ENCLOSURE DESIGN RETROFIT
for EPPLEY RECREATION CENTER

ARCH 478A/678A - Spring 2015
University of Maryland
School of Architecture, Planning and Preservation
ACKNOWLEDGMENTS

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## INTRODUCTION

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In September 2012, Craig Carignan, a Research Scientist in the University of Maryland Department of Aerospace Engineering, contacted a number of faculty members in the School of Architecture, Planning and Preservation, looking for someone to collaborate on a project to investigate a building on campus. Craig was a frequent visitor to the Eppley Recreation Center (ERC), and believed, based on his experiences there, that the building was not energy efficient. He thought that it would make a good study for the energy efficiency and sustainability of a building on campus, and particularly how an inefficient building might be made more so. I must confess to not getting around to replying to Craig for quite some time, as I was a new member of the faculty at the time and working to establish my research program. But during that time I consulted with a local structural engineering firm on some high profile building enclosure analyses and designs.

That led me to propose a new course for the Architecture program, ARCH478A/678A, High Performance Building Enclosures, which was approved in May 2014 and first offered in Spring 2015. Fortunately I remembered Craig’s idea and got back in touch with him (finally). We decided, with support from representatives from Eppley, that a study of the ERC would make a great term project for the students in the course.

This report represents the work of the students on that project. The students made field observations, interviewed the building owners and users, obtained original drawings for the building, created digital models, performed detailed analyses of the building, made detailed design proposals, and have made recommendations based on their findings. This diverse group of students, consisting of both undergraduate and graduate students of architecture, had varying levels of exposure to building enclosures prior to this class, but none had taken a course on the topic, and almost all were essentially new to it. Over the course of the semester they learned the fundamentals of building enclosure design and also learned advanced computational tools for design and analysis. Their hard work culminated in this report, which will be presented to representatives of the ERC for their consideration of implementation. This represents a remarkable achievement on behalf of the students as well as for what it suggests for the architectural curriculum. Over the course of a semester, a collaborative group of students was able to understand the fundamentals of building enclosures, apply their understanding through proposing cutting edge design interventions, and integrate their understanding and design abilities with a local public need and a real client. I am proud of my students’ work and excited about what it suggests for the future of architectural education.

- Powell Draper, Ph.D.
Assistant Professor
School of Architecture, Planning and Preservation
University of Maryland, College Park
METHODOLOGY

The organization of this document reflects the project team’s approach for gathering information and developing design proposals. The project team addressed five areas of analysis including site conditions, lighting and sun glare, heat gain/heat loss, air quality and air flow, and energy and comfort. Information gathered during analysis includes academic research, user surveys and general building evaluation using analytical modeling software and provides insight about existing conditions.

Along with the analysis of existing conditions, case studies of enclosure design that successfully address problems in each of the analysis areas inform the design team to generate initial design ideas.

The project team decided early on to provide multiple design options, each accompanied by analysis and a summary of benefits and limitations to assist the Eppley Recreation Center (ERC) in making a decision about improvements to south-facing glazing. Design and analysis focus primarily on the weight room and fitness area. Building drawings provided by ERC allowed the modeling team to generate a digital model in Rhinoceros for this portion of the building. Analysis programs operate as Rhinoceros plug-ins and are discussed further in each section.

Design targets two different façade treatment systems, louvers and shades. Each system includes three design iterations and analysis compared to the baseline model. The research, design, analysis and iteration process is outlined graphically below. The Design and Analysis section of the document provides images and information about the louver and shade iterations compared to the existing conditions and is followed by a summary of conclusions and recommendations.
Site
Lighting and Sun Glare
Heat Gain/Heat Loss
Air Quality/Air Flow
Energy and Comfort
**SITE: WIND**

**Data:**
Commercial Wind Turbines require speeds of 10-12mph for 6 Hours a day to produce energy.

On a typical day in College Park, wind speeds stay between 2-8mph. While the highest recorded speeds have reached 15 - 25 mph from the south these speeds aren’t constant enough throughout the year for energy production.²

**Recommendation:**
Lighter wind speeds could be used for an artistic wind driven facade or could be captured using a micro energy capturing system. See precedents on the next page as examples.
WIND PRECEDENTS

Charles Sower’s wind-driven kinetic installation, Randall Museum, San Francisco

Murtada Alkaabi, Ammophila System for Habitable Wind Farms
The Baltimore/College Park area receives an average of 2,597 hours (roughly 108 days) of sunlight annually.6

**Total Daylight Hours**
- June: 15 h
- March/September: 12 h 45 m
- December: 9 h 15 m

**Hours of Sunlight on South Glazing** (% of total daylight hours)

- **June**
- **Mar/Sept**
- **Dec**

**SITE DESIGN STRATEGIES**

- Planting deciduous trees in front of the weight room windows will help block unwanted sun in warm summer months and permit warming winter sun.
  - **Benefits:** Relatively low cost solution, short implementation time.
  - **Drawbacks:** Trees will take years to reach mature height and provide appropriate shading, restricted views during summer months, strategy cannot be implemented in front of fitness area windows due to entry location.

*South Building Elevation  
*Glazing areas for weight and fitness areas*
SHADING

In Maryland’s climate region, shading is considered to be advantageous to human comfort when dry bulb temperature exceeds 68° F.\(^7\)

Dry Bulb Temperature > 68° F

Hours of Day and Months of Year with Greatest Solar Radiation

DESIGN GUIDELINES

• Significant overlap between periods of the year when shading is advantageous to comfort and solar radiation levels are highest suggests an opportunity for integration of photovoltaics (pv) with a shading strategy (see example on following page).

• Shading system should aim to shade direct sunlight only during warmer weather months and should permit sunlight during cooler months when average temperature is below 68°F.

