# Milestone 2

Project Overview

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Publisher: CEE 398 PBL (FA15)
Start: Oct 16, 2015
Due: Nov 23, 2015

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## Newmark Insulation Review Milestone 2

Version 3

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Nov 21, 2015 at 11:36 PM

Our project aimed to identify potential resource of unnecessary heat flow by studying the current insulation material to improve the energy efficiency of Newmark.  In order to detect the ineffective insulation, we constructed a 2D thermal model of the south façade of Newmark.  By looking from the thermal pictures, area of insulation defect could be detected. Then, we analyze the insulation value (R-value) for the building assemblies and calculated the heat loss through the material.  We realized that the insulation material is poor comparing to the standard, so we suggested by adding extra insulation to minimize the disproportionate use of energy.  Then, we evaluated the feasibility of adding or replacing the present insulation by conducting cost estimations. For our anticipation, the return period for both solutions will be long. But with environmental consideration, we suggest that the school should either applying add-on insulation or doing retrofit for the façade.

## Introduction & Background

In 2015, Newmark Civil Engineering Laboratory ("Newmark") at the University of Illinois at Urbana-Champaign (UIUC) was billed for over $950,000 in energy costs. Newmark's annual energy consumption data was taken from its metered billing system, and deviates into consumption and costs of chilled water, steam, water and sanitary, and natural gas. Steam (produced from the Abbott power plant) accounted for 35%, or $345,000, of the energy bill for the Newmark Civil Engineering Laboratory ("Newmark") at the University of Illinois at Urbana-Champaign (UIUC). High energy costs can be associated to both the size of space needed to heat, such as the massive space that is the Crane Bay, and unnecessary heat flow through the building enclosures during hot and cold seasons (Roth et al. 2005 and U.S. DOE 2012a). In addition to large spaces and any inefficiencies in the current HVAC system, inadequate insulation material can be a crucial factor to the building's energy consumption and costs. Investigating an alternative insulation material, or applying additional insulation, is a key to increasing the energy performance of and reducing the energy costs of Newmark. Before taking any decision on which insulation material to apply and to where, areas of abnormal energy loss must be identified first.

One method we are using to identify areas of heavy heat loss along the facade is analyzing thermal images. From the "FLIR Thermal Imaging Guidebook for Building And Renewable Energy Applications", the poorly insulated area along a wall will have contrast in temperature readings than other sections of said wall (2015). At UIUC, Professor Golparvar-Fard and Youngjib Ham, one of his PhD students, conducted a similar study at Virginia Tech, where they wrote a software that stitched multiple digital images of a small room or wall into a 3D model, overlaid infrared (IR) images paired with digital ones, recognized differences in temperatures in the IR overlay, and calculated continuous R-values along the walls.

## Objective

In an endeavor to reduce the carbon emissions of the building sector, governments around the world are establishing and modifying new requirements on the private sector and public buildings. For example in Illinois, Governor Quinn signed Executive Order 7 to better coordinate energy savings activities in State government in April 2009. Executive Order No. 7 sets a goal of a 20% energy reduction by 2020 for state facilities. (ASCEE. 2015). For University of Illinois at Urbana-Champaign, the school spent $80 million on energy in 2014 (Illini Energy Dashboard,2015). Part of the UIUC's energy usage is heating, ventilation, and air conditioning (HVAC). In a broader view, heating and cooling alone account for 48.8 and 24.8% of the total energy usage in residential and commercial buildings, respectively (U.S. DOE 2010).

In response to the increasing interests in improving thermal resistance of existing buildings, the U.S. Department of Energy and the International Energy Conservation Code (IECC) have established the recommended level of building insulations to facilitate insulation retrofits (Energy Star 2013) The cost required for these insulation retrofit alternatives can be estimated based on the cost of: (1) the insulation materials and de- livery to the job sites; (2) the delivery of equipment to the job sites; (3) the required labor and their expected productivity; (4) the restoration of existing finishes and structural components; and finally (5) the cleanup and debris removal for completion. Ultimately for cost-benefit analysis, the estimated retrofit costs are balanced against the expected monetary savings from insulation retrofit alternatives. (Ham and Golparvar-Fard 2015) Based on the data, we believe add-on insulation would reduce unnecessary energy loss by a great amount.

