com/discussions/building-techniques/home-insulation-title-24/

The purpose of a geothermal system is to reduce the use of traditional energy sources. In fact, a geothermal system can use 25-50% less electricity than conventional heating and cooling systems. This system works by using the temperature of the earth to moderate the temperature of the glycol which is pumped through the system.[9] For residential installations, a horizontal system is generally the most cost-effective, especially for new construction. However, the e-Quest modeling program only allows for vertical wells to be modeled. In addition, the quotes received talking with a representative from Process Engineering was based on a vertical system. It was estimated that each unit would need two wells dug at 215 feet deep (total of 8 wells per building).

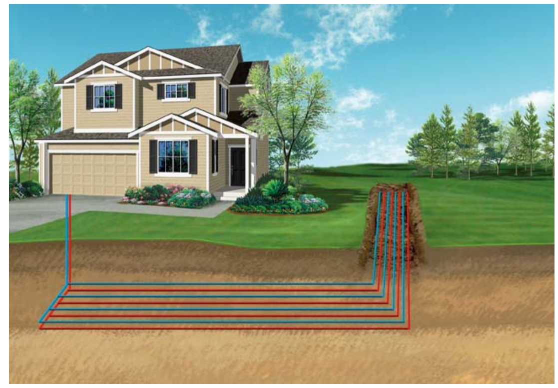


Figure 15: Example of a vertical geothermal system.

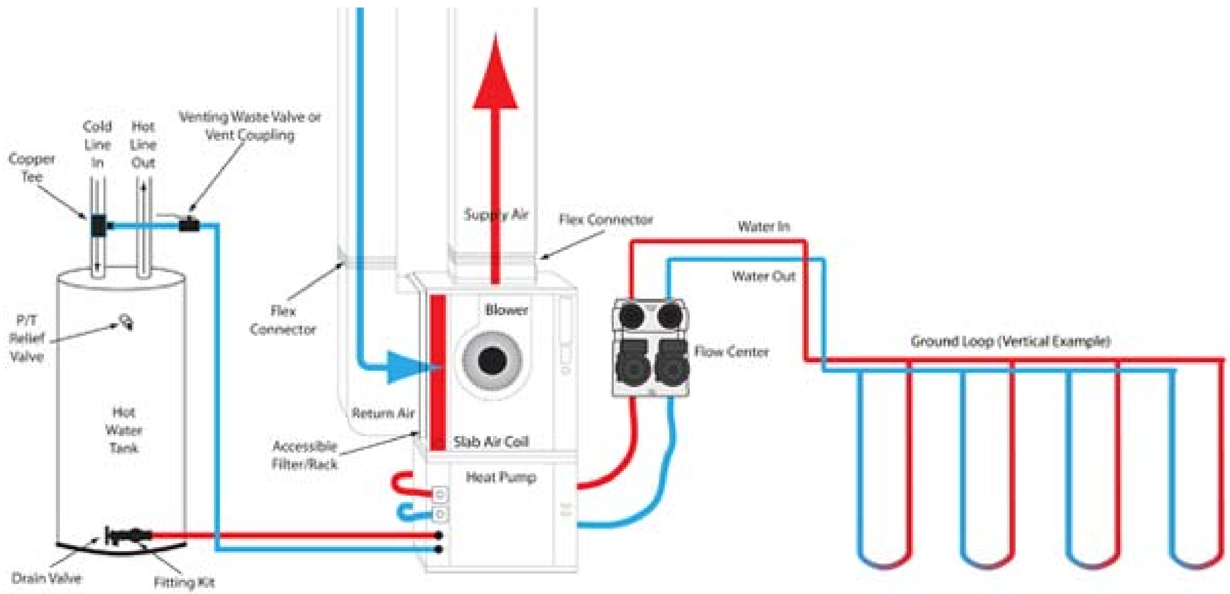


Figure 16: Diagram showing how a geothermal heat pump system works

Implementing a geothermal heating and cooling system would also allow a desuperheater to be installed. In the summer this would allow the hot air from the rooms to be collected and used to heat the domestic hot water rather than being discarded into the ground, therefore supplementing the heat pump system.[10] A desuperheater is a small, auxiliary heat exchanger that uses superheated gases from the heat pump's compressor to heat water. This hot water then circulates through a pipe to the home's storage water heater tank. Figure 16 shows how this system works.[11]

