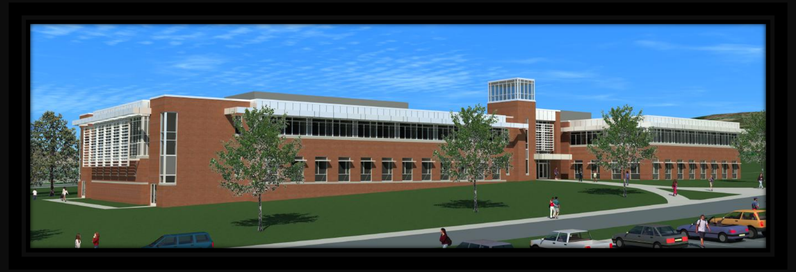
Rev. James G. Gambet Center

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

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

DeSales University

ALVIN H. BUTZ, INC.
CONSTRUCTION MANAGER

BRESLIN RIDYARD FADERO ARCHITECTS

LEED® 2009 Scorecard

LEED® Category	Credits Earned	Possible Credits
Sustainable Sites	7	26
Water Efficiency	8	10
Energy and Atmosphere	11	35
Materials and Resources	6	14
Indoor Environmental Quality	10	15
Innovation and Design Process	6	6
Regional Priority Credits	2	4
Total (LEED® Silver)	**50**	**110**

LEED® Evaluation

- 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

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 Analyses

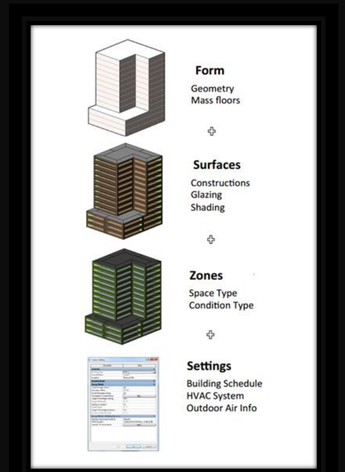
I. Conceptual Energy Modeling
Understand early design implications

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

Technical Analysis I
Conceptual Energy Modeling



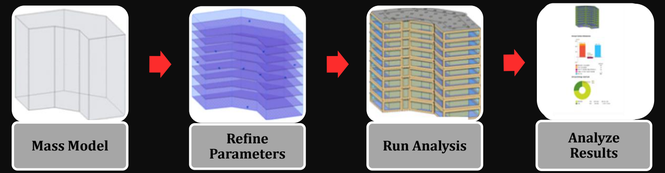
Anatomy of an Energy Model

Project Vasari

- **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**

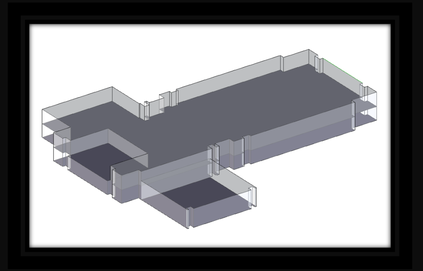
Steps for Energy Model Analysis

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



Images Courtesy of Autodesk

Energy Analysis



Mass Energy Model of Gambet Center

Original Design Parameters	
Location and Orientation	(40.5°N, 75.4°W), S19°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

Compare effect on annual energy consumption when using a **Geothermal Heat Pump**

Information Provided from Energy Analysis:

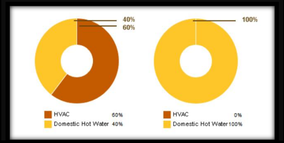
- Annual Carbon Emissions
- Annual Energy Use/Cost
- Fuel and Electricity Consumption
- Lifecycle Energy Use
- Monthly HVAC Loads
- Weather Design Data
- Renewable Energy Potential

Implications:

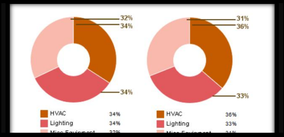
- 60% reduction in natural gas consumption
- Estimated annual fuel savings of $16,257
- 3.4% increase in whole building power consumption
- Total annual savings estimated to be $13,434
- Optimizes energy efficiency of the building by 6%

Vasari Results

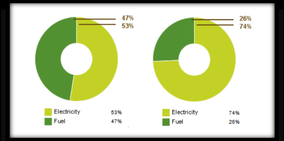
Fuel Usage



Electricity Usage



Total Energy Usage



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.