• Horizontal shading is considered most effective for south-facing glazing. Vertical shading is most effective for east and west-facing glazing.\(^6\)

The above graphics were generated using average hourly data taken from BWI Airport over a several year period and chart the annual sun path at 39.17° N latitude. Software: Rhinoceros digital building massing model used with Ladybug Environmental Plugin for Grasshopper to chart sun path diagram and measure temperature, radiation and sunlight hours throughout the year.
LIGHTING AND GLARE

OBJECTIVE

The goal of this set of analyses is to understand the impacts and affects the design has on the glare and lighting of the Eppley Recreation Center weight room and track area. Data is gathered through simulations run in Diva for Rhinoceros. Designs will be tested using the metrics below and will be evaluated in comparison to existing conditions and design iterations.

MEASURING LIGHTING AND GLARE

RADIATION MAP: a map which show the emission or transmission of light /heat energy on to a facade

DAYLIGHT GLARE PROBABILITY (DGP): “percentage of people disturbed” due to the level of vertical eye illuminance

ANNUAL GLARE: the simulation run is an evaluation of comfort within a space. It is determined through an annual DAYSIM prediction to calculate vertical eye illuminance to predict contrast from direct sunlight; a process which is repeated for each hour in the year.

POINT IN TIME ILLUMINANCE: measures the light levels at a specific time and date, recorded in lux
LIGHTING AND GLARE

RADIATION MAP SAMPLE - EXISTING CONDITION

The radiation map shows the annual irradiation on the surfaces of the building facade. The red areas indicate locations where there is excessive solar exposure. These surfaces are in need of shading and/or are locations for capturing solar energy.

Areas with the most solar exposure in kilowatt hours per meter squared:

Roof: 1441.9 kWh/m²
Weight Room Glass (South Facade): 10001.54 kWh/m²
Weight Room Brick (South Facade): 133.73 kWh/m²
South Brick Facade: 70.73 kWh/m²
Weight Room Glass (West Facade): 740.64 kWh/m²
Defining Heat Gain and Heat Loss

Just as the human body has a heat exchange process with the environment, a building has a similar heat exchange process with the outdoor environment. Heat energy tends to distribute itself evenly until a perfectly difussed uniform thermal field is achieved. Heat flows from higher temperatures to lower temperatures by conduction, convection and radiation. When the outside environment is colder than it is inside a building, the cold will try to suck the heat out of the building through exposed walls and ceilings, and through windows and floors. This process is known as Heat Loss. Conversely, when it is hotter outside than inside a building, heat will transfer inside a building, which is known as Heat Gain.1

Window Types in Eppley

Currently there are 4 different types of glass used on the envelope of the building:

Glass Type 1: East and West Gym, Spine North and South
Glass Type 2: Natatorium, Elevator (ramp)
Glass Type 3: Weight room, Director’s offices, Spine East
Glass Type 4: Spandrel Glass

Windows: Heat Gain and Heat Loss

- A typical house loses 10% of its heat through the windows
- Heat is absorbed by glazing in two ways:
  - Solar gain directly transmitted (primary transmittance) through the glazing
  - Energy absorbed by the glazing and subsequently transferred inwards by convection and radiation (secondary transmittance)
- Windows lose heat in a number of ways:
  - Around 2/3 of the energy lost from a standard window is through radiation through glazing
  - A small amount of heat is lost through convection within the glazing cavity
  - After radiation, air leakage is probably the biggest contributor to heat loss from existing windows

Window Films in Eppley

Currently there are 74 exterior windows that have a film applied on them. The film being used is Vista Window Film (type V-33 SR, DR15). The film has helped to reduce the overall Kilowatts per Hour consumption by 6.6% annually.
HEAT GAIN / HEAT LOSS

Design Opportunities

1) Shading:
   - Shading the window areas during the summer months is usually desirable
   - Using shading devices as part of the building or using landscaping features such as trees can help reduce summer solar gain and optimize winter solar gain

2) Low-E glazing:
   - By coating the face of the inner pane of glass with metal or metal oxide, short wave radiation from the sun is permitted to enter the building, while long wave radiation in the form of heat from the inside is reflected back into the room

3) Nano-Ceramic window film:
   - Apex non-reflective nano ceramic window films, manufactured by Huper Optik, use ‘Nano Ceramic’ technology to achieve high performance solar control with high visible light transmission
   - The light reflectance of these window films are kept very low, enhancing the view as it minimizes the distorting mirror effect created by some solar films

4) Shading devices
   - Exterior louvers
   - Blinds
HEAT GAIN / HEAT LOSS

EXTERIOR LOUVERS/ BLINDS

Window blinds—vertical or horizontal slat-type—are more effective at reducing summer heat gain than winter heat loss.

The advantage of an exterior shading device is that it reflects and absorbs solar energy outside the building. The exterior shade will absorb, reflect, and re-emit a total of up to 95% of the total solar radiance while only 5% is admitted into the interior space—interior blinds admit about 46% of the solar radiance. Thus, heat gain is significantly reduced.

As the sun’s angle changes—through the days and seasons—the percentage of sunlight and heat gain that the blinds block out also changes. The effectiveness of the exterior blinds in reducing heat gain can be maximized by using operable blinds.

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<td>Protective film</td>
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HEAT GAIN / HEAT LOSS

FACADE SYSTEM COMBINATIONS AND OPTIONS

First Level

- Multi-layered, transparent facade system
  - Double-skin is covering the outer wall in part
  - Window systems projecting from the outer wall
  - Attached conservatory, oriel

Second Level

- Double-skin is covering the outer wall completely
- Double-skin facades
  - Ventilation openings in both skins
  - Two-layer facade with natural ventilation

Third Level

- Space within the two-layer facade not divided
  - Unsegmented two-layer facade
  - Integrated conservatory
  - House-within-a-house system
- Space within the two-layer facade divided
  - Corridor facade
  - Shaft type facade
  - Box-window facade
AIR FLOW

Research

Based on research, the patrons of recreation centers are constantly exposed to excessive carbon dioxide and air pollutants from cleaning products. To examine the potential to improve air flow through Eppley Recreation Center, both survey responses from the patrons and personal experiences helped to develop some conventional options for improving the enclosure envelope.