When the geothermal system for the building was analyzed in e-Quest, it was first assumed that the HVAC equipment would remain in the attic (factoring in a 20% decrease in efficiency), therefore lowering the EER to 10.4 and COP to 2.24. This analysis was compared to the Baseline model that had the HVAC system in the attic. As shown in ECRM 3A in Table 4, implementing a geothermal system with the HVAC in the attic would save 1,816 therms annually or 42% of the building's total energy use. However, the annual electricity use would increase resulting in an estimated increase of $498 a year for

[9] For more information regarding the different geothermal systems, visit: http://www.energysavers.gov
[10] For more information, visit: http://www.energystar.gov/
[11] http://www.sheridansheetmetalonline.com/Ground-Source-Heat-Pump-Illustrations-2.htm

utilities. This is a result of the geothermal system relying on electricity being the only energy source, compared to the baseline design having both gas and electricity.

The model was then analyzed in e-Quest assuming the HVAC equipment had been removed from the attic and moved to a different location within each apartment, therefore increasing the HVAC system to its full efficiency levels; a cooling size of 2.5 tons per unit (10 tons for the entire building), an Energy Efficiency Ratio (EER) of 13, and a heating efficiency COP of 2.8. This analysis was compared to the Baseline model that had the HVAC system in the building. As shown in ECRM 3B in Table 4, this would also save 1,816 therms annually or 51% of the building's total energy use. However, the annual electricity use would increase only half as much compared to having the HVAC in the attic resulting in saving an estimated $466 a year for utilities.

ECRM 3A: Geothermal System (HVAC in attic)						
Annual Energy Savings				**Economic Analysis**		
kWh	**Therms**	**Cost**	**% Energy**	**Investment**	**IRR**	**NPV**
-14,900	1,816	-$498	42%	$50,000	N/A	-$53,535
			With incentives	$40,810	N/A	-$44,782
			Baseline with traditional system	$44,000		

ECRM 3B: Geothermal System (HVAC in building)						
Annual Energy Savings				**Economic Analysis**		
kWh	**Therms**	**Cost**	**% Energy**	**Investment**	**IRR**	**NPV**
-6,860	1,816	$466	51%	$50,000	-12%	-$42,084
			Investment over traditional system	$6,000	5%	-$179
			Baseline with traditional system	$44,000		

Table 4: Geothermal System Energy Savings

A traditional residential split heating and cooling system as described earlier in this report with an AFUE of 95% and EER 14.5 was estimated to cost $11,000 for each unit, including $6,000 for the equipment and $5,000 for labor and installation ($44,000 for the whole building). Initial investment costs for the geothermal system was estimated at $25,000 for a loop field and wells dug, mechanical equipment for the building costing $15,000, and labor costs estimated at $5,000 for a total of $50,000.[12] Therefore, installing a geothermal system instead of a traditional split system would cost an estimated $6,000 more.

The second economic analysis includes incentives from the federal government and the City of Dowagic. For installing a geothermal system into the building, the Pokagon may be eligible to receive a tax credit from the federal government for $1.80 per square foot (approximately $9,190 total per building) which is approximately a 25% savings of the total cost. The City of Dowagic also offers electric customers a rebate for new equipment, including ENERGY STAR high efficiency heat pump water heaters installed in residential units.[13]

The IRR and NPV analysis were based on a 20 year study period. The economic analysis shows that even though a geothermal system would help save roughly half of the building's annual energy use, due to investment costs being nearly that of a traditional system with incentives, the measure would not pay back in the estimated 20 year lifespan. If considering the cost difference between the geothermal system and a traditional system as basis for pay back, then the IRR is favorable.

[12] The installation costs for the loop field and wells dug came from conversations with Process Engineering.
[13] See Addenda A.

4.4 ECRM 4: Upgrade Windows to Triple-Pane

While windows can provide views, day lighting, ventilation, and heat from the sun during the winter, they can also account for nearly 20% of a building's air infiltration.[14] Therefore installing high-performance windows could help improve a building's energy performance.

