Rev. James G. Gambet Center
DeSales University | Center Valley, PA

Penn State Architectural Engineering Capstone Project
Brett Tallada | Construction Option | Advisor: Ray Sowers
## Project Background

- New building for Business and Healthcare Education
- 10 classrooms and lecture hall
- Business classrooms with mock trading floor
- Cutting edge patient, simulation, and anatomy labs
- Faculty and administrative offices

### Building Location:
DeSales University - Center Valley, PA

### Building Size:
77,000 SF

### Number of Stories:
2 Stories

### Occupancy/Function Type:
Business - Offices, Education, Labs

### Project Cost:
$27 Million

### Dates of Construction:
June 2011 – February 2013

### Project Delivery Method:
Design-Bid-Build

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**Owner:** DeSales University  
**Architect:** Breslin Ridyard Fadero Architects  
**Construction Manager:** Alvin H. Butz, Inc.  
**Mechanical/Electrical Engineer:** Snyder Hoffman Associates  
**Civil/Structural Engineer:** Barry Isett and Associates

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LEED® Evaluation

Project Overview

• DeSales focusing more attention to mission of sustainability
• Gambet Center to be second LEED® building on campus
• Designed for high performance and efficiency
• Expected to achieve LEED® Silver rating

LEED® 2009 Scorecard

<table>
<thead>
<tr>
<th>LEED® Category</th>
<th>Earned Credits</th>
<th>Possible Credits</th>
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</thead>
<tbody>
<tr>
<td>Sustainable Sites</td>
<td>7</td>
<td>26</td>
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<tr>
<td>Water Efficiency</td>
<td>8</td>
<td>10</td>
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<tr>
<td>Energy and Atmosphere</td>
<td>11</td>
<td>35</td>
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<tr>
<td>Materials and Resources</td>
<td>6</td>
<td>14</td>
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<tr>
<td>Indoor Environmental Quality</td>
<td>10</td>
<td>15</td>
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<tr>
<td>Innovation and Design Process</td>
<td>6</td>
<td>6</td>
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<tr>
<td>Regional Priority Credits</td>
<td>2</td>
<td>4</td>
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<tr>
<td><strong>Total (LEED® Silver)</strong></td>
<td><strong>50</strong></td>
<td><strong>110</strong></td>
</tr>
</tbody>
</table>

Technical Analyses

I. Conceptual Energy Modeling
   Understand early design implications

II. Green Roof Implementation
   Reduce mechanical load of Lecture Hall

III. On-Site Renewable Energy
    Provide 13% of building’s electricity

IV. Advanced Lighting Controls
    Increase energy efficiency

Areas for Improvement

• 15/19 credits available for optimizing energy performance
• 7 credits available for on-site renewable energy
• 2 credits available for innovative wastewater technology
• 1 credit available for use of certified wood
Technical Analysis I
Conceptual Energy Modeling
Project Vasari

Conceptual Energy Modeling

- Beta software from Autodesk Labs – integrated into Revit 2014
- Conceptual energy analysis based on mass model
- Used throughout design to compare alternative options
- Provides detailed report on annual energy usage
- Based on building form, assemblies, function, and systems

Steps for Energy Model Analysis
1. Create or Import Building Model
2. Set Building Parameters
3. Run Energy Model Simulation
4. Analyze Results
5. Modify Building Simulation
6. Run Additional Simulations
7. Compare Results

Images Courtesy of Autodesk
Energy Analysis

Original Design Parameters

| Location and Orientation | (40.5°N, 75.4°W, 519'W) |
| Function and Operating Schedule | Year-Round University Building |

| Construction Type | New Construction |
| Glazing Percentage | 38% |
| Target Sill Height | 2'-6" |
| Glazing Shade Depth | 2'-6" |
| Wall Construction | Standard Construction, High Insulation |
| Roof Construction | Metal deck with 8" Insulation |
| HVAC System | High efficiency Packaged Gas VAV |

Information Provided from Energy Analysis:
- Annual Carbon Emissions
- Annual Energy Use/Cost
- Fuel and Electricity Consumption
- Lifecycle Energy Use
- Monthly HVAC Loads
- Weather Design Data
- Renewable Energy Potential

Compare effect on annual energy consumption when using a Geothermal Heat Pump.
Implications:

- 60% reduction in natural gas consumption
- Estimated annual fuel savings of $16,257
- 3.4% increase in whole building power consumption
- Total annual savings estimated to be $13,434
- Optimizes energy efficiency of the building by 6%