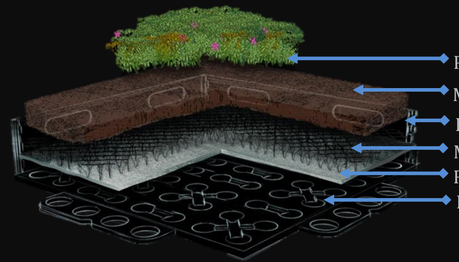
Technical Analysis II

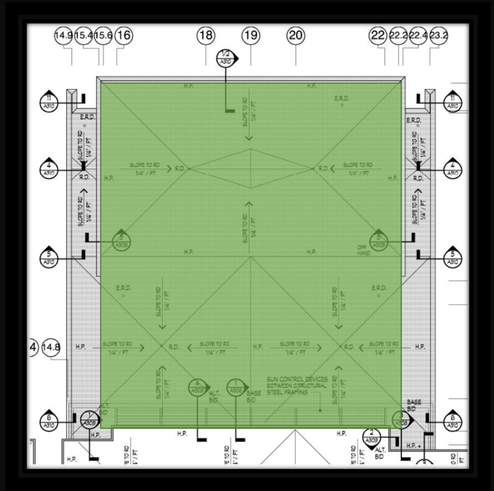
Green Roof Implementation

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





5,855 SF Extensive Green Roof Above Lecture Hall

Structural Breadth

Applicable Equations

Live Load Reduction

$$L_r = L_o[.25 + \frac{15}{\sqrt{K_{LL}A_t}}]$$

Factored Distributed Load

$$W=(1.2)(D)+(1.6)(L_r)+(0.5)(S)$$

$$w_u=(W)(\text{Tributary Width})$$

Factored Shear Force

$$V_u = \frac{(w_u)(l)}{2}$$

Factored Bending Moment

$$M_{max} = \frac{(w_u)(l^2)}{8}$$ | pin-pin

$$M_{max} = \frac{(w_u)(l^2)}{12}$$ | fixed-fixed

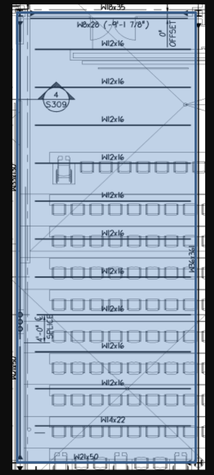
Steel Members

Girders:

(1) - 63’-9” W33x130
(1) - 63’-9” W36x361

Beams: spaced 5’-4” on center

(10) 23’-10” W12x16
(1) 23’-10” W14x22
(1) 23’-10” W18x35
(1) 23’-10” W21x50



Typical Bay

Dead, Live, and Snow Loads

Item	Built-Up Roof	GroRoof™
Steel Beam Self Weight	5 psf	5 psf
Metal Deck	2 psf	2 psf
5” Rigid Insulation	2 psf	2 psf
M,E,F,P	15 psf	15 psf
Ceiling	2 psf	2 psf
4 ½” GroRoof™	-	32 psf
Total Dead Load	**26 psf**	**58 psf**
Total Roof Live Load	**20 psf**	**20 psf**
Total Snow Load	**30 psf**	**30 psf**

Structural Breadth

Applicable Equations

Live Load Reduction

$$L_r = L_o[.25 + \frac{15}{\sqrt{K_{LL}A_t}}]$$

Factored Distributed Load

$$W=(1.2)(D)+(1.6)(L_r)+(0.5)(S)$$

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Steel Members

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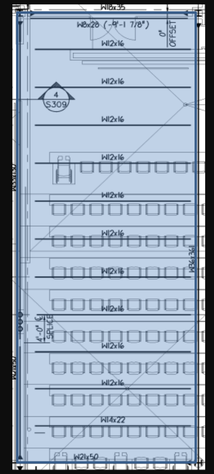