It was assumed in the e-Quest baseline model that the building would have double-pane windows with low-e coating on the windows facing south. Low-emissivity (Low-e) coatings on glazing or glass control heat transfer through windows with insulated glazing. Windows manufactured with Low-E coatings typically cost 10-15% more than regular windows, but they can help reduce a building's energy loss.[15] Windows with low-e coatings reflect back part of a room's heat in the winter months which helps to decrease the amount of energy it takes the HVAC system to warm up a room. In the summertime, the sun shining through a window heats up the room. Therefore, windows with low-e coatings on the glass reflect some of the sunlight, which helps to keep the room cooler.[16]

Figure 17: Example of a triple-pane window.

Insulated windows are generally windows with two or more panes of glass. These additional glass layers and the air spaces between them help to resist heat flow. Therefore, the e-Quest baseline model was compared to the scenario of upgrading the windows from double-pane to triple-pane. Table 3 shows that by upgrading these windows to triple-pane with low-e coating where appropriate, there would be 2% energy savings of the building's total energy use and a savings of $79 a year for utilities.

ECRM 4: Triple-Pane Windows						
Annual Energy Savings				Economic Analysis		
kWh	Therms	Cost	% Energy	Investment	IRR	NPV
380	46	$79	2%	$16,800	-16%	-$15,068

Table 5: Triple-Pane Window Upgrade Energy Savings

The investment cost is based off estimates of upgrading all 28 windows from double-pane to triple-pane with low-e coating on the South facing windows, and was estimated at a cost of $600 window.[17] These estimates include the purchase cost and installation cost of each window. The IRR and NPV analysis are based on a 20 year study period. Although installing high-performance windows will improve a building's energy performance, it will take far longer than the replacements lifespan to pay off in energy savings. However, the benefits of added comfort can sometimes offset the cost.

[14] http://www1.eere.energy.gov/buildings/betterbuildings/neighborhoods/why_ee_upgrades.html
[15] http://www.energysavers.gov/your_home/windows_doors_skylights/index.cfm/mytopic=13430
[16] www.energysavers.gov
[17] Price of windows came from the 2008 addition of *RS Means Building Construction Cost Data*.

4.5 ECRM 5: Additional Windows

The NDG's current floor plan indicates that each bedroom currently only has one window. While maintaining the same building footprint and dimensions, the SCinIC team investigated switching the floor plans for Unit 1 and Unit 4 so that the staircases are on the inside of each unit, rather than being on the outside wall. As Figure 18 shows, this allows for additional windows to be placed in each bedroom and the living room in these end apartments. Although this may increase heating loads in the winter for these units, cooling loads would decrease assuming the residents would open the windows for cross-ventilation at night during the summer. Switching Unit 3 and Unit 4 would provide a symmetrical balance on the façade as shown in Figure 19. While adding additional windows on the South facing wall of these units may increase heating loads in the winter, both cooling and lighting loads would decrease assuming the residents would open the windows for cross-ventilation at night during the summer and utilize natural daylight during the day.