Among other toxic agents, ammonia is perhaps the strongest and most pungent odor. It is easily recognizable in cleaning products and human sweat. It not only reduces interior air quality, but also poses threats to human health. Prolonged exposure to gaseous ammonia can result in lung damage.

Airborne infection is also a health problem resulted from exposure to microorganisms. Invisible micro-organisms grow when air and humidity combine and cause disease. Volatile Organic compounds (VOCs) include a variety of chemicals, some of which may have short and long-term adverse health effects.

Spas, gymnasiums and sports clubs utilize many chemical disinfectants and general cleaning agents. These agents give off gaseous odors (VOCs). While eliminating viruses, germs and fungal spores, they often contain toxic agents such as aldehydes (formaldehyde and glutaraldehyde) or phenol. Continuous low-dose exposure to aldehyde may lead to chronic toxic effects. Symptoms can vary (nausea, impairment of the memory, motivation, dexterity or reactivity). Less toxic compounds such as isopropanol, ethanol and n-propanol can cause irritation of the respiratory tract and the mucous membranes. Disinfectant odors are the only indication that unhealthy pollutants are present.

CO₂ on its own can cause fatigue, light-headedness, and foggy thinking but working out magnifies the detrimental effects, says Carla Ramos, the lead author of the study published in the journal Building and Environment. “When we exercise, we take in more air with each breath and most of that air goes through the mouth, bypassing the natural filtration system in the nostrils. The pollutants go deeper into the lungs compared to resting situations.” This is a serious issue present at Eppley Recreation Center. Due to the lack of ventilation and air circulation many visitors are subjected to high levels of CO₂ and possibly causing irreversible harm to their respiratory system.
AIR FLOW

Survey

Eppley Interior Comfort Questionnaire
This questionnaire will help us improve the design of Eppley.

1. How would you describe the air in Eppley?
   Mark only one oval.
   - Stuffy
   - Humid
   - Comfortable
   - Dry
   - Other: ..............................................................

2. Do you believe the gym is comfortable during crowded hours?
   Yes or No? If no, please explain.
   ..............................................................................

3. How would you describe the temperature?
   Mark only one oval.
   - Comfortable
   - Too Hot
   - Too Cold

4. Do you believe there is enough air circulation/flow in the treadmill/elliptical area?
   Yes or No.
   ..............................................................................

5. Do you believe there is enough air circulation/flow in the weight lifting area?
   Yes or No.
   ..............................................................................

6. What areas do you think there is too much sunlight?
   Mark only one oval.
   - Track
   - Weight Room
   - Both
   - Neither

7. Is there any overwhelming odor present in the gym?
   Yes or No. If yes, please explain where and what type of odor.
   ..............................................................................

8. Any other related comments
   ..............................................................................
   ..............................................................................
   ..............................................................................
   ..............................................................................
AIR FLOW
Survey Analysis

Based on the 70 responses of the Questionnaire, a majority of students believe there is not enough air circulation in the gym, especially during peak hour between approximately 3pm to 6pm. Approximately 40 percent of patrons described that indoor temperature as overall comfortable, but still complain about excessive heat during peak hours. Since the adapted building enclosure will directly affect the users of facility in the treadmill area and the weight room, the survey also address the level of comfort at the areas at existing condition. Approximately 60% of patrons demand more air circulation at the treadmill and cardio area. About the same percentage of response applies to the weight room area as well.
AIR FLOW

Survey Analysis and Personal Experience

Regarding survey questions about natural sunlight, the respondents expressed overall satisfaction toward the amount of natural lighting in the room. However, 11 percent of the respondents still reported excessive sunlight in the track/field, and 7 percent of the respondents felt the same way about the weight room. Regarding the odor in gym, about 70 percent of the respondents still complained about the presence of odor in the space, especially during peak hours. These survey results provide vital information for the design team for the adapted enclosure design that will maximize opportunity for ventilation.

We visited Eppley at different occupancy hour and observed the occupants. In the Group Fitness room the temperature rose during class time. Even though there are fans present in the room, when the doors were closed it seemed as though the air was somewhat suffocating, making for a bad workout environment. The open environment in the weight room and track seemed to help with the amount of air circulation. As for the treadmill/elliptical areas during peak hours we noticed multiple visitors yawning during exercise, as though they were in need of more oxygen.

A possible solution to the air pollutants would be to enhance the filtration system. Removal of particles and chemicals from the air requires different types of filtration. Particles are best trapped by moving the contaminated air through HEPA filters, where they adhere to fibers that make up the filters. However, particle filters are not particularly effective at capturing chemical molecules. That's where activated carbon filtration comes in. Minute crevices and openings in activated carbon granules trap many types of chemical molecules. Activated carbon can be specially treated to absorb an additional set of chemical molecules. Aldehydes, including formaldehyde, are in that set. In a gym environment, you need both types of filters to remove contaminants from the air.
AIR FLOW

Conventional Options

Option 1: Vents in Between Windows

By implementing vents into the current window layout we will be able to filter air coming in and increase the airflow dramatically. A positive of this option is it won't interrupt the current aesthetics of the building enclosure.

Option 2: Louver System

A louver system will provide shade which will help improve the amount of heat entering the workout areas. This will help reduce the humidity and odor issues within the facility. We also to propose to make the louver system operable and work will the window system in order to improve air circulation.
**Option 3: Operable Windows**

Operable windows will allow the control of airflow throughout the facility. We can use the current wind pattern to our advantage in order to bring in more outdoor air. Any increase in air movement will improve the “stuffy” atmosphere.

**Option 4: Interior Plant Life**

To reduce the levels of Carbon Dioxide and increase the levels of Oxygen we propose to place plants within the facility. The most active locations will require more plant life. This will also improve the stuffy atmosphere within Eppley.
**Design Conclusion**

In order to improve air quality within the facility for future development we suggest the integration of any of the options we provided. As far as an easy solution, we suggest to incorporate one or many of the plants listed below in order to filter the air. They will not only produce oxygen from CO2 but also will absorb benzene, formaldehyde and trichloroethyelene.