Typical Bay

Beam and Girder Analysis

	Shear	Max. Shear	Moment	Max. Moment	Pass/Fail
Beams					
W12x16	7.44 k	79.2 k	44.3 k-ft	75.4 k-ft	Pass
W14x22	7.44 k	94.9 k	44.3 k-ft	125 k-ft	Pass
W18x35	7.44 k	159 k	29.45 k-ft	249 k-ft	Pass
W21x50	7.44 k	237 k	29.45 k-ft	413 k-ft	Pass
Girders					
W33x130	31.66 k	576 k	378.37 k-ft	1750 k-ft	Pass
W36x361	63.32 k	1280 k	756.74 k-ft	5810 k-ft	Pass

Applicable Equations

CLTD Method – ASHRAE Ch. 28

$$q = (U)(A)(\sum CLTD)$$

Corrected CLTD

$$CLTD_{corr} = CLTD + (78\text{-}t_r) + (t_m\text{-}85)$$

t_r = inside temperature (65˚F)

t_m = mean outdoor temperature (73˚F)

Energy Efficiency Ratio (EER)

$$EER = \frac{Cooling\ Load(BTU)}{Input\ Watts\ (W)}$$

Mechanical Breadth

Roofing System Component	R-Value
1 ½” Metal Roof Decking	-
5” Rigid Insulation	20
½” Insulation Cover Board	.85
Single-Ply Asphalt Waterproofing Membrane	.15
GroRoof™ Extensive II Module	3
Total R-Value (∑R)	**24**
U-Value (1/∑R)	**.0417**

