Inflow-Outflow Net Equivalents for Recovery Point Analysis of Improvement Model

Aspen Thomas
Department of Engineering and Physics
Southern Arkansas University
Arkansas, USA
althomas1423@muleriders.saumag.edu

Hayder Zghair
Department of Engineering and Physics
Southern Arkansas University
Arkansas, USA
hzghair@saumag.edu

Abstract

One of the major expenses to operate facilities is the cost of energy. An education enterprise such as school facility requires every year major budget consideration for the consumed electricity; especially, facilities need to be powered day long. This project tries to an analysis of adding basic improvement technology for dorms in a typical public-school by using investment recovery approach. Equivalents flow model has been developed to the consumed electricity system for five years term, and used to test the improvements. Analyzing the result showed the payback period is 6.275 years while the lifespan of windows tint on average lasts 10 years, therefore investing in this technology instillation is strongly supported decision to decrease the amount of electricity consumed which provides more saving in the budget as a result of annual evaluation.

Keywords
Payback, Present Value, Interest value.

1. Introduction

One of major expense for schools is the cost of electricity, so the school wanted to investigate ways to reduce electricity costs. If problem the dorm equipment is losing efficiency over longtime and annual budget tiles to different priorities, then engineering solution need to step up showing feasible alternatives to control energy consumption. The most feasible and applicable alternative planned to explore in this analysis research work offering a valid option to measure school economic improvements. Improvements need show difference in bill cost saving, and not to raise the budget. Therefore, the purpose has been set for this research work is to explore savings in the form of energy-efficient facility; specifically, school's dorms. The goal is to analyze different approaches to make the dorms more energy efficient and in a cost-effective manner. Building gating was the first to examine in terms of functionality of open and close in addition to venerate the air and sun light the rooms. One of the focus found significantly influencing the hosing performance is the dorm window system, the size compared to the weather outside and room inside in addition to the mounting setup of sealing around were obviously improvement opportunities. Window tinting is the technology this work proposed to process in terms of adding fill to the windows of buildings. The purpose is to reduce the amount of heat and radiation that enters the building. This then reduces the amount of cooling that must be completed to keep the building at temperature in the hot weather of southern area. Searching for the breakeven point, create a cash flow model, and provide a conclusion about whether this would be best feasible and applicable alternative. In section 2 of this paper, a review for a collection of related works have been covered, section 3 is to approach and objective analysis, data collection section is in section 4, discussion the results included in section 5, and then a set of conclusions has been drawn in section 6.

2. Works Review

Kumar and McCaffrey (2003) analyzed how much time is spent in each phase of hard disk Manufacturing, and every step of the manufacturing process and noted how long it took for those stages. Robust models have been developed. These models show the difference in price when delayed. It found that money can be saved by not being late at any point in these processes. Chen et al. (2020) analyzed oil shale waste vs its other competitors, multiple test were ran on all materials to Find the optimal range of oil shale waste residue and the analysis of oil shale waste. It found that oil shale waste was best used as a replacement in asphalt mixtures AC-16, SMA-13, OGFC-16 at the ranges 2.36mm - 0.075 mm, and Oil Shale waste is a better replacement for asphalt. Shaobin Li et al. (2021) analyzed how the water flows on farms to create program to integrate technology environment economics in a model for the watersheds. Integrated technology-environment-economics model (ITEEM) system that was created allowed for more testing that could be used for system analysis. The ITEEM enables testing hypothesis for food-energy-water (FEW) systems analysis. Conclusion shows that it is normal that annual budget has more significant priorities than in vesting in equipment efficiency instead decision makers are more with accumulated improvements that reach to the limit.

3. Analysis Approach

The applied procedure to explore alternative solution for the dorm facilities is based five main phases with a subs for each as follows: (1) Evaluate the current operational efficiency in terms of how much the facility totally consumed energy per the number of equipment and buildings and, how much the total cost; (2) Find similarities in terms of size of facilities, energy consumed, cost estimation, and improvement plans; (3) Generate solutions by varying the model equivalences depending on which of cases is applicable; (4) Analyzing the results to select the first run best solution by analyzing each solution in terms of how much investing, how much returning, and how long will take; (5) searching to find the best feasible and applicable alternative. Figure 1 illustrates the approach logic flow to explore the most feasible and applicable alternative.