- English Ivy (Hedera Helix)
- Spider Plant (Chlorophytum Comosum)
- Golden Pothos or Devil’s Ivy
- Peace Lily (Spathiphyllum)
- Chinese Evergreen (Aglaonema Modestum)
- Bamboo Palm (Chamaedorea Sefritzii)
- Snake Plant (Sansevieria Trifasciata)

The next best solution would be to improve the HVAC system, providing more intake from outdoor air. We suggest in the future that Facilities Management considers reevaluating the building envelope and possibly implementing an operable system for the windows. In conclusion, we have determined that Eppley Recreation Center needs improvement upon the amount of fresh air brought into the facility as well as the circulation and filtration of the air.
ENERGY AND COMFORT

OVERVIEW

What is comfort?
Comfort is defined as being in a state of satisfaction where one does not have any physically unpleasant feelings caused by pain, temperature, light, etc. One way of looking at this is thermal comfort. Thermal comfort is the state of mind that is satisfied with the thermal environment. Factors that are included when analyzing and/or measuring comfort are as follows:

- Temperature of the surrounding air
- Radiant temperature of surrounding surfaces
- Humidity of the air
- Air motion
- Odors
- Dust
- Aesthetics
- Acoustics
- Lighting

Only the first four bulleted factors deal directly with thermal comfort. Though these are all quantifiable things we can gather using various measuring device and data, satisfaction with the thermal environment is a complex subjective response to many interactive variables such as:

- Air (dry-bulb) temp.
- Humidity
- Mean radiant temperature (MRT)
- Air movement
- Clothing
- Activity level
- Rates of change of the above

Fig. 1 represents a comfort chart, known as a psychrometric chart, that takes the various factors listed above to determine comfort levels.

![Comfort Chart](http://courses.washington.edu/me333afe/Comfort_Health.pdf)

![Physiological reaction to changes in temperature](http://courses.washington.edu/me333afe/Comfort_Health.pdf)
ENERGY AND COMFORT

The most important detriment to comfort is temperature since a narrow range of comfortable temperature can be established independently of other variables. ASHRAE (American Society of Heating, Refrigerating, and Air-Conditioning Engineers) looked for ways of determining good design standards and practices for good thermal environmental conditions for human occupancy. This describes the combination of indoor space conditions and personal factors necessary to provide comfort addressing temperature, thermal radiation, humidity, air speed, personal activity levels and clothing. According to ASHRAE Thermal Comfort Standards 55 the effective temperature (ET) and or temperature baseline for most spaces is about 75º F (29º C). This was established based on an 80% acceptance of this temperature as being a setting that most people feel comfortable doing most activities at. This was determined experimentally as acceptable standards within the space.4

Due to the variety of factors such as activity levels that take place in different built environments there is a chart that describes acceptable settings for various institutions (see table 1.6). 5

According to the chart above, the guideline room air temperature for gymnasiums and exercise rooms ranges from 68ºF minimum to 72ºF maximum in the summer and during the winter 55ºF minimum and 65ºF. *These are just guidelines which are taken on average of 80% acceptance because there is no condition that will satisfy all people. 80% is the minimum percentage for patrons being comfortable in an environment according to ASHRAE standards.

**Fig.3: Table 1.6 gives baseline room temperature settings for different type of spaces, from “Human comfort and health requirements”**
ENERGY AND COMFORT

SURVEY

In order to access the best implementation in addressing the sunlight coming in through the windows of the Eppley Recreation Center, it was vital to conduct a survey. The survey asked 50 University of Maryland students various questions pertaining to their personal comfort, specifically in the location of the weight room and the track.

1. Have You Noticed Sun Glare in the Weight Room or on the Track at the ERC?

- Yes
- No
Along the lines of comfort however, a majority of patrons believe the weight room or track area’s room temperature varies. This variation can be a mixture of comfort, hot, humid, or cold temperatures.

There was an overwhelming response in the notice of sun glare in the weight room and track areas of the ERC, though many patrons were not affected or unsure whether the sun glare affected their time of work out.

Furthermore, the survey revealed that a little under half of the patrons have noticed exercise equipment, specifically near the windows, getting hot from being exposed to direct sunlight throughout the day.

Along the lines of comfort however, a majority of patrons believe the weight room or track area’s room temperature varies. This variation can be a mixture of comfort, hot, humid, or cold temperatures.

There was an overwhelming response from the patrons surveyed, expressing the motion to take action in correct the sunlight situation occurring in the ERC.
ENERGY AND COMFORT

SUGGESTIONS

Based on the data gathered from the survey study, it is important to note that measures need to be taken with regards to correcting sunlight glare and overall thermal comfort of the various exercise rooms so that Eppley can become a much more comfortable environment to its patrons. These issues can be solved through the use of various different kinds of window treatments. Some simple strategies for treating windows against overexposure to sunlight and heat gain can also lead to overall energy cost saving benefits.

Some simple strategies mentioned by U.S. Department of Energy for creating energy efficient window treatments are as follows:

• Interior Blinds: Are more efficient during the summer than the winter but can help reduce heat gain by 45%

• High Reflective film: High-reflectivity window films help block summer heat gain. They are best used in climates with long cooling seasons, because they also block the sun's heat in the winter. (This method has already been put in place at the Eppley Center and some advantages have been seen though not numerous)

• Shades: Several manufacturers have designed two- or three-cell pleated or cellular shades with dead air spaces, which increase their insulating value. These shades, however, provide only slight control of air infiltration. When properly installed this can be one of the simplest and most efficient way of reducing solar heat gain and saving energy.

• Louvers, awnings, and fins are only some examples of shading devices that are mechanically attached to a building facade in order to limit the amount of glare and solar heat gain entering through the windows.