Conclusion

- Conceptual energy modeling allows comparative analysis for smarter design choices
- Project Vasari is effective at easily calculating changes in energy consumption for various locations, systems, and assemblies
- A geothermal heat pump HVAC system increases energy efficiency by 6%, eligible for 3 additional LEED® credits
- It is the designer’s responsibility to understand and balance the owner’s goals and budget

Recommendation

- The designers of the building can easily use this tool to create a more energy conscious building
- If needed, a geothermal heat pump should be installed for the purpose of helping the Gambet Center achieve LEED® Gold.
Technical Analysis II
Green Roof Implementation
Proposed Design

GroRoof™ Hybrid Green Roof

- 18” x 18” x 4.5” Modular Green Roof System
- Interlocking trays for full soil integration
- Instant Vegetation
- Dedicated drainage channels

On-Site Renewable Energy
Advanced Lighting Controls

5,855 SF Extensive Green Roof Above Lecture Hall
Project Overview
Conceptual Energy Modeling
Green Roof Implementation
Proposed Design
Breadth Analyses
Lifecycle Cost Analysis
Recommendation
On-Site Renewable Energy
Advanced Lighting Controls
Conclusion

Applicable Equations

Live Load Reduction
\[ L_v = L_o \left[ 25 + \frac{15}{2\delta_4} \right] \]

Factored Distributed Load
\[ W = (1.2)(D) + (1.6)(L_r) + (0.5)(S) \]

Factored Shear Force
\[ V_u = \frac{(w_u)(l)}{2} \]

Factored Bending Moment
\[ M_{max} = \frac{(w_u)(l^2)}{8} | \text{pin-pin} \]
\[ M_{max} = \frac{(w_u)(l^2)}{12} | \text{fixed-fixed} \]

Structural Breadth

Steel Members

Girders:
1. 63'-9" W33x130
2. 63'-9" W36x361

Beams: spaced 5'-4" on center
1. 23'-10" W12x16
2. 23'-10" W14x22
3. 23'-10" W18x35
4. 23'-10" W21x50

Applicable Equations

Dead, Live, and Snow Loads

<table>
<thead>
<tr>
<th>Item</th>
<th>Built-Up Roof</th>
<th>GroRoof™</th>
</tr>
</thead>
<tbody>
<tr>
<td>Steel Beam Self Weight</td>
<td>5 psf</td>
<td>5 psf</td>
</tr>
<tr>
<td>Metal Deck</td>
<td>2 psf</td>
<td>2 psf</td>
</tr>
<tr>
<td>5&quot; Rigid Insulation</td>
<td>2 psf</td>
<td>2 psf</td>
</tr>
<tr>
<td>ME,F,P</td>
<td>15 psf</td>
<td>15 psf</td>
</tr>
<tr>
<td>Ceiling</td>
<td>2 psf</td>
<td>2 psf</td>
</tr>
<tr>
<td>4 ½&quot; GroRoof™</td>
<td>32 psf</td>
<td>32 psf</td>
</tr>
<tr>
<td>Total Dead Load</td>
<td>26 psf</td>
<td>58 psf</td>
</tr>
<tr>
<td>Total Roof Live Load</td>
<td>20 psf</td>
<td>20 psf</td>
</tr>
<tr>
<td>Total Snow Load</td>
<td>30 psf</td>
<td>30 psf</td>
</tr>
</tbody>
</table>

Typical Bay
Structural Breadth

**Applicable Equations**

- **Live Load Reduction**
  \[ L_r = L_0 \left( 1 + \frac{15}{2(K+4)} \right) \]

- **Factored Distributed Load**
  \[ W = (1.2)(D) + (1.6)(L_r) + (0.5)(S) \]
  \[ w_r = (W) \text{(Tributary Width)} \]

- **Factored Shear Force**
  \[ V_a = \frac{(w_r)L}{2} \]

- **Factored Bending Moment**
  \[ M_{\text{max}} = \frac{(w_r)L^2}{8} \text{ | pin-pin} \]
  \[ M_{\text{max}} = \frac{(w_r)L^2}{12} \text{ | fixed-fixed} \]

**Steel Members**

- **Girders:**
  1. 63'-9" W33x130
  2. 63'-9" W36x361

- **Beams:** spaced 5'-4" on center
  1. 23'-10" W12x16
  2. 23'-10" W14x22
  3. 23'-10" W18x35
  4. 23'-10" W21x50