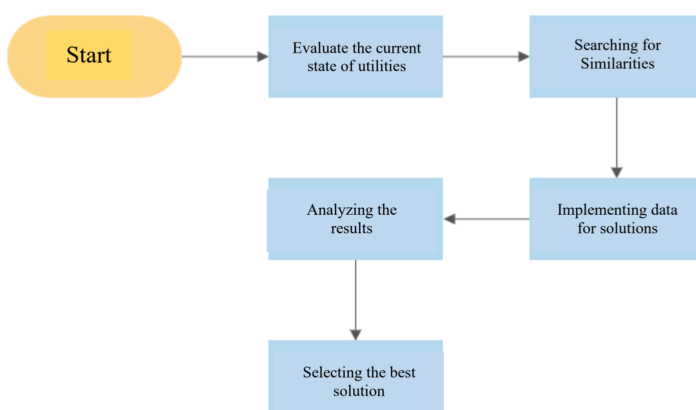

Figure 1: Shows the approach phases and methodology

Each phase has been broken down into a subsets of internal flow circles of collecting data for the cash model as flows: for the first phase; (1.1) Number of equipment, (1.2) Number of buildings, (1.3) Type of equipment, (1.4) How much they consumed under each category, and (1.5) How much cost. The second

phase; (2.1) Rank the school using the criteria (size, energy, cost, and improving results) and (2.2) Compare the dorm facilities to the most similar in base of average measurements. Third was in implementing the data, the fourth to compare with the current data model, the fifth is to find the feasible applicable one in terms of the more saving and less investing.
The approach applied to implement data in the third, and analyze the results in the fourth, and selecting the best solution in the fifth is to develop cash-flow model for the last five years showing the cost of operation. The model has been validated to be used as a baseline for the analysis and shows the impact results of investing in installing window tinting to increase the equipment efficiency.

4. Data Collection

The approach of developing cash-flow model for the last five years of cost of operation is requiring to look into utilization records. The model has been validated to be used as a baseline for the analysis and shows the results of investing the impact of installing efficient equipment. All data was collected from the energy reports provided by the school departments and expert references. Windows size and other information have been evaluated manually by using the metric tools. Figure 2 shows the buildings map located southern east of the campus.

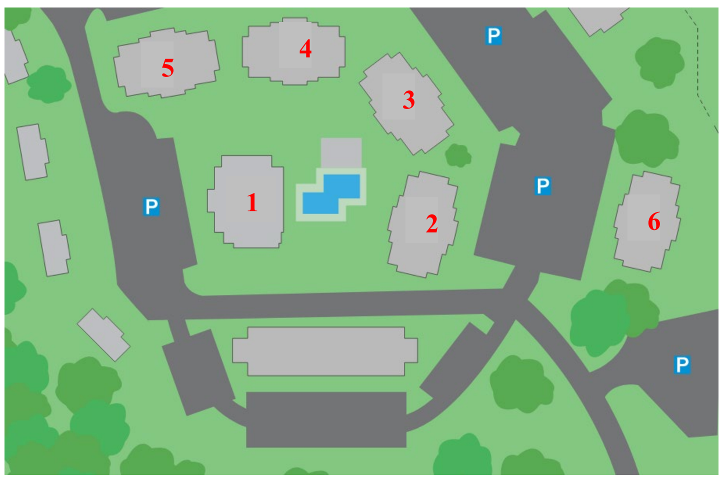

Figure 2: Shows the facilities location on the map

Data collected for the window tinting is as follows: Each window size has been evaluated based on Average Window Size (AWS), and it was 15 ft^2, total window area is11625 ft^2 needed to be covered to save 10% on electricity bill lasts on average 10 years, Formula 1 used to evaluate the Total Window Area (TWA). Total Installation Cost (TIC) is \$69,750 to install tint on all the windows, Formula 2 used to evaluation. Assumptions are as follows: \$6 / ft^2 tint Installation Cost Rate (ICR), \$0.11/kW×hr. electricity costs, tint will last the full 10 years. Simply substituting variables results in: 755 (windows) ×15 ft^2 = 11625 ft^2 × \$6 /ft^2 = \$69,750 for installing tint in six building demonstrated in Table 1.

$TWA \ = \ AWS \ \times \ Number \ of \ Windows \ (NoW) \ldots$ (1)
$TIC \ = \ TWA \ \times \ ICR \ldots$ (2)

Table 1. Campus buildings for the improvement and implementing the tinting

#	Building	Number of Windows
1	Village Apartments	408
2	AR Hall	93
3	Eichenberger Hal	30
4	Burns-Harsh Hall	56
5	Magnolia Hall	94
6	Columbia Hall	94
	Total	775

In addition to the manual data collected, a search has been conducted on the historic records to the last five years of cost of operation is requiring to look into utilization records. Table 2 shows the electricity cost for the six facilities last five years starting 2017 through 2021 in dollars. Table 3 shows the adjusted values of costs as targeted by 10% reduction.