The National Institute of Building Sciences states that buildings outfitted with shading systems can consume between 5 to 15 percent less energy due to the reduced cooling needs.

According to article published by the Architectural Record, cooling loads dominate with more than 2/3 needed simply to counteract heat gain from lighting systems and sun-loaded glass surfaces. This article focused on the idea of “Robo-Buildings: Pursuing the interactive Envelope”. This article did a good job at explaining the skepticisms that exist about pursuing an interactive envelope, but also illustrated through the mention of various projects that energy efficiency has been achieved throughout the process as well as the overall comfort of the space for the patrons.
**SOLAR ENERGY ANALYSIS**

**Solar Energy**

There are several advantages of photovoltaic solar power, which makes it considered one of the most promising renewable energy sources in the world.\(^9\) Solar Electric Systems utilize Photovoltaic (commonly referred to as PV) to convert light into electricity. Because solar energy coincides with energy needs for cooling, PV panels can provide an effective solution to energy demand peaks.\(^{10}\)

**PV Systems**

Systems vary in size, but commercial applications are typically 77 inches by 39 inches. \(^{11}\)

**Power**

Shading and orientation of the PV locations will affect production. All systems are unique and every area offers a different daily solar energy availability level.

**Site**

The ideal site for PV panels is a southern orientation with a fairly unobstructed view. Based on the longitude and latitude of an area, PV panels are to be places on a particle tilt to allow for optimal energy consumption. This is a factor if PV panels are too be placed on a louver system, that either moves or is tilted in a particular angle an direction.\(^{12}\)

**Maintenance**

Solar requires very little maintenance if the PV panels are stationary. Panels attached to louvers are more likely to require attention and care.
Efficiency

Efficiency plays no part in the production of more power in a building. Efficiency only reflects the price and physical size of a module. PV panelled louvers compared to a set of large PV panels placed on a commercial building are not nearly as efficient.\textsuperscript{13}

Payback

A typical system payback ranges between 3 to 10 years. There are many calculation estimates that can predict potential paybacks. As a major renewable energy system, it is promoted through government subsidy funding (FITs, tax credits, etc.), creating financial incentives.\textsuperscript{14}

Cost

There are many different system sizes, and size does matter in terms of cost. A typical residential system can run around $3-$4 per installed watt, while commercial systems cost a bit more.\textsuperscript{15}

ERC Analysis

After running basic energy analyses and through the use of online solar energy calculators, our research has a preliminary conclusion on solar panelled louvers for the ERC. Solar panelled louvers would not be enough to create a significant amount of energy for the ERC to use in production.

The orientation of photovoltaic panels on the building’s louvers would have to be stationary and not move or be adjusted for maximum efficiency. The price for solar panelled louvers is high because of the customization level of panels.

The overall footprint of the ERC would need an equal size area to obtain enough solar panels in order to create the proper amount of energy to benefit savings. Solar Panels placed on the roof of the ERC is a good option for future building projects. It is important to keep in mind that it take at least five years to see a significant payback from solar energy.
ENDNOTES

SITE


LIGHTING AND GLARE


HEAT GAIN AND HEAT LOSS


Images:


AIR FLOW


ENERGY AND COMFORT

2. “Human comfort and health requirements” by the University of Washington http://courses.washington.edu/me333afe/Comfort_Health.pdf pg. 16

3. “Human comfort and health requirements” pg. 24

4. “Human comfort and health requirements” pg. 25

5. “Human comfort and health requirements” pg. 28

ENERGY AND COMFORT (CONT.)


CASE STUDY: BIODESIGN INSTITUTE

GOULD EVANS AND ASSOCIATES

RESEARCH FACILITY

2006 TEMPE, ARIZONA


A large, easterly expanse of windows uses aluminum louvers that are controlled continuously by photocells and sun-tracking software. The design allows occupants to control most of the louvers in their offices using their PCs, although at above 8 feet from floor level the louvers are controlled automatically.¹
Different elevations of the building have different systems. On the south side (left), large photovoltaic panels form a brise-soleil. On the east and west facades, perforated solar-shading screens hang a foot from the exterior wall. When they heat, air around them rises, which draws cooler air from ground level. Each day, about 1,000 screens (middle), which are located in front of windows, open and close. This project was $165 per sqft which is average cost for typical project. Cost savings have been projected at 40%.2
CASE STUDY: FREE UNIVERSITY

FOSTER & PARTNERS

LIBRARY

2005 BERLIN, GERMANY

Different elevations of the building have different systems. On the south side (left), large photovoltaic panels form a brise-soleil. On the east and west facades, perforated solar-shading screens hang a foot from the exterior wall. When they heat, air around them rises, which draws cooler air from ground level. Each day, about 1,000 screens (middle), which are located in front of windows, open and close. This project was $165 per sqft which is average cost for typical project. Cost savings have been projected at 40%.


http://ad009cdnb.archdaily.net/wp-content/uploads/2013/10/525d5999e8e44e67bf0009b2_free-university-of-berlin-foster-partners_0980_fp85939.jpg

http://ad009cdnb.archdaily.net/wp-content/uploads/2013/10/525d5932e8e44e67bf0009af_free-university-of-berlin-foster-partners_0980_fp85934.jpg
Existing Condition
LOUVER: Basic, Advanced, Advanced Revised
SHADE: Basic, Advanced, Advanced Revised
DESIGN AND ANALYSIS

METHODOLOGY

Design solutions focus on addressing the client’s greatest needs: reducing heat gain and sun glare in the weight room. Two facade treatment types, louvers and shades, were prioritized based on initial research findings. Through an iterative process of research, design, modeling and analysis the project team transformed early design ideas into successful design solutions.

To demonstrate the success of design ideas in improving building performance, the team conducted analysis of solar radiation, annual glare, point-in-time illuminance, and heat gain/heat loss. Analysis was conducted in DIVA for Rhinoceros for each of the shade and louver design options.

After gathering the data from these simulations, each design was compared in relation to the existing condition of Eppley Recreation Center, as well as previous design iterations to evaluate performance.