**Apparent Equations**

- **Beam and Girder Analysis**

<table>
<thead>
<tr>
<th>Beam Type</th>
<th>Shear</th>
<th>Max. Shear</th>
<th>Moment</th>
<th>Max. Moment</th>
<th>Pass/Fail</th>
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<td>W12x16</td>
<td>7.44</td>
<td>79.2</td>
<td>44.3</td>
<td>75.4</td>
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<tr>
<td>W14x22</td>
<td>7.44</td>
<td>94.9</td>
<td>44.3</td>
<td>125</td>
<td>Pass</td>
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<tr>
<td>W18x35</td>
<td>7.44</td>
<td>159</td>
<td>29.45</td>
<td>249</td>
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<tr>
<td>W21x50</td>
<td>7.44</td>
<td>237</td>
<td>29.45</td>
<td>413</td>
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<tr>
<td>W33x130</td>
<td>31.66</td>
<td>576</td>
<td>378.37</td>
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<tr>
<td>W36x361</td>
<td>63.32</td>
<td>1280</td>
<td>756.74</td>
<td>5810</td>
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</table>
Mechanical Breadth

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Applicable Equations

**CLTD Method – ASHRAE Ch. 28**

\[ q = (U)(A)(\overline{CLTD}) \]

**Corrected CLTD**

\[ CLTD_{corr} = CLTD + (78 - t_r) + (t_m - 85) \]

- \( t_r \) = inside temperature (65˚F)
- \( t_m \) = mean outdoor temperature (73˚F)

**Energy Efficiency Ratio (EER)**

\[ EER = \frac{Cooling \, Load (BTU)}{Input \, Watts (W)} \]

**CLTD Method Results**

<table>
<thead>
<tr>
<th>Roofing System Component</th>
<th>R-Value</th>
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<tbody>
<tr>
<td>1 ½” Metal Roof Decking</td>
<td>-</td>
</tr>
<tr>
<td>5” Rigid Insulation</td>
<td>20</td>
</tr>
<tr>
<td>1 ½” Insulation Cover Board</td>
<td>.85</td>
</tr>
<tr>
<td>Single-Ply Asphalt Waterproofing Membrane</td>
<td>.15</td>
</tr>
<tr>
<td>GroRoofTM Extensive II Module</td>
<td>3</td>
</tr>
<tr>
<td><strong>Total R-Value (( \sum R ))</strong></td>
<td><strong>24</strong></td>
</tr>
<tr>
<td><strong>U-Value (1/( \sum R ))</strong></td>
<td><strong>.0417</strong></td>
</tr>
</tbody>
</table>

**CLTD Method Results**

- Total Daily Cooling Load in BTU: 194,834
- Total Annual Cooling Load in BTU (153 days): 29,809,677
- Green Roof Cooling Load Reduction in BTU (60%): 17,885,806

**Energy Savings**

\[ \frac{Reduced \, Load}{EER} = \frac{17,885,808 \, BTU}{10.9} = 1,640 \, kW h \]

1,640 kWh x $0.09/kWh = $147.68

**Mechanical Breadth Wrap-Up**

- Low cost savings implies an unfavorable payback period
- CLTD method considers U-Value; excellent thermal performance of original design reduces most solar heat gain on its own
Lifecycle Cost Analysis

Payback Period
25 Years

Return on Investment
$22,263 (20%)

*Contingent upon the passing of proposed legislation

Up-Front Cost Estimate
- 4.5” GroRoof Installed Cost per SF: $19.00
- GroRoof Area: 5,855 SF
- Total Up-Front Cost: $111,245

Energy Savings
- $147.86 per year

Increased Lifespan Savings
- $77,688 in the 25th year

Tax Incentive Savings
- $50,000 over first 6 years
**Recommendation**

**Not Recommended**
- Small ROI and unfavorable payback period
- Low energy savings
- No affect to LEED®

**Recommended – If Legislation Passes**
- Saves owner from replacing roof in 25 years
- Depends on if owner is willing to invest
- Investment could profit owner approx. $20,000 by increasing lifespan

**Conclusion:**
- Although a 20% ROI, the goal of this analysis was to increase energy efficiency
- The energy savings are negligible and will not affect LEED® score
- Owner has two options
Rooftop Array
• (310) 250W Astronenergy NOVA Solar Panels
• 77,500 Wdc generation capacity
• SatCon Powergate Plus 100 kW Inverter
• 33.5° panel tilt; 6’ - 1.5” row spacing

Envision® Solar Tree Parking Canopy
• (8) 14.4 kW Solar Tree Structures in parking lot
• 115,200 Wdc generation capacity
• SatCon Powergate Plus 130 kW Inverter
**PVWatts® Results**