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

$$\frac{Reduced\ Load}{EER} = \frac{17{,}885{,}808\ BTU}{10.9} = 1{,}640\ kWh$$

1,640 kWh × $0.09/kWh = **$147.68**

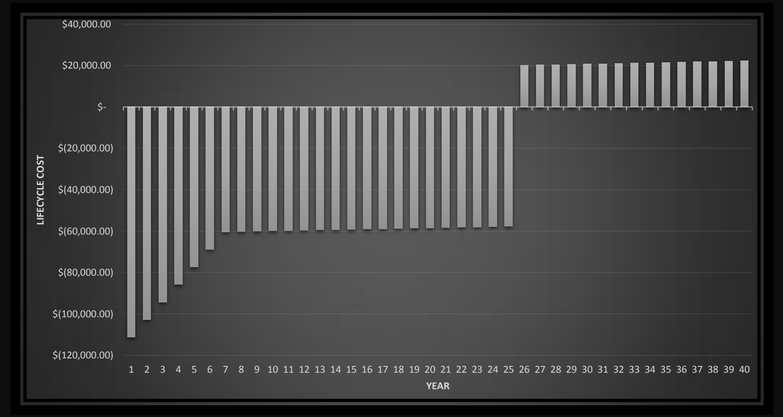
Mechanical Breadth Wrap-Up

- 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

Final 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

Technical Analysis III
On-Site Renewable Energy

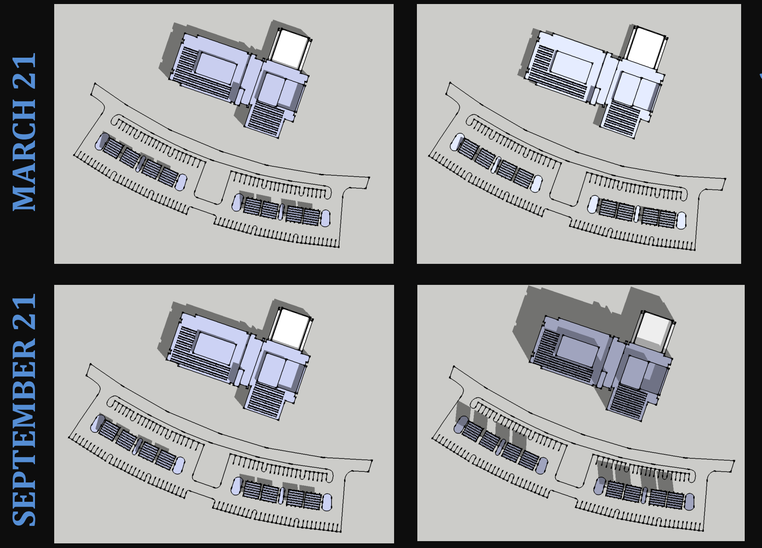
Proposed Design

Rooftop Array

- (310) 250W Astronenergy NOVA Solar Panels
- 77,500 Wdc generation capacity
- SatCon Powergate Plus 100 kW Inverter
- 33.5º 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



Solar Shading Study (12 pm)

Generation Capacity

Annual Power Generation
220,894 kWh
Building Annual Power Use
781,313 kWh
Renewable Percentage
28%
Annual Cost Savings
$21,206

PVWatts™ Input Parameters

City	Allentown
State	Pennsylvania
Latitude	40.65° N
Longitude	75.43° W
Elevation	117 m

PV System Specifications	Roof	Parking 1	Parking 2	Parking 3	Parking 4
DC Rating (kW)	77.5	28.8	28.8	28.8	28.8
DC to AC Derate Factor	0.77	0.77	0.77	0.77	0.77
AC Rating (kW)	59.7	22.2	22.2	22.2	22.2
Array Type	Fixed Tilt	Fixed Tilt	Fixed Tilt	Fixed Tilt	Fixed Tilt
Array Tilt	33.5°	15°	15°	15°	15°
Array Azimuth	199°	189°	192°	205°	209°

PVWatts™ Results

	Monthly AC Energy Generated (kWh)					
Month	Roof	Parking 1	Parking 2	Parking 3	Parking 4	Total
1	5737	1737	1731	1686	1662	12,553
2	6273	2068	2063	2032	2016	14,452
3	8554	2993	2989	2956	2939	20,431
4	9230	3413	3412	3400	3391	22,846
5	9230	3605	3604	3588	3581	23,608
6	8816	3540	3538	3524	3517	22,935
7	9540	3743	3740	3725	3720	24,468
8	8856	3338	3337	3324	3317	22,172
9	7924	2828	2826	2807	2797	19,182
10	7358	2434	2430	2389	2368	16,979
11	4781	1514	1510	1481	1467	10,753
12	4829	1451	1446	1405	1384	10,515
					Annual Electricity Generation (kWh)	220,894
					Annual Cost Savings at $0.09/kWh	$ 21,205.82

Lifecycle Cost Analysis

Annual Cost Savings

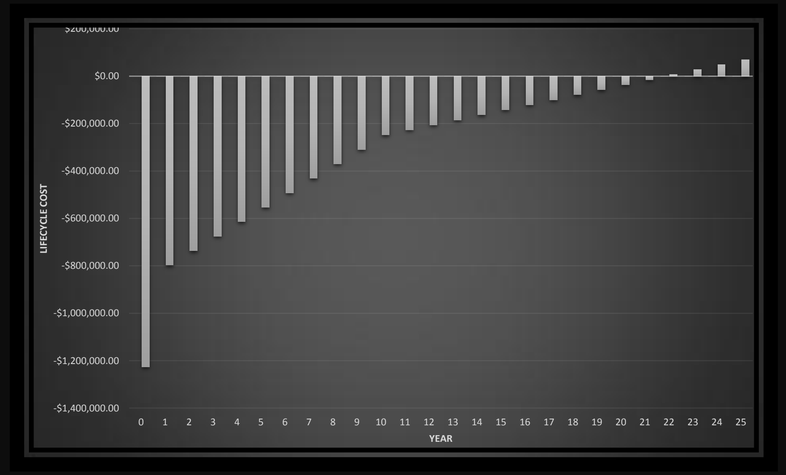
$21,206 per year

ITC Tax Incentive (30%)