## Scope

Scope

To figure the major heat section lost section of Newmark, our team decides to use digital and thermal camera to capture images of Newmark's south facade.  From the electricity, chilled water, and natural gas meter data, we realized that each section of Newmark consumes around the same amount of energy every month; yet, we know that there are some major leaks of energy in the building. Since there are only a few locals where the leak could possibly be, we identify that the offices could potentially be the major heat loss of Newmark, so we choose to study about the south side offices.

The first task was to take images of the offices and one of the garage gates. At least two hundred consecutive photos from each area are needed for the program to connect all the photos together. Those photos have to overlap for 60%-80% in order to have a cohesive 3D image created at the end. No direct sunlight can be on the digital photos, so before sunrise and after sunset with enough sunlight will be the right time to take the photos. With the digital and thermal images, the high-resolution panoramic thermal images can be created (Cho, Ham, and Golparvar-Fard 2015).

The second task is to formulate the 3D images to calculate the temperature distribution of the south wall of the offices and the gate. The modeling program recognizes the similar points on the photos and connects them into a bigger 3D image. Using Epipolar geometry, the orientation and translation of the photos taken can be calculated. With the relative positions and the digital photos, calibration information can be formulated. The calibration information can then be used to calculate the 3D thermal cloud points; from the built-in calibration from the digital cameras, 3D building geometrical cloud points can be formed. With the two sets of cloud points, the final 3D image can be superimposed. According to Professor Golparvar-Fard and Ham, his PhD student, their new program uses the boundary points from the building geometrical point cloud to produce a baseline mesh model.

The third task is to calculate the heat lost through the south façade.

$$Q = \frac{1}{R} * A * HDD * 24$$

A is the area of the façade excluding the area of the offices' windows. R is the insulation value, and HDD is the number of days that the outside air temperature is lower than a "base temperature". To calculate R-value, we measured the outside and inside temperature of the walls.