Table 2. Annual cost spent on electricity for five years

Year	Amount of Dollars Spent
2017	$62,176.19
2018	$107,874.47
2019	$121,642.40
2020	$122,732.17
2021	$130,111.19
Total	$544,536.42

Table 3. Annual reduced costs of electricity for five years

Year	Amount of Dollars Spent
2017	$6,217.62
2018	$10,787.45
2019	$12,164.24
2020	$12,273.22
2021	$13,011.12
Total	$54,453.65

5. Results and Discussion

Equations 3 represents the present cost, equation 4 represents the flow factor of the model, and equation 5 represents the factor based on standard table annuities, all have been fundamentally applied to develop the clash-flow model. Figure 3 shows a sample of the algorithmic calculations for interest rate, future worth, and payback periods. Calculating Interest Rate for Tinting Solution. Results shown in table 4, table 5, and table 6 illustrate the outcomes of running search trails for the most feasible applicable alternative of the saving. Table 4 shows the in and out flows net for the fives yeas of analysis resulted in targeted saving subtracting the expenses. These resulted data based on the calculations in table 2 and table 3. It shows there an annual consistent increasing of approximately $12,397.14 for the five years. This is visually represented in Figure 3 and Figure 4 that showing the cash-flow diagram for the tinting model and cash-flow diagram for the current state of facilities respectively.

$$P = A\left[\frac{(1+i)^N-1}{i(1+i)^N}\right] \ldots (3)$$

$$\left({}^{P}/_{A}, i, N\right) = \left[\frac{(1+i)^N-1}{i(1+i)^N}\right] \ldots (4)$$

$$P = A\left({}^{P}/_{A}, i, N\right) \ldots (5)$$

```
2017: 69750=55958.57((P/A, i, N)    (P/A, i, N)=1.2464579= ((1+i)^1-1)/(i(1+i)^1)  i=-0.1977266%
2018: 69750+55958.57=97087.02 (P/A, i, N)   (P/A, i, N)=1.2948= ((1+i)^2-1)/(i(1+i)^2)  i=0.3460743%
2019: 69750+55958.57+97087.02=109478.16(P/A, i, N)
(P/A, i, N)=2.03507= ((1+i)^3-1)/(i(1+i)^3)  i= 0.2223%
2020: 69750+55958.57+97087.02+109478.16=110458.95 (P/A, i, N)   (P/A, i, N)=3.0081198
3.0081198= ((1+i)^4-1)/(i(1+i)^4)  i= 0.12460577%
2021: 69750+55958.57+97087.02+109478.16+110458.95=117100.07 (P/A, i, N)
(P/A, i, N)=3.7808= ((1+i)^5-1)/(i(1+i)^5)   i= 0.10103276%
Calculating Interest Rate for Current Scenario
2017: 0=62176.19(P/A, i, N)   (P/A, i, N)=0=((1+i)^1-1)/(i(1+i)^1)  i=Undefined
2018: 62176.19=107874.47(P/A, i, N)  (P/A, i, N)=.5763754= ((1+i)^2-1)/(i(1+i)^2)  i=1.444677%
2019: 62176.19+107874.47=121642.40(P/A, i, N)  (P/A, i, N)=1.397955483=((1+i)^3-1)/(i(1+i)^3)  i=0.505835%
2020: 62176.19+107874.47+121642.40=122732.17(P/A, i, N)  (P/A, i, N)=2.3766634
2.3766634 =((1+i)^4-1)/(i(1+i)^4)  i=0.2464356979%
2021: 62176.19+107874.47+121642.40+122732.17=130111.19(P/A, i, N)  (P/A, i, N)=3.185162
3.185162= ((1+i)^5-1)/(i(1+i)^5)  i=0.171935795%
Calculating Future Worth for Tinting Solution
F=P(F/P, i, N)
2017: F1=P(F/P, i, N)-A1   69750(.8022734)-55958.57=0
2018: F2=F1(F/P, i, N)-A2  0(1.8119)-97087.02=-97087.02
2019: F3=F2(F/P, i, N)-A3  -97087.02(1.826137)-109478.16=-286772.39
2020: F4=F3(F/P, i, N)-A4  -286772.39(1.5995626)-110458.95=-569169.33
2021: F5=F4 (F/P, i, N)-A5  -569169.33(1.6189845)-117100.07=-1038064.16
Calculating Future Worth for Current Scenario
2017: F1=P(F/P, i, N)-A1   0-62176.19=-62176.19
2018: F2=F1(F/P, i, N)-A2  -62176.19(5.976446)-107874.47=-479467.09
2019: F3=F2(F/P, i, N)-A3  -479467.09(3.41454)-121642.40=-1758801.79
2020: F4=F3(F/P, i, N)-A4  -1758801.79(2.413679009)-122732.17=-4367915.14
2021: F5=F4 (F/P, i, N)-A5  -4367915.14(2.21064546)-130111.19=-9786022.96.
Payback Period
69750-6217.62-10787.45-12164.24-12273.22-13011.12=15296.35/12000=1.275+5=6.275 years.
```

Figure 3: Illustration to show the calculation procedure of the cash-flow savings

Table 4. Annual worth for tinting solution.