Following each stage of analysis, recommendation to the design team improved successive iterations of the louver and shade.

Design Brainstorming Diagram
DESIGN AND ANALYSIS

DESIGN CONSIDERATIONS

After studying the depth of intervention of a new shading system, the design team decided that the system must be attached on the exterior to provide heat gain mitigation.

Visual continuity should be provided for people using to the gym to see outside.

Prevention of sun glare is important, especially at the human eye level at both the second and third floors.

South facing walls needed continuous sun protection.

Design Thinking: Louver v. Shade Argument
EXISTING CONDITION

ANNUAL GLARE

- All twelve months receive a consistent intolerable glare 12:00 PM - 2:00 PM
- The months receiving the most amount of intolerable glare are May - August from 6:00 AM - 6:00 PM

Conclusions:
After analyzing the annual daylight glare probability, there is an intolerable glare on the front facades of Eppley Recreation Center for numerous hours of the day during all twelve months of the year. Since the gym is frequently occupied, the amount of intolerable glare that is currently entering the building would deter occupants from using the front weight room areas. Since the summer months have the highest percentage of intolerable glare, it would be essential to equip the facade with some sort of mechanism to make the front weight room an occupiable space during this time frame.
The Point-in-Time Illuminance measures the light levels at a specific time and date. The results are for the floor surface in the weight room and the southern glass facade of the weight room. Currently, the interior of the weight room receives over 1,000 more lux than necessary for the tasks being performed.

**JUNE 21st**
- Weight Room Floor: 2,126 lux
- Weight Room Glass: 15,663 lux

**DECEMBER 21st**
- Weight Room Floor: 2,273 lux
- Weight Room Glass: 36,681 lux
The heat gain/heat loss map shows the annual heat loss and heat gain on the window surfaces of the facade. The red area indicates the area with the highest amount of heat gain, while the blue area indicates heat loss. This model shows that the windows on the west and south facade in front of the weight room experiences the highest amount of heat gain, while the strip of windows above that on the south facade experience the highest amount of heat loss.

The graph to the right shows the values for heat gain and heat loss over a 365 day period for both the south and west facade. This graph indicates that the south facade can experience a high of 800 Kw/hr for heat gain, while the west facade experiences a high of almost 200 Kw/hr.

Negative values indicate heat loss. Heat gain is indicated by positive numbers.
BASIC LOUVERS

Design Decision: Horizontally organized, fixed, aluminum panels.

The design team focused on:

- **A basic fixed louver system that would not inhibit views to outside for people using the facility**

- **Louver depth and orientation based on typical winter and summer sun angles**

Conclusions

Although the Design Team’s goal was to keep the view to the exterior of the building, the large amount of small louvers started to act like a screen.

To be more efficient the design team decided future iterations should explore changes to the amount of louver panels and their orientation.

Precedent

The Design Team looked at many louver systems but were particularly interested in the SCAD Museum of Art Sottile & Sottile and Lord Aeck Sargent, in association with Dawson Architects.
BASIC LOUVERS

ANNUAL GLARE

- The most intolerable glare is concentrated between the hours of 7:00 AM - 9:00 AM, from March - September
- The months of November - January receive the least amount of glare

Conclusions:
The addition of louvers to the Eppley Recreation Center front facade has significantly reduced the amount of glare that enters the weight rooms. The louvers have reduced the amount of glare in the midday - evening hours, but there is still a significant amount of intolerable glare in the early hours of the day for eight out of the twelve months. Since the sun is low in the sky in the morning, the louvers are not as effective in blocking the glare.
BASIC LOUVERS

POINT-IN-TIME ILLUMINANCE

The basic louvers decrease the amount of lux hitting the interior space, but the number is still higher than necessary for working out, especially during the winter when the lower sun is not directly blocked by the louvers.

JUNE 21st

Weight Room Floor: 1,946 lux
Weight Room Glass: 8,119 lux

DECEMBER 21st

Weight Room Floor: 1,795 lux
Weight Room Glass: 25,292
ADVANCED LOUVERS

Design Description: Horizontally organized, fixed, aluminum panels.

The design team focused on:

- A fin or louver that would not inhibit views to outside for people using the facility

- A fixed location of a louver that would both block sun, and prevent glare

Conclusions

After analyzing both horizontal and vertical fixed louvers, the design team concluded that fixed vertical louvers did not perform well for the south facing facade and for views outside; the vertical louvers would have to closed continuously to block the south facing sun and would disrupt the view outside.

Louvers pinned in the middle instead of fixed at a hinge would provide better glare and sun protection as well as a more interesting aesthetic.

Precedent

The Design Team looked at many louver systems but were particularly interested in the corner condition of the weight room and looked at the CMT Headquarters for inspiration.

Batlle i Roig Architects

Concept Sketch

The louver size got smaller as a result of the calculations of number and sizes of louvers.
ADVANCED LOUVERS

ANNUAL GLARE - VERTICAL 50% CLOSED

- Months of March - October show the most amount of intolerable glare entering the building, from the hours of 6:00 AM - 6:00 PM
- Months of November - February receive a less amount of glare, from the hours of 9:00 AM - 5:00 PM

Conclusions:
When compared to the existing conditions of Eppley Recreation Center, the designed louver has not helped solve the problem of intolerable glare.
The vertical designed louvers did not perform as well as the horizontal base louvers. The vertical louvers allowed more light, especially during the fall and spring months when the building would be in greatest use.
The revised design of the advanced louvers are the most successful in reducing the heat gain experienced in both the south and west facades. This scheme reduces the max heat gain on the south facade from 800 Kw/hr to just under 350 Kw/hr. It also reduces the max heat gain on the west facade from 200 Kw/hr to just a high of under 150 Kw/hr. Max heat loss on the south facade is reduced to under 50 Kw/hr, compared to a max of just under 100 Kw/hr in the base design.