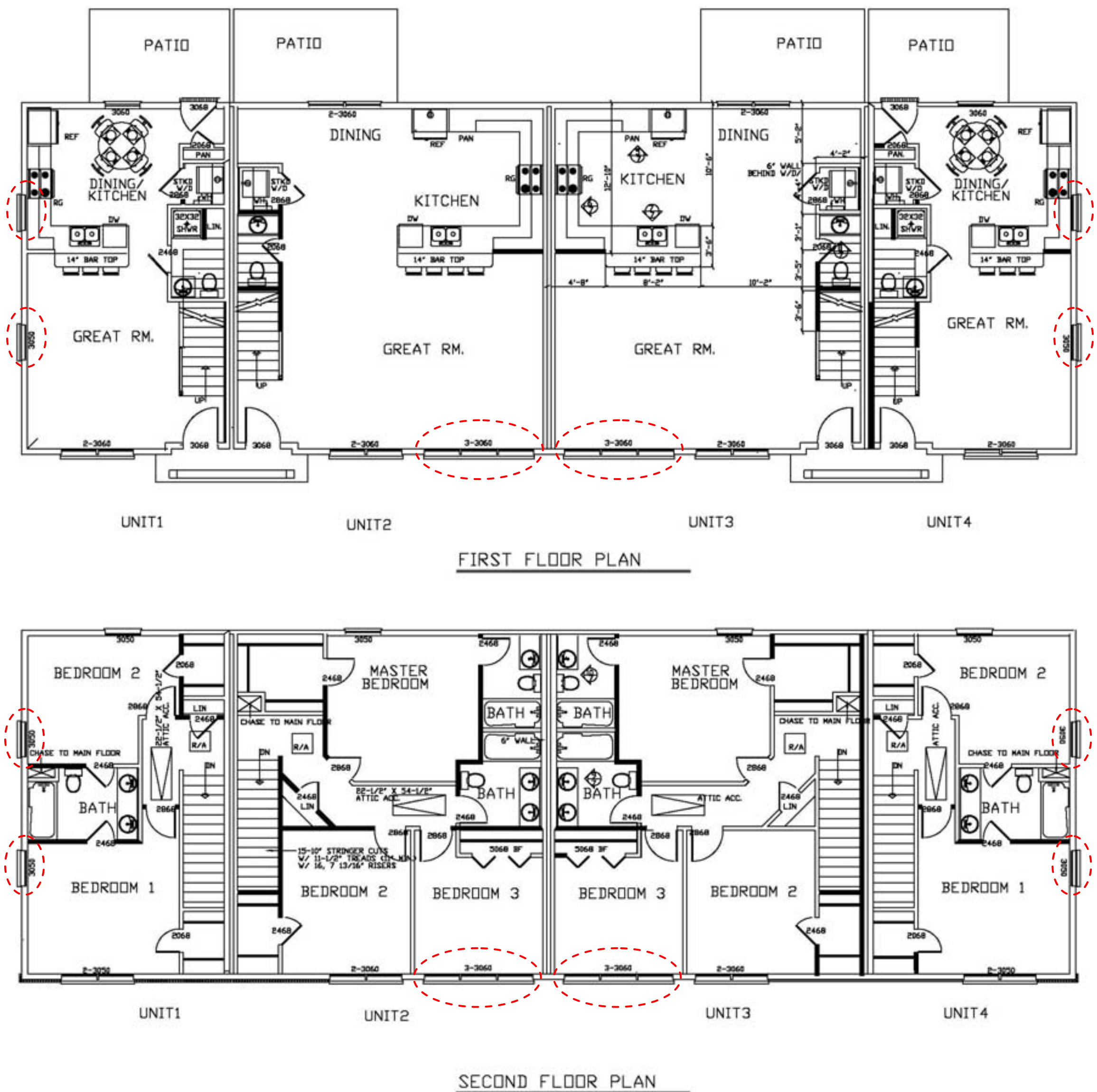


Figure 18: Floor plan alterations by the SCinIC team. The circles indicate locations of additional windows.

Figure 19: Elevation alterations by the SCinIC team

Modeling these changes in e-Quest, Table 4 indicates that adding these additional windows would save approximately 1,180 kWh of electricity. However, the heating loads would increase an estimated 213 therms resulting in the utilities for the building to increase $9 annually. This would result in an annual energy savings of less than 1%.

ECRM 5: Additional Windows						
Annual Energy Savings				Economic Analysis		
kWh	Therms	Cost	% Energy	Investment	IRR	NPV
1,180	-213	-$9	<1%	$7,000	N/A	-$6,777

Table 6: Additional Window Energy Savings

The investment cost is based on adding an additional 20 double-pane windows at an estimated rate of $350 per window (48 windows total). This includes the cost of the window and installation costs. The IRR and NPV analysis are based on a 20 year study period. As mentioned earlier, it will take far longer than the lifespan of the windows for them to pay off in energy savings. However, the benefits of additional views, increased levels of day lighting, opportunities for cross-ventilation, and increased heat gain from the sun during the winter, can sometimes offset the cost.

4.6 ECRM 6: Lighting Upgrade

Research shows that an average household dedicates about 6% of its energy budget to lighting.[18] Switching to energy-efficient lighting is one of the fastest ways to cut energy bills. Compact Fluorescent Lamps (CFL) last about 10 times longer and use about 75% less energy than traditional incandescent bulbs. A typical CFL can pay for itself in energy savings in less than 9 months and can continue to cut down energy costs each month. Furthermore, incandescent bulbs are slowly being phased out and in a few years will no longer be produced.

