An Analytical Evaluation of the Lifecycle Cost Effectiveness of Implementing Section 5.5 of the DFCM 2014 High Performance Building Standard

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Executive Summary

The State of Utah Division of Facilities Construction and Management (DFCM) applies design requirements[1] to all capital development projects. One of these requirements is the High Performance Building Standard (HPBS)[2]. The HPBS, which establishes energy and sustainable performance, requires various building performance consultants be contracted directly by DFCM. This report studies if the fees incurred to the project, by contracting these additional consultants, provides significant positive economic impact over the life of the building.

The results of several case studies presented in this report show that the fees incurred for Energy Modeler/Engineer (EME), ranging between $34,000 and $74,000, are recouped by the initial cost savings alone, which range between $267,000 and $1,695,000. Annual energy cost savings of up to $70,600, which translates to $0.64/FT^2, are realized by projects that utilize the HPBS process. Additionally, private donations, of up to $1,300,000 have been raised for projects, using the results of the HPBS as supporting documentation.

Introduction and Overview of DFCM HPBS

DFCM applies various design standards to all commercial projects subject to its jurisdiction. Among these standards, energy performance requirements are prescribed by section 5.5, of the HPBS. In 2012, DFCM commissioned a study[3] to determine the economic impacts of buildings constructed under the 2009 version of the HPBS. The results of the study showed little to no measurable energy cost savings compared to buildings constructed without energy performance requirements. This lack of performance was not solely due to the requirements but do to how the requirements and associated processes were implemented. Due to the results of this study, the HPBS was revised in 2014 to address many of the problems of the 2009 HPBS. One of revisions requires DFCM to directly contract an EME, Building Envelope Commissioning Agent (BECxA), and Commission Agent (CxA), during the programming phase, to maximize the value to the owner, of design and construction efforts. Contracting by DFCM directly ensures that there are no conflicts of interest when making recommendations to the owner and design team towards maximizing the value of the project. The scope of this report is to study if the additional cost to projects incurred by contracting additional third party consultants and following the HPBS process, specifically by the EME, is justified.

Prior to the HPBS being adopted as a requirement, energy efficiency measures (EEMs) were often included on projects based on inappropriate criteria or observations. Some of these included perceptions by architects and/or engineers based upon lack of quantitative analysis & supporting documentation or succumbing to aggressive marketing tactics. This practice led to EEMs being erroneously included on projects, with the intent to save money, but resulted in costing the project more money than they save, either through egregiously over estimated savings and/or increased maintenance costs.

In response to this issue, section 5.5 of the HPBS details the specific requirements for managing energy consumption and selecting EEMs specific to the project. Section 5.5 requires projects to achieve, when life-cycle cost effective, a 20% reduction in energy cost performance,

[1] http://dfcm.utah.gov/downloads/design_manual/design_requirements.pdf
[2] http://dfcm.utah.gov/downloads/design_manual/design_requirements.pdf - Section 5
[3] UT DFCM High Performance Building Standard Review and Analysis. May 2012

when compared to a Baseline building, using ASHRAE 90.1-2010 Appendix G modeling protocol. Because DFCM must demonstrate fiscal responsibility to tax payers rather than blindly maximizing energy savings, the required energy performance is only required if the funds being spent are life-cycle cost effective[4]. The goal of 20% annual energy cost reduction was determined with considerable research from past projects as well as national averages. A reduction of 20% annual energy cost is intended to challenge design teams to create energy efficient projects, but not be so aggressive, that exceptions become the norm. Over time as energy efficient technology gets cheaper, the goal is intended to be adjusted to continue to challenge design teams to a level where the first cost associated with the technologies are life cycle cost effective. If a design approach, through individual EEMs that meet the required energy cost saving goal cannot be found, then the design approach with the highest energy cost savings while being life cycle cost effective may be used.