Years	Annual Worth (Savings - Expenses)
2017	-\$55,958.57
2018	-\$97,087.02
2019	-\$109,478.16
2020	-\$110,458.95
2021	-\$117,100.07

Results analysis for the tinting model interest rates illustrated in table 5 compared to the interest rates in table 4 of the current state facilities showed validity of the targeted reduction of 10%. The net annuities of the tinting cash-flow diagram in figure 3 show similar changing behavior of the in cash-flow diagram of the current state model reflected from the calculated interest rates for both models. This obviously validates the developed cash-flow model used for the analysis and the results.

Table 5. Interest rate per year for tinting solution.

Year	Interest
2017	-0.1977266%
2018	0.3460743%
2019	0.2223%
2020	0.12460577%
2021	0.10103276%

Table 6. Interest rate per year for current state of the model.

Year	Interest
2017	Undefined
2018	1.444677%
2019	0.505835%
2020	0.2464356979%
2021	0.171935795%

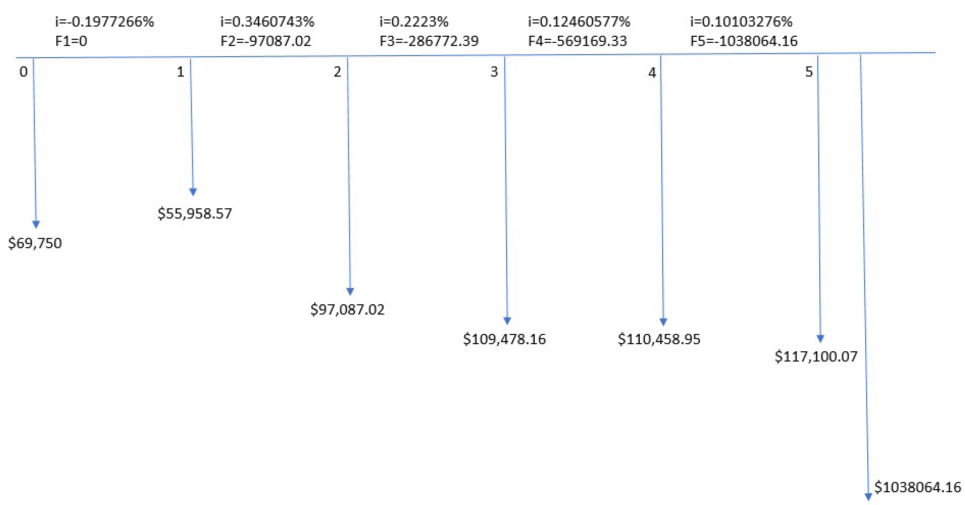

Figure 3. Cash-flow model for tinting solution

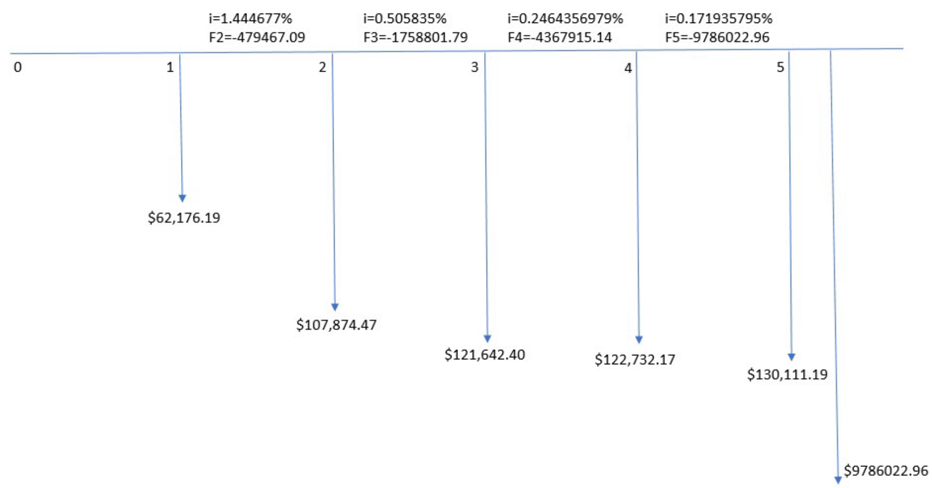

Figure 4. Cash-flow model for current state of the facilities

6. Conclusion

Cash-flow modeling is a powerful toll to plan economic alternative over long term budgeting. Since on average the tinting technology lasts 10 years and the 6.275 years to pay for itself, this is a worthwhile investment for the dorm facilities to make. The remarkable about this solution is that it can be implemented on any building around campus.