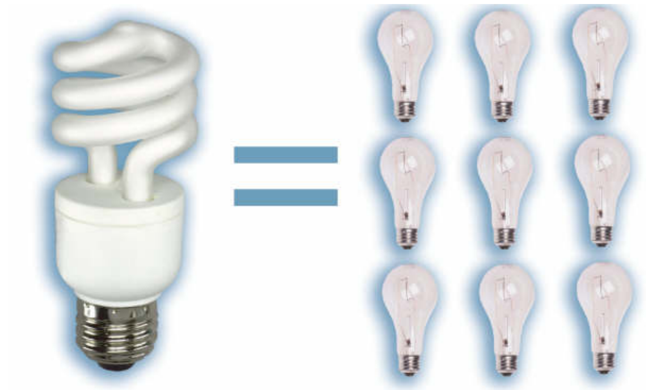


Figure 20: CFL bulbs last longer than incandescents.

The main and upper floor electrical plans for the NDG's design were provided and indicated that there are a total of 146 lamps in the building. As mentioned earlier, lighting in each apartment is provided by a 2'x4' florescent light in the kitchen with four 32 W T-8 linear fixture with rapid start electronic ballast, screw-in light fixtures throughout the apartment, and from the ceiling fans in the great room and bedrooms. In the baseline model for e-Quest, it was assumed that each light fixture would have a 60W incandescent lamp providing a total average of 1.25 W/sq. ft. for the whole building. The baseline in e-Quest was then compared to replacing the 60W incandescent lamps with 13W CFLs, decreasing the lighting intensity to 0.90 W/sq. ft. Table 7 shows that this lighting upgrade would save the building an estimated 3% in annual energy consumption and an estimated $665 in annual utilities. While the building would be saving 6,310 kWh annually for lighting and cooling the building, more energy would be required for space heating (130 therms) since CFLs generate less heat than incandescents, therefore requiring the HVAC system to work more to heat the rooms.

ECRM 6: CFL Lighting						
Annual Energy Savings				Economic Analysis		
kWh	Therms	Cost	% Energy	Investment	IRR	NPV
6,310	-130	$665	3%	$251	265%	$4,652

Table 7: Lighting Upgrade Energy Savings

The investment cost is based on only replacing the 60W incandescent lamps with CFL lamps (a total of 122 lamps in the building) at an estimated rate of $1.72 per CFL and not replacing the T-8 fixtures.[19] However, the Pokagon may be eligible to receive free CFLs resulting in a lower investment cost and therefore higher internal rate of return (IRR) and net present value (NPV).[20] The IRR and NPV analysis are based on a 10 year study period and indicates that such a lighting upgrade will prove to be economical and cost-effective. Therefore this initiative is highly recommended.

[18] http://www.energysavers.gov/tips/indoor_lighting.cfm
[19] Price of CFLs was taken from: http://www.easywebcalculators.com/cf.htm
[20] Refer to section 6 of this report for more information.

4.7 ECRM 7: Slab Foundation Insulation

As mentioned earlier in this report, 15% of a building's energy can be lost through the floor.[21] As shown in Figure 21, there are two areas of heat loss from a floor slab.[22] The first is perimeter loss. This is due to the fact that the shortest distance from the slab to the outside is at the perimeter. Approximately 80% of the heat loss occurs through the edge of buildings, so this is the area of highest importance and should be insulated first. The second heat loss area is the downward heat flow from the slab. This heat flow generally moves in a radial pattern down and out to the edges of the slab and then up to the ground surface. All heated slabs and unheated slabs with a conditioned space above, lose heat in this manner.

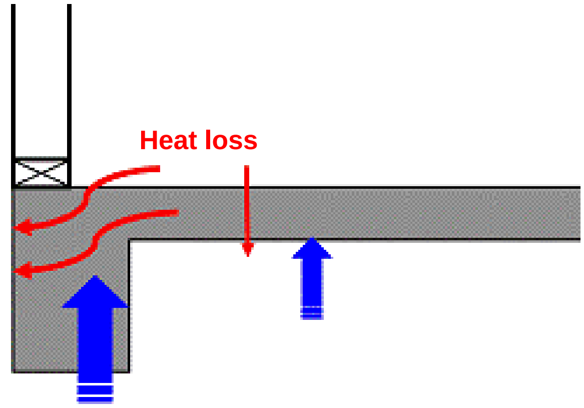


Figure 21: Example of an uninsulated floor slab.