By not requiring expenditures beyond what is life-cycle cost effective, the HPBS does not unnecessarily inflate project budgets, and does not require projects to pursue additional EEMs, which do not provide owner benefit. Additionally, the HPBS makes provisions to exempt small projects, below a threshold based on project budget, size, or expected energy consumption, but must still utilize an EME for qualitative assessments of the design. Qualitative assessments involves leveraging the experience and lessons learned from past energy/LCCA analysis of past DFCM projects and similar installations. Fees for qualitative consulting are generally an order of magnitude less than for quantitative analysis.

Life-cycle cost effectiveness is determined using the guidelines outlined by the federal government in 10 CFR 436, to ensure uniform results, and eliminate gamesmanship of the results. 10 CFR 436 requires that the life-cycle cost analysis (LCCA) include all costs associated with each EEM, including initial capital costs, annual energy cost savings, yearly maintenance costs, replacement and repair costs with appropriate time intervals, and residual value. The analysis also includes the predicted inflation of energy costs as provided by the Department of Energy, and predicted inflation of dollar value as provided by the US Treasury. Unless noted otherwise, all dollar results from the LCCA are offered in present value (PV) US dollars. PV indicates the current worth of a future sum of money, given a rate of return determined by the results of the EEM.

Current building performance rating systems do not reward all EEMs with value to the owner. Therefore, the 2014 HPBS has eliminated the requirements for US Green Building Council's Leadership in Energy and Environmental Design (LEED) Silver certification, a requirement of the 2009 HPBS. LEED awards project "points" based on meeting certain thresholds throughout a variety of categories, including sustainable sites, water efficiency, energy efficiency, and material use. If a project achieves the required number of points it is awarded a LEED rating, which range from LEED Certified to LEED Platinum. By creating standards that require projects to achieve a certain LEED threshold, these standards could often result in the project spending money pursuing LEED points, that have minimal value to the owner, to achieve the LEED standard.

LEED is costly, by requiring registration fees, at the cost of ten thousand dollars or more[5]. Additional or clarified reviews, called appeals, require, in some cases, additional fees. Lastly LEED's review process has been demonstrated to be very inconsistent and inadequate, with

[4] http://dfcm.utah.gov/downloads/design_manual/design_requirements.pdf - DFCM HPBS 5.5-A-2
[5] http://www.usgbc.org/cert-guide/fees

very complex DFCM projects, with glaring energy modeling issues, receiving few review comments to bring the energy model up to an acceptable standard. The review process takes place without direct communication between the reviewer and the design team, making it impossible to maintain consistency, or hold dialog regarding situations where the governing standards for the analysis lacks specific guidance. This often results in costly appeals. LEED reviews provide no constructive feedback to improve the design, and are conducted after the project design is completed, when changes will incur costly change order fees,

The issues with LEED, detailed above, are indicative of all current building rating systems. By eliminating the LEED requirement and not prescribing to other available building rating systems, the project saves initially on registration fees, gives more control to DFCM regarding the review process, creates consistent documentation, and maximizes value to the State of Utah, by not requiring projects to chase arbitrary thresholds that may not be appropriate.

It should be noted that while the problems associated with the LEED rating system above have not been an ideal fit for State projects, LEED has been a significant influence on the design and construction industry in Utah. It has brought an awareness of the value and benefit of energy efficiency and other sustainable practices to light, that have benefited the industry as a whole. The 2014 HPBS has taken many of these fundamental sustainable practices such as indoor environmental quality, recycling, and water conservation and made them requirements for state projects while keeping the owner cost benefit in check.

Once a project design and HPBS evaluation process is completed, a review of all LCCA energy models, and supporting documentation is completed by a third party reviewer, also directly contracted by DFCM. The intent of this review is to ensure that all modeling protocols are followed consistently across all projects, and that appropriate cost estimations were provided in the best interest of the owner. Once the review of all documentation is complete, appropriate documentation is available for future projects regarding EEMs and lessons learned, that could be applied to future projects, where appropriate. By contracting the reviewer directly, DFCM can also include credit towards building energy savings measures that provide considerable owner value, such as infiltration control, for which credit cannot be taken in other building rating systems.