References

Kumar, S., & McCaffrey, T. R. (2003). Engineering economics at a hard disk drive manufacturer. Technovation, 23(9), 749–755. https://doi.org/10.1016/s0166-4972(02)00040-8

Chen, W., Li, Y., Chen, S., & Zheng, C. (2020). Properties and economics evaluation of utilization of oil shale waste as an alternative environmentally-friendly building materials in Pavement Engineering. Construction and Building Materials, 259, 119698. https://doi.org/10.1016/j.conbuildmat.2020.119698

Li, S., Cai, X., Emaminejad, S. A., Juneja, A., Niroula, S., Oh, S., Wallington, K., Cusick, R. D., Gramig, B. M., John, S., McIsaac, G. F., & Singh, V. (2021). Developing an integrated technology-environment-economics model to simulate food-energy-water systems in Corn Belt watersheds. Environmental Modelling & Software, 143, 105083. https://doi.org/10.1016/j.envsoft.2021.105083

Sullivan, W. G., Wicks, E. M., & Koelling, C. P. (2020). Engineering economy. Pearson.

2022 home window tinting cost guide (benefits, options, & more...). HomeGuide. (n.d.). Retrieved May 3, 2022, from https://homeguide.com/costs/home-window-tinting-cost

Business energy advisor. (n.d.). Retrieved May 3, 2022, from https://esource.bizenergyadvisor.com/article/colleges-and-universities

College Programs to Reduce Energy Consumption in Dorms. Electric Choice. (n.d.). Retrieved May 3, 2022, from https://www.electricchoice.com/blog/college-programs-to-reduce-energy-consumption-in-dorms/

Deanne, E. (2021, August 10). This EE Day: Green your college dorm room. Energy Efficiency Day. Retrieved May 3, 2022, from https://energyefficiencyday.org/this-ee-day-green-your-college-dorm-room/

E Source Companies. (2010). Managing Energy Costs in Colleges and Universities Managing Energy Costs in Colleges and Universities. Retrieved May 4, 2022, from https://dsoelectric.com/sites/dsoelectric/files/My%20Business/schools.pdf

Mullen, R., Tran, K., Benson, A., & Broesamle, B. (2009). Green Living Project Energy. Retrieved May 4, 2022, from https://www.ioes.ucla.edu/wp-content/uploads/ART-2009-Green_Living_Project-Energy.pdf

National Grid. (2003). Managing energy costs in E colleges and universities ... - national grid. Retrieved May 4, 2022, from https://www9.nationalgridus.com/non_html/shared_energyeff_college.pdf

Powers, E. (2008, January 25). Energy in the dorms. Inside Higher Ed. Retrieved May 3, 2022, from https://www.insidehighered.com/news/2008/01/25/energy-dorms

Solar Care Window Tinting. (2019, October 17). How much energy savings can be made with window tinting? How Much Energy Savings Can Be Made with Window Tinting? -. Retrieved May 3, 2022, from https://solarcareinc.com/how-much-energy-savings-can-be-made-with-window-tinting/

Acknowledgements

The authors present a big acknowledgment to SAU Honor College, SAU Foundation, and the physical plant for the support this project has been provided.

Biography

Aspen Thomas A senior engineering student in the College of Science and Engineering, Department of Engineering and Physics at Southern Arkansas University, Magnolia AR.

Hayder Zghair is an assistant professor of industrial engineering in the College of Physics and Engineering at Southern Arkansas University, UAS. Dr. Zghair earned master's degree in Manufacturing Systems Engineering and Doctor's Degree in Manufacturing Systems Engineering from Lawrence Technological University, Michigan, USA. He has published journal and conference papers. His research interests include Flexible-Automated Manufacturing, Robotics, Analytical Modeling & Simulation, and Optimization. He is member of ASEE, SAE, and IEOM. Dr. Zghair's contact information is Tel: 870-235-4256, ENG 109, hzghair@saumag.edu