Insulating under the entire floor slab and the perimeter can help minimize energy loss. This is especially important when considering implementing a geothermal system, because the heated slab will respond much faster to control inputs rather than the ground temperature as the indoor temperature changes. In other words, insulation under the slab can help reduce temperature swings in the heated space and respond quicker to new changes in thermostat settings, as shown in Figure 22.

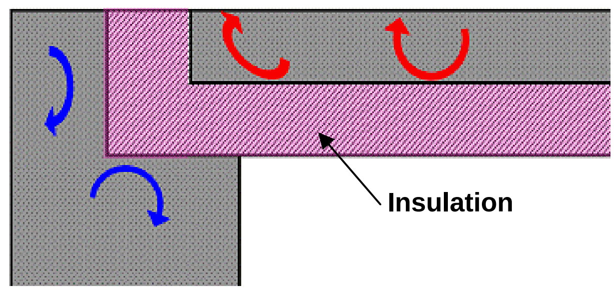


Figure 22: Example of an insulated floor slab.

Based on the current architectural plans for the NDG design, there is no insulation underneath the slab foundation. An uninsulated foundation can result in a large heat loss from an otherwise tightly sealed, well-insulated house.[23] Therefore, foundation insulation can result in lower heating requirements. The SCinIC team recommends installing rigid R-10 insulation at the bottom of the slab to keep the slab insulated from the earth. This allows the floor surface to be approximately the ambient interior air temperature and more comfortable to stand on than concrete. When modeled in e-Quest and compared to the baseline model, Table 8 indicates that insulating the slab foundation will save 7% of the building's annual energy, decrease space heating requirements by 228 therms, and save an estimated $162 in annual utility costs.

ECRM 7: Slab Foundation Insulation						
Annual Energy Savings				Economic Analysis		
kWh	Therms	Cost	% Energy	Investment	IRR	NPV
	228	$162	7%	$1,350	10%	$636

Table 8: Insulating the Slab Foundation Energy Savings

The investment cost was based on an estimated cost of $450 per 1,800 sq. ft. and included the cost of labor.[24] The IRR and NPV analysis are based on a 20 year study period, which indicates that the return of investment is favorable and this measure is highly recommended.

[21] http://www.energyunion.eu/en/intelligent_energy/energy_efficiency
[22] http://www.steadfastsystems.co.nz/warmfloor.html
[23] For more information, visit: http://www.doityourself.com/stry/insulatingfoundation
[24] http://www.energysavers.gov/your_home/insulation_airsealing/index.cfm/mytopic=11490

5. Additional Energy Reduction Measures

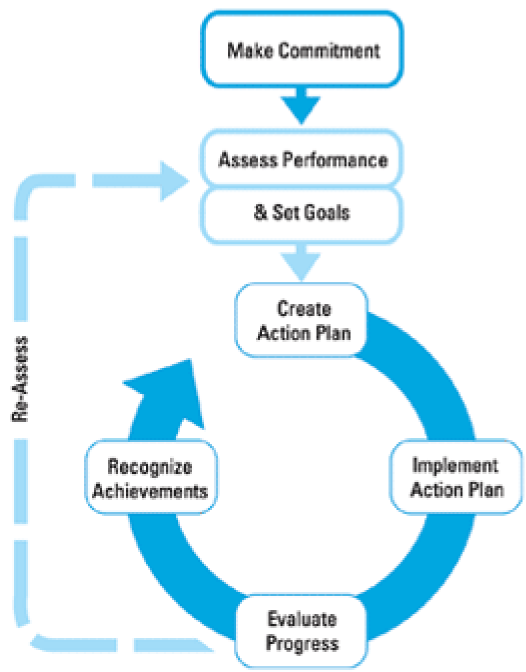
5.1 Install Low Flow Fixtures

Although storm water and domestic water management was not addressed as part of the building energy analysis, a large amount of energy 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. We recommend 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 Plan

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.[25] The SCinIC team recommends this plan to the housing authority employees. Here are the steps that describe an energy management strategy offered by ENERGY STAR.[26]



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 measureable 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.