$$R = \frac{T_h - T_c}{T_a - T_h} * 0.68 + 0.68$$

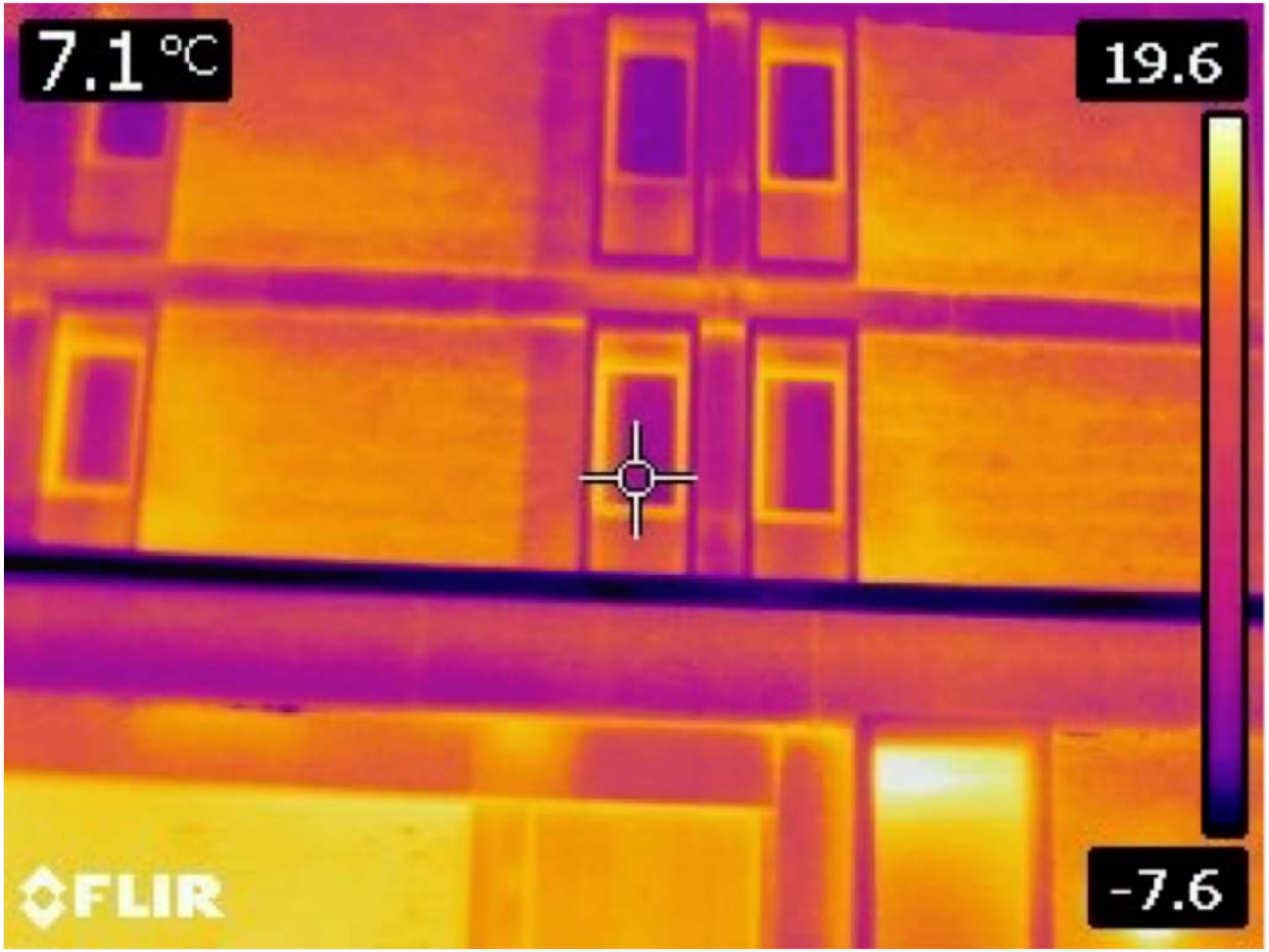
By comparing our data with the standard, we realize that the south façade has poor insulation comparatively. Then, with the area of the façade, the R-value, and the HDD at UIUC, we can use the equation above to calculate the heat loss through the façade.

The fourth task is to calculate the potential cost saved. We consider adding 3-inch closed-cell spray polyurethane foam (ccSPF), which then we can calculate the new heat loss. The ccSPF costs about seven cents per board feet, and the labor cost is about two and a half times the material cost. From the new insulation, we know the amount saved per year, and we can divide the total cost of installing the new material and the labor cost by the amount saved to figure out the returning period.

## Alternative Solutions

An alternative solution is also the addition of new garage doors. The two garage doors on the north and south wall of the Crane Bay are a major source of heat loss. By replacing said doors with ones that contain a higher R-value, the amount of heat loss through the steel roll-up doors would be reduced. The restrictions on said alternative are that the new system would have to be roll-up, given that slide-up doors would requiring more re-organization of HVAC and electrical systems along the inside ceiling of the garage doors. (http://www.overheaddoor.com/commercial-doors/Pages/sectional-steel-thermacore-doors-596.aspx )

Another alternative is purchasing new and changing the double-pane windows of the façade such that the air space increases from the current ¼'' to ½''.  Below is a photo of the current IR reading of the window:




If 24 windows were swapped out, increasing the R-value of the windows from 1.69 to 2.04 hr·ft2·°F/Btu, then over the course of the winter,

$$U = \frac{t * A * \Delta T}{E} = \frac{24hr * 150days * 3ft * 6ft * (23 - 7.1)°C}{1} = 609656.8\ BTU$$