Negative values indicate heat loss. Heat gain is indicated by positive numbers.
Design Description: Horizontally organized aluminum panels that are operable around a central pivot point.

The design team focused on:

- A fin or louver that would not inhibit views to outside for people using the facility
- A movable location of a louver that would both block sun, and prevent glare
- That could rotate on a pin on its center

Conclusions

After analyzing both horizontal and vertical fixed louvers, the design team concluded that horizontal louvers pinned in the center worked well for the south facing facade and for views outside; the vertical louvers would have to be closed during the afternoon but at peak hours of the gym would frame the human body as well as provide views outside.

A perforated horizontal panel would be best. The design team suggests using a custom perforation design that would both help brand the building and super impose an image on students while using the gym as well as shine through at night.

Precedent

We looked at many louver systems and were particularly interested in perforated metal louvers. The USCF Mission Bay Garage provided inspiration for perforated metal patterns.

WRNS and Sahner Consultants

Concept Idea for Perforation

A light pattern shines on all people using the facility. Why not use this as an opportunity to show a message of inclusiveness at UMD.
Months of March - September show the most amount of intolerable glare entering the building, from the hours of 6:00 AM - 5:00 PM.

Months of November - January receive mostly disturbing and perceptible glare, with patches of intolerable glare from 11:00 AM - 2:00 PM.

Conclusions:
This horizontal design louver system is not as effective as the basic louver, as most of the hours of the day, seven months a year still receive intolerable glare. When compared to the existing conditions at Eppley, this shade design has impacted the months of November - February the most, by lowering the factor of glare from intolerable to perceptible during the hours of 10:00 AM - 1:00 PM. Another small difference that can be seen is in the evening hours of day. Currently, the existing condition during the summer months has intolerable glare during all hours of sunlight, whereas with the new shade system the evening hours have been lowered to perceptible glare.
The re-designed horizontal louvers were the most successful. The louvers blocked the excess sunlight throughout the whole year, lowering the light in the space to a level appropriate for working out.

**JUNE 21st**
- Weight Room Floor: 1,792 lux
- Weight Room Glass: 5,469 lux

**DECEMBER 21st**
- Weight Room Floor: 1,155 lux
- Weight Room Glass: 10,057 lux
**BASIC SHADES**

Design Description: Fabric Rolling Screen

The design team focused on:

- A basic unrolling shade system that would provide semi-transparent views to outside or people using the facility

- Based on a typical fabric shade system

**Conclusions**

Although the Design Team’s goal was to keep the view to the exterior of the building, the large rolling shade started to act like a screen.

The South facing glass was left unprotected from the sun when the shades were deployed, making the system inefficient.

Precedent
The Design Team looked at many exterior shading systems including Forrest City Office.
Gensler, Washington, D.C.
BASIC SHADES

ANNUAL GLARE - SHADE 50% CLOSED

- Months of February - October show the most amount of intolerable glare entering the building, from the hours of 6:00 AM - 5:00 PM
- Months of November - January receive mostly a mix of intolerable and perceptible glare from 10:00 AM - 3:00 PM

Conclusions:
When compared to the existing conditions of Eppley Recreation Center, the basic shade has not helped solve the problem of intolerable glare. At best, there is a slight lowering of intolerable glare to perceptible glare during the evening hours of the months from November - January.
ADVANCED SHADES

Design Description: Vertically folding dynamic shade system.

The design team focused on:
- A folding shade that would not inhibit views to outside for people using the facility
- Folding upward and downward to provide overhang shading, a light shelf in the upper levels as well as direct shading when unfolded
- Dynamic facade throughout the day

Conclusions
After analyzing a semi transparent shade as a baseline, the Design Team quickly decided to move to operable shade system that could both fold as an overhang and completely close the south facing wall as needed. After analysis, when folded, the overhang wasn’t covering enough of the glass wall to be efficient. The overhang either needed to get larger which would be difficult structurally or the shade system could employ another transparent moving shade that extended upward. The upper downward folding shade also was inefficient, letting too much heat gain.

Precedent
The Design Team looked at many exterior shading systems including metal panels and fabric similar to those used on Kiefer Technic Show Room (right) and F40 Office Building (left).
Petersen Architects (Right), Ernst Giselbrecht + Partner (Left)

Folding shade blocks sun and acts as overhang
ADVANCED SHADES

ANNUAL GLARE - SHADE 50% CLOSED

- Months of March - September show the most amount of intolerable glare entering the building, from the hours of 6:00 AM - 5:00 PM
- Months of November - February receive mostly perceptible glare, with certain patches of intolerable glare from 11:00 AM - 2:00 PM

Conclusions:
This shade system is not as effective as the basic louver, as most of the hours of the day, eight months a year still receive intolerable glare. When compared to the existing conditions at Eppley, this shade design has impacted the months of November - February the most, by lowering the factor of glare from intolerable to perceptible during the hours of 10:00 AM - 1:00 PM. Another small difference that can be seen is in the evening hours of day. Currently, the existing condition during the summer months has intolerable glare during all hours of sunlight, whereas with the new shade system the evening hours have been lowered to perceptible glare.
The designed shades drastically lowered the lux levels hitting the interior space in September and March. This would be beneficial as it is the time of highest occupancy since classes are in session.
ADVANCED SHADES
HEAT GAIN/HEAT LOSS - SHADE 50% CLOSED

The revised advanced shade is effective in reducing the heat gain and heat loss values experienced on the south and west facades. With this shading design, the max heat gain value is just under 350 Kw/hr on the south facade, and about 150 Kw/hr on the west facade. The max heat loss value is reduced from just under 100 Kw/hr to just over 50 Kw/hr on the south facade.

Negative values indicate heat loss. Heat gain is indicated by positive numbers.
**ADVANCED SHADE - REVISED**

Design Description: Vertically folding dynamic shade system with semi-transparent shade at eye level.