Several institutions throughout the state, such as the University of Utah, have written requirements that go beyond those of the HPBS, including requiring LEED certification with specific energy performance beyond the HPBS, on buildings within their control. This is supported by the language in the HPBS, as the HPBS is intended to be a minimum standard for projects.

Individual Projects Case Studies

University of Utah Crocker Science Center

The University of Utah Crocker Science Center (Crocker), is a 115,000 ft^2 remodel and addition of the existing historic George Thomas building, located on the University's main campus in Salt Lake City, Utah. The final project design includes 70,000 ft^2 of classrooms and offices, and 45,000 ft^2 of teaching and research labs, that include fume hoods, high ventilation requirements, specific lighting requirements, and tight temperature control requirements. Due to the nature of the lab space requirements, the building is expected to use a considerable amount of energy, particularly related to HVAC and lighting, within the lab spaces.

The existing building was constructed in 1935, is listed as a historic building on the National Register of Historic Places, and is under the care of the State Historic Preservation Office (SHPO). From the original construction, the existing envelope components have aged considerably, and the envelope was not insulated to the same level as a code minimum building built to today's standards. This provided considerable potential opportunity to upgrade the energy performance of the project, however due to the historic nature of the building, and budget constraints, not all components could be upgraded, without violating SHPO's requirements.

With these design considerations and restrictions in mind, the design team proposed EEMs for the project to be analyzed using the protocol outlined in the HPBS. EEMs that were proposed included additional insulation applied to the existing envelope, exceeding code minimum insulation on the new construction, enhancing the thermal performance of the existing windows, installing shading devices, improving building infiltration, high efficiency lighting, evaporative cooling, and high efficiency HVAC systems. In all 73 specific EEMs were proposed for the project.

Crocker - Envelope

During the initial walkthrough with the owner, architect, energy engineer, and BECxA, some assumptions were made regarding the infiltration rates of the existing envelope. It was assumed that the existing construction had deteriorated over time and would be very leaky. This high infiltration would result in increased energy consumption of the building and therefore would need to be investigated further.

As a result of this assumption the BECxA conducted a whole building air leakage test, where the results of the whole building air test showed an average infiltration rate of 0.3 CFM/ft^2 of envelope area; a better than average building, by today's standards.[6][7] By conducting a whole building air test, the actual infiltration rate could be leveraged in the energy model to ensure appropriate results. The operable, single pane, steel framed windows leaked at an average rate of 2 CFM/ft^2, considerably worse than an NFRC typical leakage of 0.3 CFM/ft^2, and would need to be addressed, not just for energy cost implications, but also for thermal comfort[8], and to ensure proper building pressurization[9]. Subsequent analysis showed that a modern window framing system could save the project approximately $36,045, annually.

While the building users expressed a desire to replace the windows with a modern system, SHPO took exception, calling the existing windows, "A character defining feature of the building." Through coordination with SHPO, the design team suggested options to address the window performance, including replacing the windows, installing a secondary storm window behind the existing windows, and leaving the windows untouched. In total, 19 specific window options were evaluated for life-cycle cost effectiveness, as well as thermal comfort, and visual appeal. The results were then presented to SHPO, DFCM, project steering committee, and The University, to make a final selection. The final decision was to replace the windows with a

[6] ASHRAE Fundamentals 2013 16.25
[7] UT DFCM Infiltration Study, August 2013
[8] ASHRAE Standard 55-2010 Section 5
[9] ASHRAE Standard 62.1-2010 Section 5.17

system that was visually similar to the existing windows, but with modern thermally broken framing and double pane glazing.

The energy modeling effort demonstrated that the cost to improve the existing wall insulation, $532,000, would have limited life-cycle cost effectiveness, with a 36-year discounted payback period. This, coupled with concerns that construction on the existing envelope may cause damage to the patina, via unsightly repairs, meant that the existing walls would remain in their current condition.