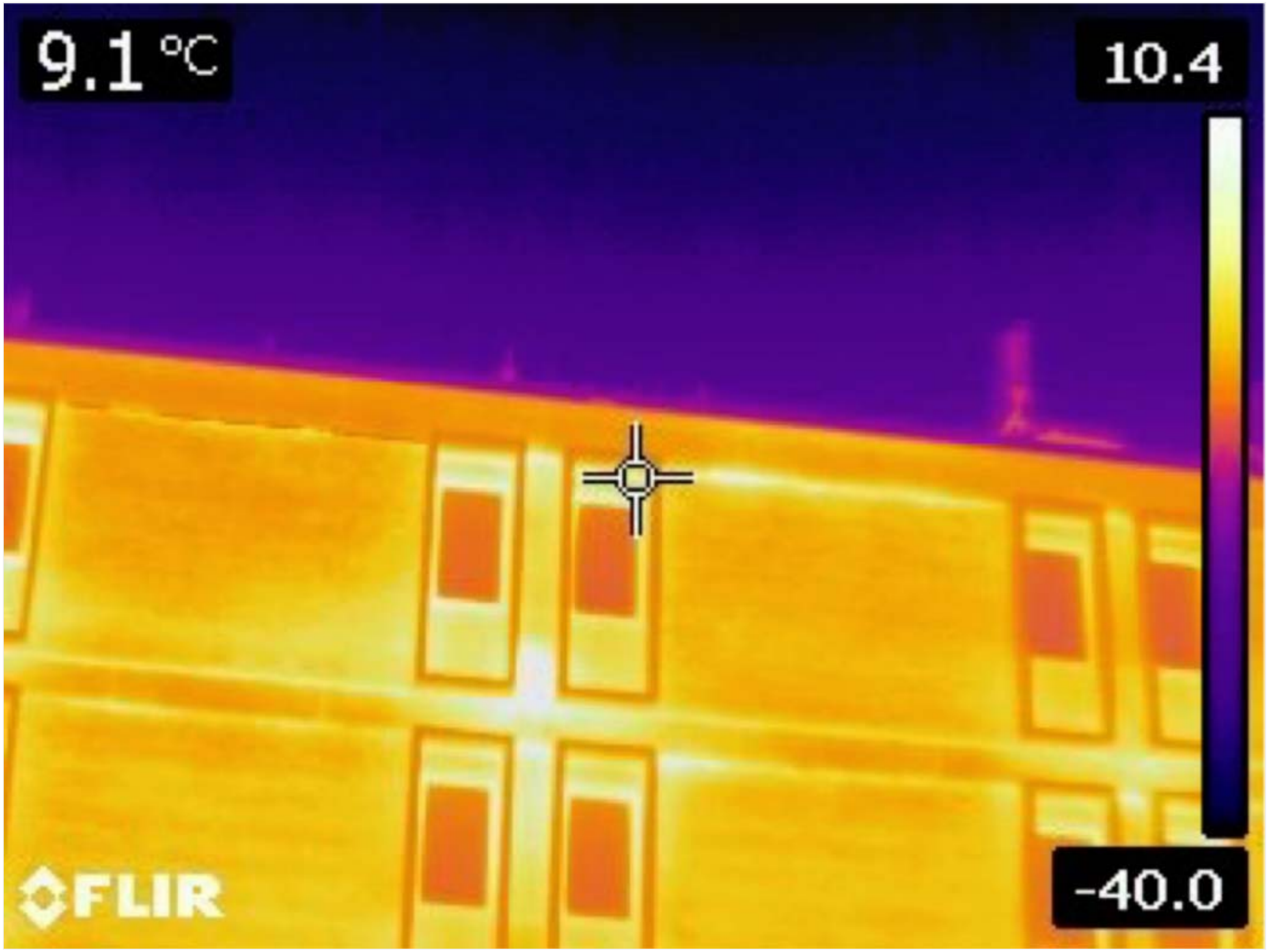
would increase to

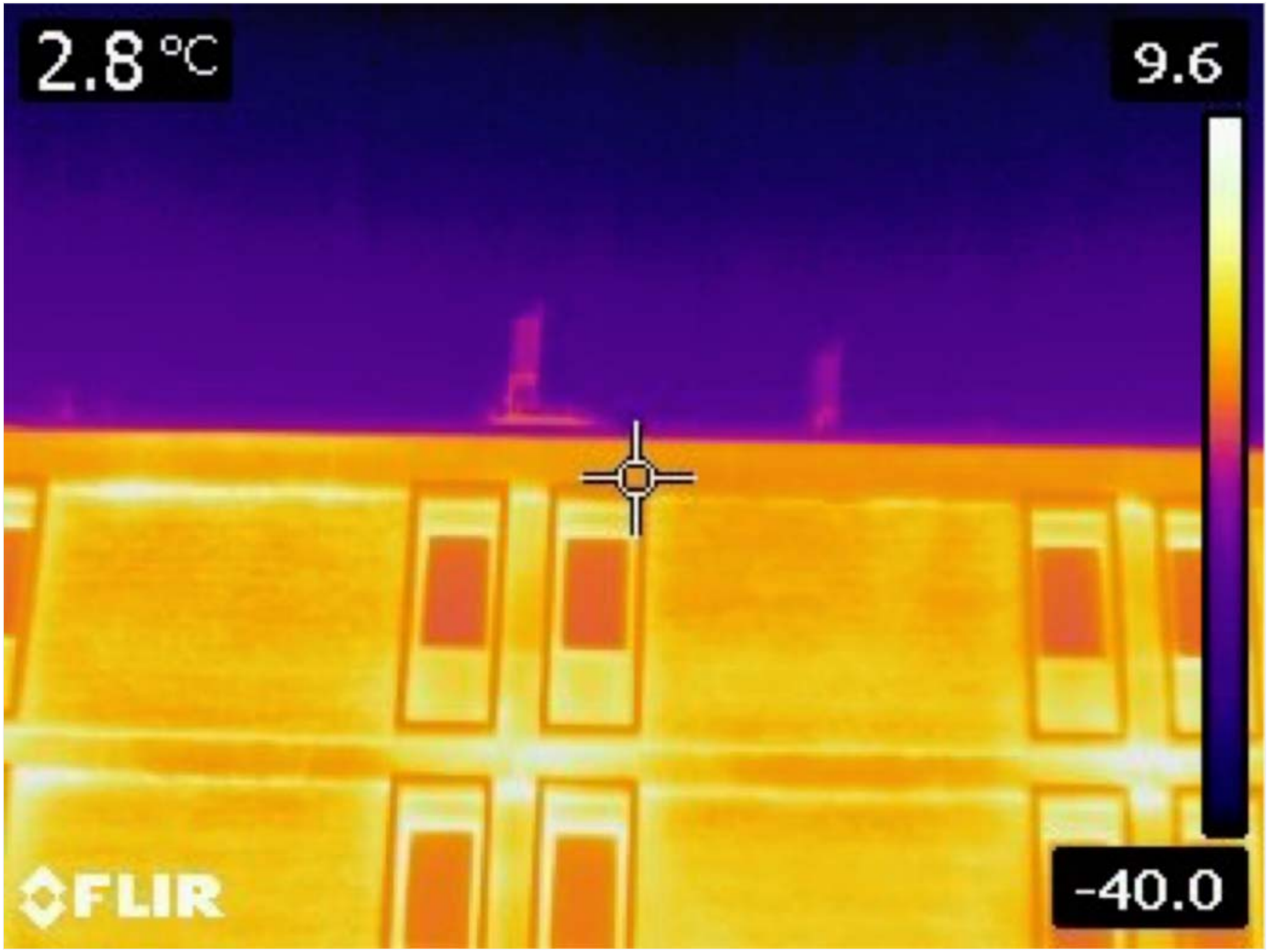
$$E = \frac{t * A * \Delta T}{R} = \frac{24hr * 150days * 3ft * 6ft * (23 - 7.1)°C}{2.04} = 505058.8\ BTU$$

Qsaved would equal 104,598 BTU, or about $1.82 savings a year at $17.41/MBTU of heat. Swapping out the windows is not a feasible solution, given the low yearly return without even considering materials and labor.