<table>
<thead>
<tr>
<th>Month</th>
<th>Roof</th>
<th>Parking 1</th>
<th>Parking 2</th>
<th>Parking 3</th>
<th>Parking 4</th>
<th>Total</th>
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<tr>
<td>1</td>
<td>5727</td>
<td>1737</td>
<td>1731</td>
<td>1696</td>
<td>1662</td>
<td>12,553</td>
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<td>2</td>
<td>6273</td>
<td>2068</td>
<td>2063</td>
<td>2032</td>
<td>2016</td>
<td>14,432</td>
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<tr>
<td>3</td>
<td>8554</td>
<td>2993</td>
<td>2989</td>
<td>2985</td>
<td>2959</td>
<td>20,431</td>
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<td>4</td>
<td>9230</td>
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<td>3412</td>
<td>3400</td>
<td>3391</td>
<td>22,846</td>
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<td>5</td>
<td>9230</td>
<td>3653</td>
<td>3654</td>
<td>3588</td>
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<td>9340</td>
<td>3740</td>
<td>3725</td>
<td>3725</td>
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<td>8856</td>
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<td>3324</td>
<td>3317</td>
<td>22,172</td>
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<td>9</td>
<td>7924</td>
<td>2828</td>
<td>2826</td>
<td>2807</td>
<td>2797</td>
<td>19,182</td>
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<td>10</td>
<td>7358</td>
<td>2414</td>
<td>2403</td>
<td>2389</td>
<td>2368</td>
<td>16,979</td>
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<td>11</td>
<td>4781</td>
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<td>1310</td>
<td>1405</td>
<td>1384</td>
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<td>12</td>
<td>4629</td>
<td>1451</td>
<td>1446</td>
<td>1433</td>
<td>1415</td>
<td>10,315</td>
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</table>

**Annual Electricity Generation (kWh)**: 220,894

**Annual Cost Savings at $0.09/kWh**: $21,206
Lifecycle Cost Analysis

**Annual Cost Savings**

$21,206 per year

**ITC Tax Incentive (30%)**

$367,845 after first year

**SREC ($180/MWh)**

$39,840/year for 10 years

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**Up-Front Cost Estimate**

- 310 panels × 250 \( \text{WdC/panel} \) = 77,500 Wdc
  - 77,500 Wdc × $3.68/Wdc installed = $323,950

- 100 kW SatCon Powergate Plus Inverter = $45,900

- 8 Solar Canopies × 14,400 \( \text{WdC/structure} \) × $7/Wdc Installed = $806,400

- 135 kW SatCon Powergate Plus Inverter = $49,900

**Total Photovoltaic System Cost** = $1,226,150

**Pay Back Period**

23 years

**Return on Investment**

$70,246 (5.7%)
Revised Design

- Rooftop array with one Solar Canopy
- Generates 15.7% - 7 LEED® credits
- Reduces payback period to 15 years
- $105,000 ROI (21%)

Conclusions

- The proposed system is easily eligible for 7 LEED® credits for providing over 13% of Gambet Center's electricity
- The long payback period and low ROI make the option undesirable to the owner
- Premium price of Envision® Solar Tree offsets the future savings
Quantum® Upgrade

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Quantum® Upgrade
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System Capacity Summary

<table>
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<tr>
<th></th>
<th>Used</th>
<th>Avail</th>
<th>Req'd</th>
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<tbody>
<tr>
<td>EcoSystem®</td>
<td>18</td>
<td>110</td>
<td>198</td>
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<tr>
<td>Loop 1</td>
<td>18</td>
<td>46</td>
<td>-</td>
</tr>
<tr>
<td>Loop 2</td>
<td>0</td>
<td>64</td>
<td>-</td>
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<tr>
<td>QS Devices</td>
<td>261</td>
<td>36</td>
<td>110</td>
</tr>
<tr>
<td>Link 1-A</td>
<td>94</td>
<td>5</td>
<td>-</td>
</tr>
<tr>
<td>Link 1-B</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Link 2-A</td>
<td>75</td>
<td>24</td>
<td>-</td>
</tr>
<tr>
<td>Link 2-B</td>
<td>92</td>
<td>7</td>
<td>-</td>
</tr>
</tbody>
</table>

99 QS Devices per Link
64 Eco Devices per Loop

QS Links
- Wall Keypads
- Sensor Modules
- EcoSystem® Loops
- Fixture/AV Interfaces

EcoSystem® Loop

Upgrade Summary
- 80 Keypads, 76 Occupancy Sensors and 65 Daylight Sensors for perimeter faculty offices
- 198 EcoSystem® Compatible Fixtures
- Insufficient system capacity
- Upgrading to more advanced Hubs significantly increases cost