The existing roof, a copper seamed system with insulation underneath, is original construction and does not meet the current energy code requirements. It was proposed by the design team to remove and upgrade the existing roof system, to improve thermal performance, and meet the University's design requirements[10]. Due to the complexity of the existing roofing system, and the requirements by SHPO to maintain the visual appearance of the existing roof, the cost premium to upgrade the roofing insulation was approximately $32,000. The energy model and LCCA showed that upgrading the roof would save approximately $850 per year, and have a 40-year payback of -$7,348. Due to the limited annual energy cost savings the replacement of the roof was removed from the design, saving the project $32,000 of initial costs.

Table 1 Crocker Envelope EEM Summary

EEMs Initial Capital Costs	EEM Average Annual Energy Cost Savings	EEM 40-year LCCA Savings (Future Value $)
$546,958	$41,503	$1,777,986

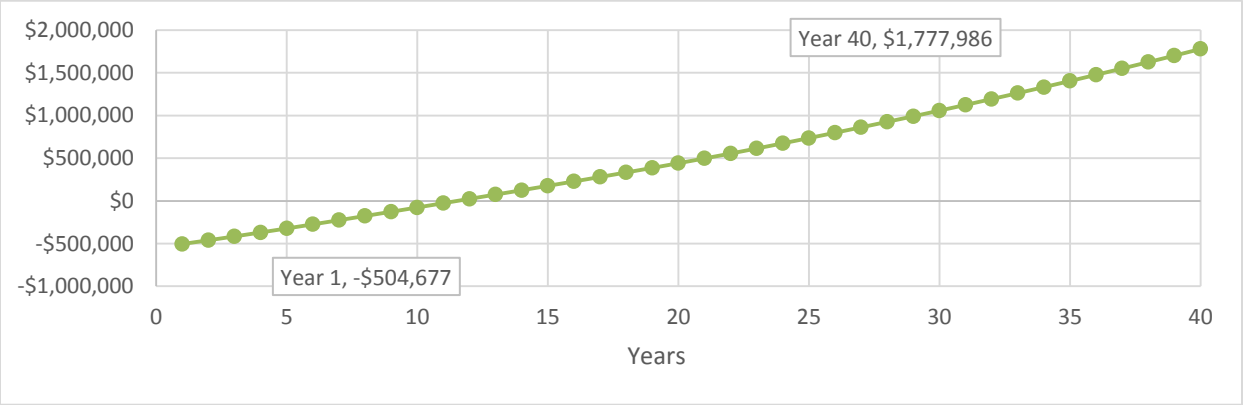

Figure 1 - Crocker Envelope LCCA Summary

Crocker - HVAC

The project HVAC system is intended to be served by central chilled water (CHW) and central high temperature hot water (HTW) plants. To reduce the demand for chilled water supplied by the central plant, and take advantage of Utah's dry climate, indirect-direct evaporative cooling (IDEC) and direct evaporative cooling (DEC) were evaluated in the energy model, per the HPBS.

[10] http://facilities.utah.edu/project-resources/documents-standards/design-standards.php

IDEC was the initial design intent, based on past project experience, and IDEC and DEC both showed considerable energy cost savings. However, IDEC would require a dedicated cooling tower to serve the indirect cooling coils, and not a cooling tower shared with a chiller. Cooling towers are maintenance intensive, both in time and costs. In this case, the additional costs associated with the cooling tower and maintenance did not justify the additional energy savings that would be realized when IDEC. By removing the cooling tower from the design of the project, the owner realized an initial construction cost savings of approximately $245,000, as estimated by the general contractor.

The HTW central plant serves the entire campus with 390°F water. Generating water at this temperature does not maximize the efficiency of burning natural gas[11], requires significant pumping power to distribute throughout campus, and is very expensive to install the specialized piping and insulation to support this system[12]. Conversely, HTW offer advantages of keeping boiler maintenance in one central location, as well as reducing the required mechanical space in each building, when compared to an individual site standalone boiler.

Both of these options, were evaluated per the HPBS, and maintenance costs of $4,000 annually, were obtained from the campus facilities department, to use in the life-cycle cost analysis. The results were presented to the steering committee to make the final decision, towards which option to include in the design. Because the LCCA demonstrated a payback of $153,743, over 40 years, when compared to connecting to the central plant, the steering committee selected a standalone boiler system for the project.