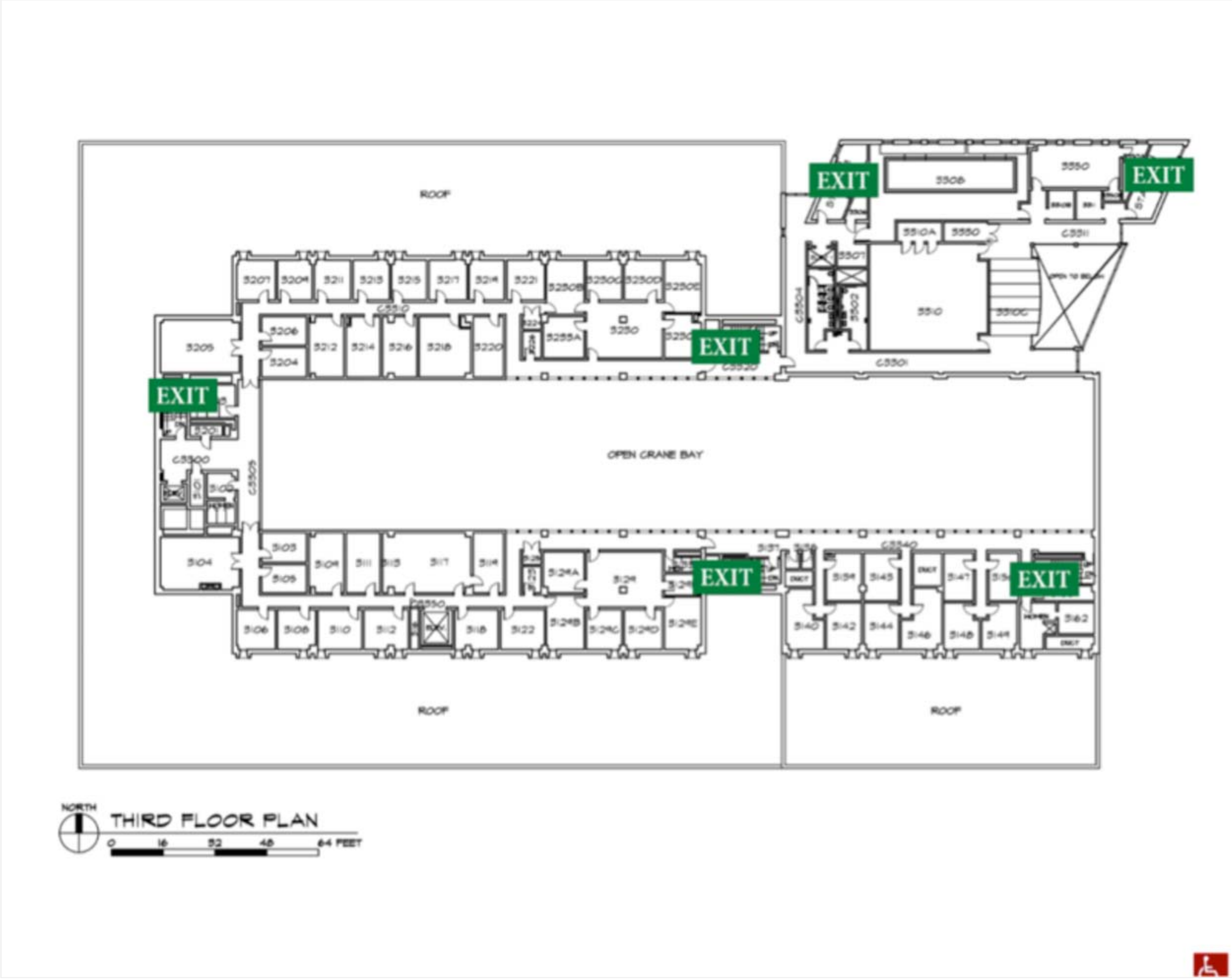
## Preliminary Results and Discussion

The following photographs were taking during the morning of _, and represent the fluctuations in temperature along the southern façade of Newmark.


9.1 °C
10.4
-40.0
FLIR




3rd  Floor Plan of  Newmark. The focus of the window retrofit is the 3rd and 4th floor windows indicated on the floor plans (4th is similar to 3rd).