The design team focused on:

- **Folding upward to provide overhang shading as well as direct shading when unfolded in both sections**

- **An unrolling semi-transparent shade the moved upward to block section of unprotected glass exposed from over hang with out any opaque visual implications at eye level**

**Conclusions**

The unrolling of the shade system allowed the overhang to get too large and also shade the untreated glass facade behind.

We would recommend looking into perforations because even when the wall is fully closed, some light is allowed in.

This option allows more view because of the transparency in the rolling shade.

Precedent

The Design Team decided to incorporate both a metal panel and fabric system by combining systems used on the Kiefer Technic Show Room (right) and F40 Office Building (left).

*Petersen Architects (Right), Ernst Giselbrecht + Partner (Left)*

Rolling shade moves up and down with panel folding system
CONCLUSIONS:
When compared to the existing conditions of Eppley Recreation Center, the re-designed shade has not helped solve the problem of intolerable glare.
The re-designed shades still drastically lowered the lux levels hitting the interior space in September and March. Both shade designs would be beneficial in helping the excessive lighting of the space.
## CONCLUSIONS

### DESIGN PERFORMANCE

<table>
<thead>
<tr>
<th>SUPERIOR PERFORMANCE</th>
<th>Annual Glare</th>
<th>Point in Time Illuminance</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Basic Louvers</strong></td>
<td>June Floor</td>
<td>September Floor</td>
</tr>
<tr>
<td></td>
<td>Glass</td>
<td>Glass</td>
</tr>
<tr>
<td><strong>Existing Condition</strong></td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td><strong>Basic Louvers</strong></td>
<td>5</td>
<td>4</td>
</tr>
<tr>
<td><strong>Advanced Louvers - Revised</strong></td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td><strong>Basic Shades</strong></td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td><strong>Advanced Shades - Revised</strong></td>
<td>3</td>
<td>3</td>
</tr>
</tbody>
</table>

**Analysis Results:** Performance of four designs compared to existing condition and ranked 1 (best performing) - 5 (worst performing)
CONCLUSIONS

COMPARISON OF POINT-IN-TIME ILLUMINANCE

<table>
<thead>
<tr>
<th></th>
<th>June 21</th>
<th>September 21</th>
<th>December 21</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Floor</td>
<td>Glass</td>
<td>Floor</td>
</tr>
<tr>
<td>EXISTING CONDITION</td>
<td>2,126 lux</td>
<td>15,663 lux</td>
<td>3,270 lux</td>
</tr>
<tr>
<td>BASIC LOUVERS</td>
<td>1,946 lux</td>
<td>8,119 lux</td>
<td>2,365 lux</td>
</tr>
<tr>
<td>ADVANCED LOUVERS</td>
<td>1,936 lux</td>
<td>9,162 lux</td>
<td>2,568 lux</td>
</tr>
<tr>
<td>ADVANCED LOUVERS - REVISED</td>
<td>1,792 lux</td>
<td>5,469 lux</td>
<td>1,539 lux</td>
</tr>
<tr>
<td>ADVANCED SHADES</td>
<td>1,883 lux</td>
<td>7,056 lux</td>
<td>1,921 lux</td>
</tr>
<tr>
<td>ADVANCED SHADES - REVISED</td>
<td>1,894 lux</td>
<td>7,125 lux</td>
<td>2,005 lux</td>
</tr>
</tbody>
</table>

The above data shows that the Advanced Louvers - Revised would be the best option for lowering the amount of light (in lux) effecting the interior spaces. Either of the two shade designs would also be beneficial as an alternate solution.
CONCLUSIONS

LOUVERS VS. SHADES

LOUVERS

ANNUAL GLARE
The most effective louver tested for annual glare was the baseline louver. The vertical designed louver did not solve the problem of intolerable glare. The re-design horizontal louver system is not as effective as the basic louver, as most of the hours of the day, seven months a year still receive intolerable glare. When compared to the existing conditions at Eppley, the re-designed louver design has impacted the months of November - February the most, by lowering the factor of glare from intolerable to perceptible during the hours of 10:00 AM - 1:00 PM.

POINT-IN-TIME ILLUMINANCE
The most effective louver system for point in time illuminance was the re-designed louver at 50%. This system was the most effective at decreasing the amount of excessive light entering the interior spaces. The system lowered the amount of illuminance in the space from 3,270 lux to 1,539 lux during the Fall and Spring. It also lowered the amount of light hitting the glass façade from 39,716 lux to 7,779 lux which will decrease the amount of heat entering the space.

SHADE

ANNUAL GLARE
The most effective shade system was the designed shade at 50% closed. However, this shade system is not as effective as the basic louver, as most of the hours of the day, eight months a year still receive intolerable glare. When compared to the existing conditions at Eppley, this shade design has impacted the months of November - February the most, by lowering the factor of glare from intolerable to perceptible during the hours of 10:00 AM - 1:00 PM. Another small difference that can be seen is in the evening hours of days during the summer months, where the re-designed shade system has lower the glare from intolerable to perceptible.

POINT-IN-TIME ILLUMINANCE
The most effective shade system for point in time illuminance was the designed shades at 50%. Even though it was not as successful as the re-designed louvers, this system was effective at decreasing the amount of excessive light entering the interior spaces. They system lowered the amount of illuminance in the space from 3,270 lux to 1,921 lux during the fall and spring. It also lowered the amount of light hitting the glass façade from 39,716 lux to 16,565 lux which will decrease the amount of hear entering the space.
Following analysis of each of the design options, we recommend that Eppley Recreation Center implement either the Advanced Louvers - Revised or Basic Shades design for their superior performance in mitigating heat and glare in the weight room. The louver system performed the best across all categories, as seen in the Analysis Results chart, and the shade system came in second place. Both options reduce glare and light entering the weight room. Based on these results we recommend a horizontal louver system across the southern façade of the weight room. Perforated aluminum panels that are operated based on the angle of the sun will block out the direct sun and prevent glare in both the summer and winter while still allowing light to enter. This will reduce problems with glare and heat gain and provide an enjoyable atmosphere for the building’s occupants.