In addition to the HVAC plant analysis, two HVAC systems were evaluated; variable air volume (VAV) IDEC with hot water reheat, and chilled beams with dedicated outdoor air system (DOAS). Due to the high exhaust requirements in the lab spaces, each lab space would require a significant number of chilled beams, or a bypass damper, to appropriately ventilate the space. Additionally, the VAV system outperformed the chilled beam system, in terms of annual energy cost. The energy models demonstrated that the VAV system was less expensive to install and operate, compared to chilled beams. With the information provided by the life-cycle cost analysis, the design team moved forward with a VAV HVAC system.

Table 2 – Crocker HVAC EEM Summary

EEMs Initial Capital Costs	EEM Average Annual Energy Cost Savings	EEMs Annual Maintenance Cost	EEM 40-year LCCA Savings (Future Value $)
$188,000	$36,897	$12,000	$1,340,473

[11] ASHRAE 2012 HVAC Systems and Equipment 32-Figure 6
[12] DFCM Project Number: 12042750 AE High Temperature Water Utility Distribution Upgrade

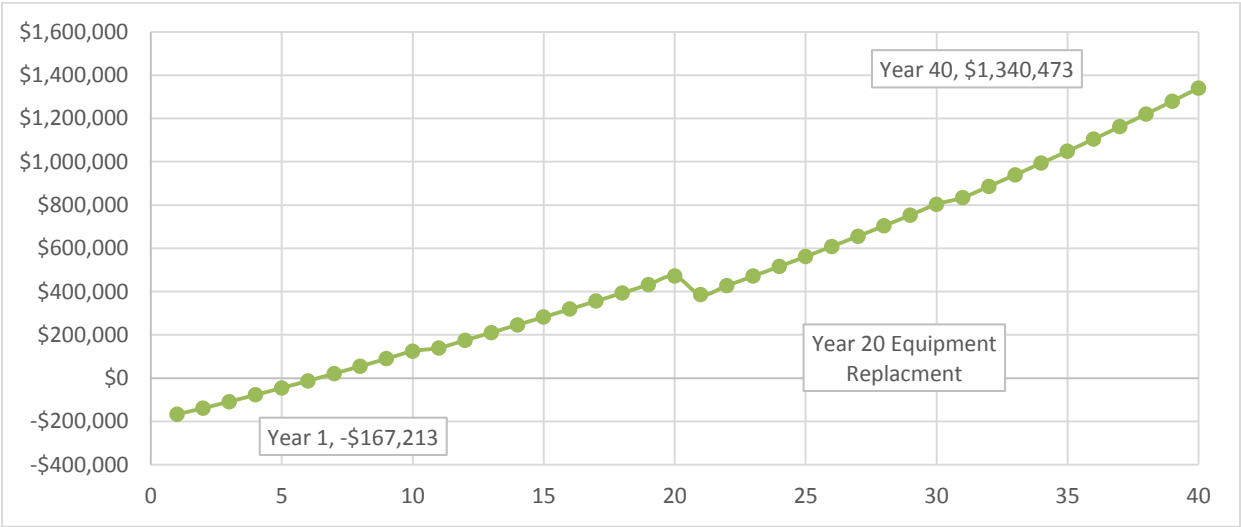

Figure 2 - Crocker HVAC LCCA Summary

Crocker – Lighting

The University of Utah requires LED lighting to be installed on all new projects[13]. However, the design team evaluated a fluorescent lighting design, as well as, a LED lighting design, to validate this design requirement. The LED lighting had a significant annual energy cost savings of $9,524, compared to the additional initial capital cost of $75,000. The maintenance costs savings associated with LED lighting was not made available to the design team and was not included in the analysis. However LED lighting is expected to be cheaper to maintain, due to less frequent lightbulb changes, and would improve the LCCA payback period.