$367,845 after first year

SREC ($180/MWh)

$39,840/year for 10 years



Up-Front Cost Estimate

310 panels × 250 $\frac{Wdc}{panel}$ = 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 $\frac{Wdc}{Structure}$ × $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%)

Recommendation

Final Recommendation

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

Technical Analysis IV
Advanced Lighting Control

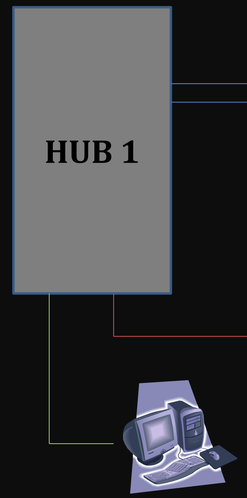
LUTRON®

System Capacity Summary

	Used	Avail.	Req'd
EcoSystem®	18	110	198
Loop 1	18	46	-
Loop 2	0	64	-
QS Devices	261	36	110
Link 1-A	94	5	-
Link 1-B	Panel Link		
Link 2-A	75	24	-
Link 2-B	92	7	-

99 QS Devices per Link
64 Eco Devices per Loop

Quantum® Upgrade



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

Annual Cost Savings
$1,330 per year
Improves Bldg. Efficiency
1% (No LEED® points)

Energy Savings

Lighting Load Summary	
Baseline Lighting Load	216,500 kWh
Current Energy Savings	27,212 kWh
Current Lighting Load	189,287 kWh
Upgraded Energy Savings	**14,878 kWh**
Upgraded Lighting Load	**174,409 kWh**
Increase in Energy Efficiency	
Current Design over Baseline	13%
Upgraded Fixtures over Baseline	34%
Upgraded Design over Current Load	**8%**
Total Savings over Baseline	**19%**

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%

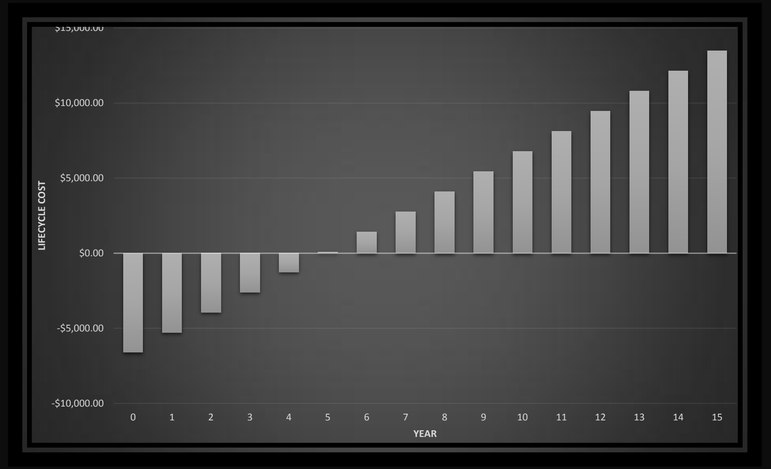
Payback Period

5 years

Return on Investment

$13,471 (203%)

Lifecycle Cost Analysis



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

Annual Cost Savings

$1,330

System Lifetime

15 years

Recommendation

Final 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

	Point Gain	YES	NO
Green Roof Implementation	0		×
Photovoltaic System	7	✓	
Upgraded Light Controls	0		×
Goal Achieved			×

Goal: Acceptable payback period and return on investment

	YES	NO
Green Roof Implementation	✓	×
Photovoltaic System	✓	
Upgraded Light Controls	✓	
Goal Achieved	✓	

Other Considerations

Goal: Achieve LEED® Gold rating

Recommendations

	Point Gain	YES	NO
Green Roof Implementation	0		×
Photovoltaic System	7	✓	
Upgraded Light Controls	0		×
Goal Achieved			×

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

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

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