ROOF
EXIT
EXIT
EXIT
EXIT
OPEN CRANE BAY
EXIT
EXIT
ROOF
ROOF
NORTH
THIRD FLOOR PLAN
0 16 32 48 64 FEET

The following equation can be used to calculate heat lost throughout heating degree days,

$$Q = \frac{1}{R} * A * HDD * 24$$

where R is the value of insulation, A is the area, HDD is the heating degree days or “how much (in degrees), and for how long (in days), outside air temperature was lower than a specific "base temperature”, and 24 is the number of hours in a day. Heating degree days for the University of Illinois area for the twelve months trailing November 2015 is: HDD = 6480

The R-value of the window can be calculated by:

$$R = \frac{T_h - T_c}{T_a - T_h} * 0.68 + 0.68$$

where Th is the interior temperature of an exterior wall, Tc is the outside temperature of the exterior wall, and Ta is the indoor temperature

The area can be calculated by subtracting the windows’ area from the total façade area and dividing the façade area into both poor and normal insulation.

| Areas of 3rd and 4th Floor Façade, Newmark | |
|---|---|
| Area | Value (ft^2) |
| Façade | 6288 |
| Windows (24 ct.) | 432 |
| Total Wall | 5856 |
| Total Wall with Poor Insulation | 200 |
| Total Wall with Normal Insulation | 5656 |

The following table gives temperature parameters to calculate the R-value of insulation. The temperature of the areas designated as either poor or normal were averaged:

| R-values, Poor and Normal Areas of Façade | | |
| --- | --- | --- |
| Parameter | Poor | Normal |
| $T_h$, interior temperature of an exterior wall (F) | 68 | 68 |
| $T_c$, outside temperature of exterior wall (F) | 48 | 37 |
| $T_a$, the indoor temperature (F) | 70 | 70 |
| R ($h \cdot ft^2 \cdot °F/Btu$) | 7.4 | 11.2 |

With the area and R-value calculated, the amount of heat loss throughout a year can be found through both the poor and normal insulation areas:

| Current Heat Loss | | |
|---|---|---|
| Parameter | Poor | Normal |
| R (h·ft$^2$·°F/Btu) | 7.4 | 11.2 |
| A (ft$^2$) | 200 | 5656 |
| HDD (days) | 6480 | |
| hours/day | 24 | |
| $Q_{current}$ (BTU) | 4.2E+06 | 7.8E+07 |
| $Q_{current}$ (MBTU) | 4.2 | 78.5 |

The total amount of heat lost throughout the year has been estimated to be about 82.7 MBTU per year, based on the HDD of the trailing twelve months of November 2015. If new 3-lb-at-75oF ccSPF insulation (ASTM C 518 04) were added to the whole façade, the R-value of the wall would increase by 6.7, including the poor sections: Rnew = 11.2064+6.7 = 17.9064

| New Insulation Heat Loss | |
|---|---|
| R ($h \cdot ft^2 \cdot °F/Btu$) | 17.9 |
| A ($ft^2$) | 5856 |
| HDD (days) | 6480 |
| hours/day | 24 |
| $Q_{new}$ (BTU) | 5.1E+07 |
| $Q_{new}$ (MBTU) | 50.9 |