Wireless Option
- Maximizes system limitation
- 29 Existing sensor modules provide enough RF range for wireless inputs
- Wireless devices are less expensive
- 2 additional EcoSystem® loops added to QS Link
Energy Savings

**Lighting Load Summary**

<table>
<thead>
<tr>
<th></th>
<th>kWh</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baseline Lighting Load</td>
<td>216,500</td>
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<tr>
<td>Current Energy Savings</td>
<td>27,212</td>
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<tr>
<td>Current Lighting Load</td>
<td>189,287</td>
</tr>
<tr>
<td>Upgraded Energy Savings</td>
<td>14,878</td>
</tr>
<tr>
<td>Upgraded Lighting Load</td>
<td>174,409</td>
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</table>

**Increase in Energy Efficiency**

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
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</thead>
<tbody>
<tr>
<td>Current Design over Baseline</td>
<td>13%</td>
</tr>
<tr>
<td>Upgraded Fixtures over Baseline</td>
<td>34%</td>
</tr>
<tr>
<td>Upgraded Design over Current Load</td>
<td>8%</td>
</tr>
<tr>
<td>Total Savings over Baseline</td>
<td>19%</td>
</tr>
</tbody>
</table>

**Annual Cost Savings**

$1,330 per year

**Improves Bldg. Efficiency**

1% (No LEED® points)

**Luminaire Takeoff**

- Complete quantity takeoff of luminaires
- Assumes 10 hours per day
- Considers Lutron's approximations for energy savings
- Calculated lighting loads for no control system, the original Quantum® system, and the proposed wireless upgrade

**Energy Savings per Control Strategy**

- Personal Dimming: 10%
- Occupancy Sensing: 15%
- Daylight Harvesting: 15%
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Payback Period
5 years

Return on Investment
$13,471 (203%)

Lifecyle Cost Analysis

Payback Period
5 years

Return on Investment
$13,471 (203%)

Annual Cost Savings
$1,330

System Lifetime
15 years

Additional Cost of Upgrade
• Exact price information not revealed, as requested by Lutron®
• Considers additional equipment, one day of field start up, and deducts the cost of the original equipment

Payback Period
5 years

Return on Investment
$13,471 (203%)

Annual Cost Savings
$1,330

System Lifetime
15 years
Recommendation

Although no change to LEED® score, upgraded system should be added to the project

Conclusions
• 6% more efficient than current design
• Upgrade does not affect LEED® score
• Very favorable payback period and ROI
Conclusion
**Analysis Summary**

**Goal:** Achieve LEED® Gold rating

### Recommendations

<table>
<thead>
<tr>
<th></th>
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<th>NO</th>
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</thead>
<tbody>
<tr>
<td>Green Roof Implementation</td>
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<tr>
<td>Photovoltaic System</td>
<td>7</td>
<td></td>
</tr>
<tr>
<td>Upgraded Light Controls</td>
<td>0</td>
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</table>

**Goal Achieved**: Yes

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**Goal:** Acceptable payback period and return on investment

### Recommendations

<table>
<thead>
<tr>
<th></th>
<th>YES</th>
<th>NO</th>
</tr>
</thead>
<tbody>
<tr>
<td>Green Roof Implementation</td>
<td></td>
<td></td>
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<tr>
<td>Photovoltaic System</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Upgraded Light Controls</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Goal Achieved**: Yes
Goal: Achieve LEED® Gold rating

Certified Wood – 1 credit
- 50% of wood certified by Forest Stewardship Council

Innovative Wastewater Technology – 2 credits
- Substitute 50% of waste water with rainwater harvesting system
- 10,000 gallon system costs $140,000-$200,000

Optimize Energy Performance – +3 credits
- Heat pump HVAC system considered in Tech I
- Improves building efficiency by 6 percent
- $584,000 cost increase over VAV system

Recommendations

<table>
<thead>
<tr>
<th>Recommendation</th>
<th>Point Gain</th>
<th>YES</th>
<th>NO</th>
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<tbody>
<tr>
<td>Green Roof Implementation</td>
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<tr>
<td>Photovoltaic System</td>
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<td>Upgraded Light Controls</td>
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Goal Achieved
Thank You

Acknowledgements
Advisor: Ray Sowers
Moses Ling
AE Faculty

DeSales University
Breslin Ridyard Fadero Architects
Alvin H. Butz, Inc.
Lutron Electronics Co., Inc.
MGV GroRoof

Family and Friends