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[25] http://www.greenschoolbuildings.org/resources.aspx
[26] http://www.energystar.gov/index.cfm?c=guidelines.guidelines_index

The quickest, easiest, and cheapest way to reduce loads during peak hours is to ensure that lights and equipment are turned off whenever it's not required. This could be achieved by developing better occupancy habits by both the students and staff of the school. Savings can also be achieved by changing the thermostat settings to minimum cooling during the peak day time.

6. Funding Opportunities

As mentioned earlier, the Pokagon electricity is provided by COOP Electric and natural gas is supplied by SEMCO Energy. In order to help fund some of the upgrades and changes mentioned in this report, it may prove useful to investigate different funding opportunities. According to the **Database of State Incentives for Renewable Energy** (**DSIRE**) website,[27] there are a number of incentives for residential and multi-family buildings through the Energy Smart program, SEMCO (Gas), Great Lakes Energy, and other utility rebate programs. Some of the rebates the Pokagon may consider applying for include the following:

Type	Amount	Equipment Req.
Central Air Conditioners	$75-$150	15 SEER min
Heat Pump Water Heater	$150	EF>0.93
CFL Giveaway	FREE*	--
Multifamily Direct Install (CFLs, Showerheads, Kitchen and Bath Aerators)	FREE*	--
Programmable Thermostat	$20	ENERGY STAR
Furnace	$100-$200	AFUE of 94% or higher
Natural Gas Water Heater[28]	$100-$150	Efficiency 0.67 or higher
Appliances (Dishwasher, Refrigerator, Clothes Washer, etc.)	$25-$50	ENERGY STAR Tier 2 or 3 only
Windows	$12.50/window	NFRC or ENERGY STAR rated
Insulation (wall or ceiling)	$200-$250	--
Geothermal Heat Pumps[29]	$500	Minimum EER 14.1 and COP 3.3 (closed loop)

*Participating utilities: Chelsea, Grand Haven, Holland, and Paw Paw. To see if Pokagon qualify, visit: http://www.mienergysmart.com/ for free CFLs and rebates for high-efficiency products for Dowagiac.

Additional rebates and savings may be found through different manufacturers of the appliances installed in the new buildings. For example, GE Appliances offers two rebates up to $150 for domestic hot water heaters that are ENERGY STAR certified.[30]

[27] Visit http://www.dsireusa.org/incentives/incentive.cfm?Incentive_Code=MI64F&re=0&ee=0 for more information on state and federal rebates and tax credits.
[28] Visit http://www.efficiencyunited.com/?page_id=420 for more information.
[29] Visit http://www.gtlakes.com/?s=heat+pump+rebate for more information.
[30] Visit http://www.geappliances.com/rebates_promotions/available-rebates.htm?ecrzip=49047&ecrproducttype for more information.

7. Conclusions and Recommendations

In summary, this report investigates strategies and provides information on how to reduce the annual operation cost of a Pokagon four unit duplex building through load reduction and energy efficiency improvements. Table 9 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[31] as shown in Figure 23 below.