Given Newmark's metered data, the cost of steam was averaged to be $17.41/MBTU

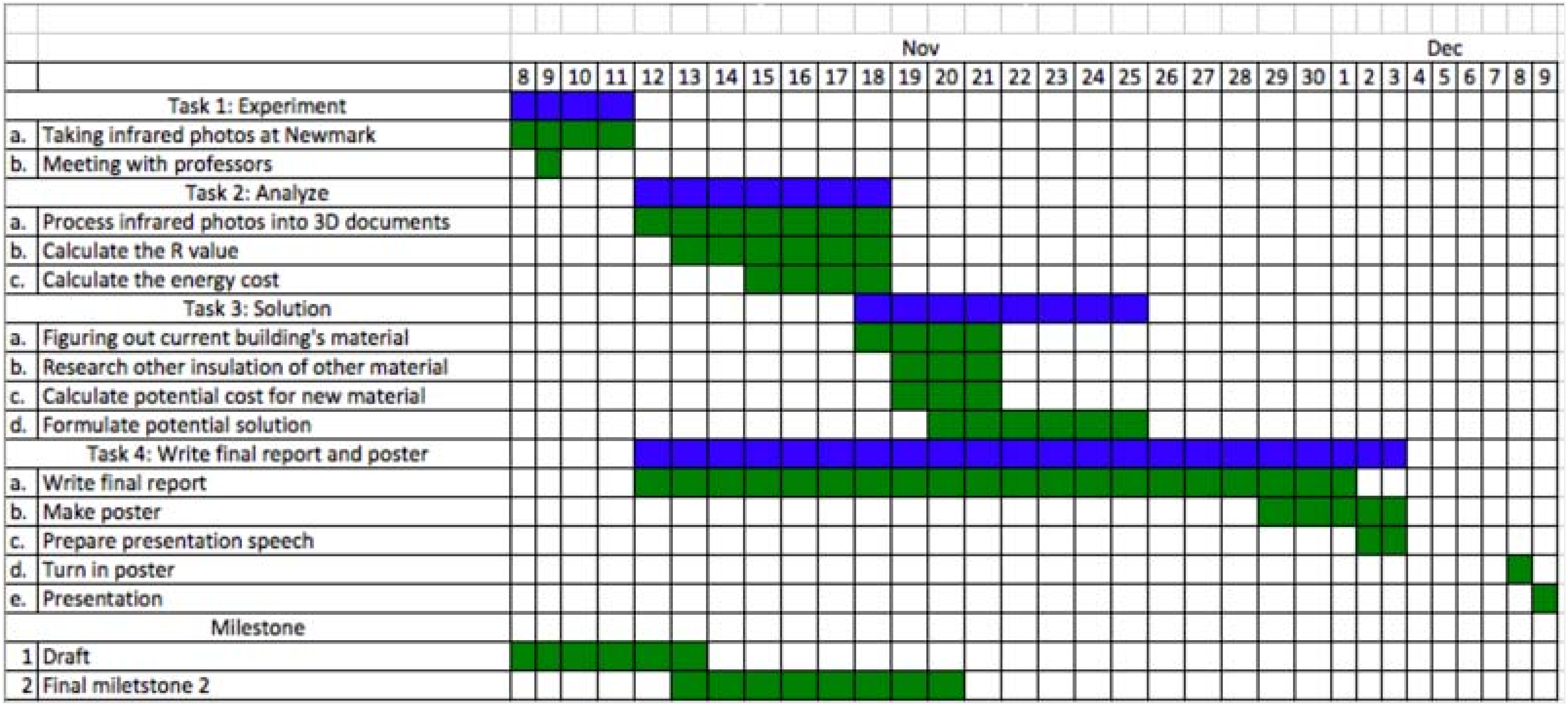
| Energy Saved with New Insulation | |
|---|---|
| $Q_{current}$ (MBTU) | 82.7 |
| $Q_{new}$ (MBTU) | 50.9 |
| $Q_{saved}$ (MBTU) | 31.9 |
| Energy Cost (per MBTU) | $ 17.41 |
| Amount saved per year | $ 555 |

The cost of material is $0.70 per board foot; a board-foot an inch of depth per square foot of insulation is applied. The cost of labor was estimated at 2.5x the cost of the material. The return period was arrived at by dividing the cost of the project by the amount saved per year.

| Project Costs, Return Period | | |
|---|---|---|
| Cost of material (per in. deep of ft^2) | $ | 0.70 |
| Depth of material | | 3 |
| Area of façade sprayed | | 5856 |
| Total Cost of Material | $ | 12,298 |
| Labor (2.5x material, standard) | $ | 30,744 |
| Total Cost of Project | $ | 43,042 |
| Return Period (yrs) | | 77.59 |

## Schedule

Schedule




The current schedule is different than the previous one because we changed the experiment. Previously, we were going to figure out the most heat lost section in Newmark with the meter data. Yet, those data did not show us any significant heat lost in any section in Newmark, so we could not conclude the location of the heat leak. Therefore, we are using the FLIR camera to take thermal photos and by using the 3D Thermography-Based method.

## References

Acknowledgements

We would like to extend a great thanks to Dr. Mani Golparvar-Fard and his graduate student Kevin Han for allowing us to use the FLIR infrared camera and running the EPAR program for us.

Morgan Johnston and Kannan Ramasamy for helping us in retrieving appropriate documents from Facilities and Services.

James Bittner for guiding us throughout the whole project and directing us towards Mani’s research.

Prof. Jeffrey R. Roesler for guiding us when we lost direction from our starting scope.

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