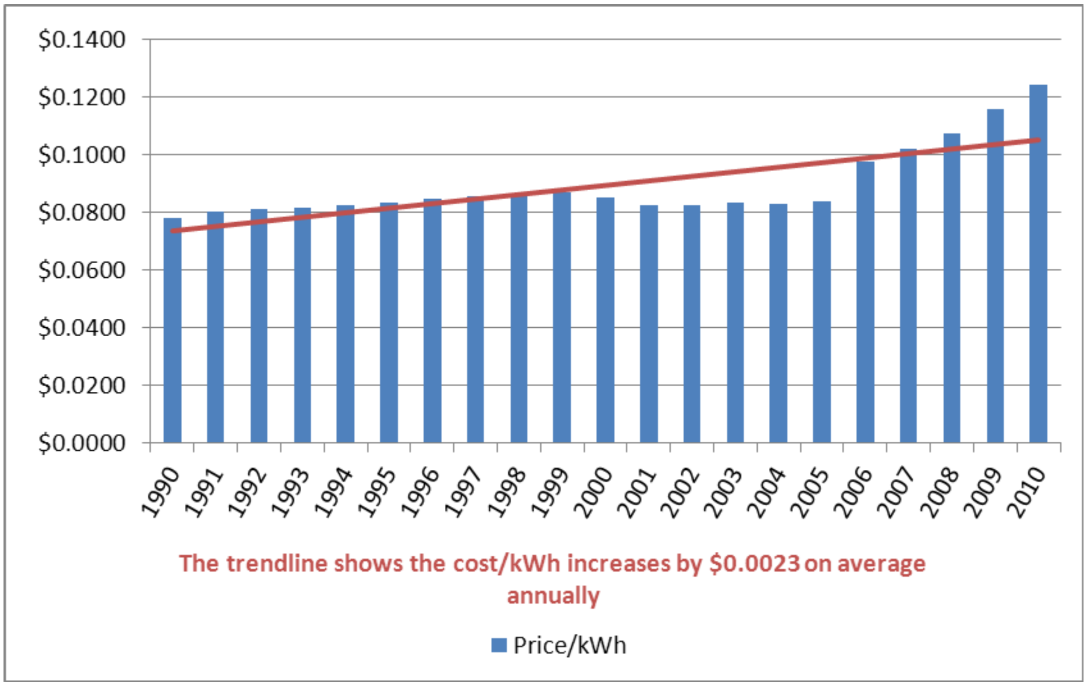

Figure 23: Michigan Average Cost/kWh by Year

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

Annual Energy Savings					Economic Analysis			
ECRM	**kWh**	**Therms**	**Cost**	**% Energy**	**Investment**	**IRR**	**NPV**	**SP**
Baseline Model-HVAC in building	0	184	$131	6%	$0	N/A	$1,553	0.00
with inflation			$131			N/A	$1,553	0.00
Attic Insulation	950	-1,157	-$708	< 1%	$3,240	N/A	-$11,485	-4.58
with inflation			-$696			N/A	-$11,344	-4.66
Geothermal (HVAC in attic)	-14,900	1,816	-$498	42%	$40,810	N/A	-$44,782	-81.88
with inflation			-$685			N/A	-$46,993	-59.60
Geothermal (HVAC in building)	-6,860	1,816	$466	51%	$6,000	5%	-$179	12.87
with inflation			$381			2%	-$1,197	15.76
Triple-Pane Windows	380	46	$79	2%	$16,800	-16%	-$15,068	213.89
with inflation			$83			-16%	-$15,011	201.70
Additional Windows	1,180	-213	-$9	< 1%	$7,000	N/A	-$6,777	-754.72
with inflation			$5			N/A	-$6,602	1,278.54
CFL upgrades	6,310	-130	$665	3%	$251	265%	$4,652	0.38
with inflation			$736			293%	$5,176	0.34
Slab Foundation Insulated	0	228	$162	7%	$1,350	10%	$636	8.34
with inflation			$162			10%	$636	8.34

Table 9: Summary of ECRMs

The results show that conducting a lighting upgrade would be a cost effective measure as it shows a positive internal rate of return (IRR) and simple pay back of under a year. The geothermal system with HVAC in the building saves 51% of the annual energy and if only considering the incremental cost difference between the geothermal system and a traditional HVAC system the equipment will pay back the investment costs over the course of its lifetime. Slab insulation also has a positive IRR and will pay back in just over 8 years. It is highly recommended that the Pokagon upgrade the lighting fixtures to CFLs and add insulation to the slab foundation.

Since these units are new construction, it is also recommended that after the units have been occupied, utility data over the course of a calendar year from both the electric and gas companies be collected and used to perform an energy analysis for each building. This information could then be used to compare actual energy consumption with annual heating and cooling degree day data.

Addenda A

Geothermal:

For the e-Quest model analysis, it was assumed that an ENERGY STAR rating 40-gallon electric water heater with heat pump would be installed with an Energy Factor of 2.0 and estimated to have a 50-gallon first hour rating. It is estimated to use approximately 2195 kWh per year.