The electrical engineer also proposed using automatic dimmers, in the exterior spaces, to adjust the lighting levels, based on the amount of available daylighting. The visible light transmittance of the new fenestration assembly was analyzed in the energy model to determine the feasibility of installing automatic dimmer controls, in spaces beyond what is required by the energy code[14]. Results of the energy model indicate that, due to the high volume of lighting and glazing area, that automatic dimmers would be feasible in the exterior spaces, despite the initial capital cost of $25,000, making them cost effective in the LCCA and were therefore included in the design.

Table 3 - Crocker Lighting EEM Summary

EEMs Initial Capital Costs	EEM Average Annual Energy Cost Savings	EEM 40-year LCCA Savings (Future Value $)
$87,897	$12,103	$415,447

[13] http://facilities.utah.edu/project-resources/documents-standards/design-standards.php
[14] 2012 IECC C405.2.2.3

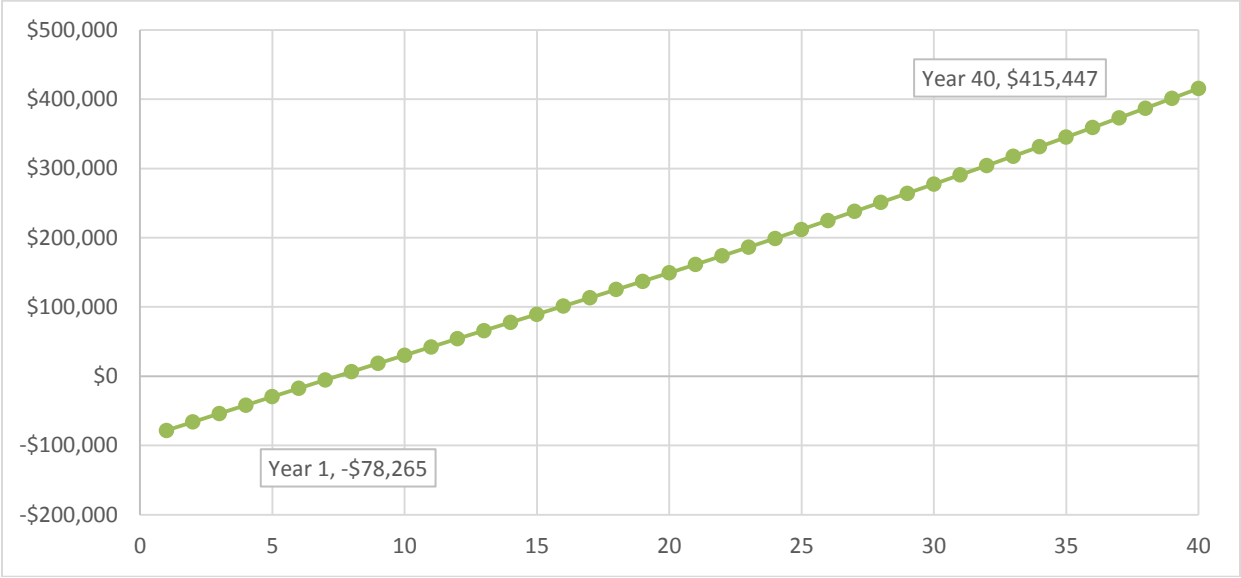

Figure 3 - Crocker Lighting LCCA Summary

Crocker – Results

In addition to the HPBS energy performance requirement, the University has an energy performance requirement that all projects achieve 13 points under LEEDv4 Optimize Energy Performance credit. Due to the combination of existing and new construction, this equates to a design that is 30% better than the ASHRAE 90.1-2010 Appendix G Baseline building[15]. However, the EEMs necessary to meet this energy performance requirement would not be life-cycle cost effective, as demonstrated by the HPBS process. Therefore, the results from the 73 EEMs analyzed, were assembled into "packages" of EEMs and presented to the project steering committee for a final selection. The packages presented included several options; lowest first cost, lowest life-cycle cost, all life-cycle cost effective measures, and all measures required to meet the University's design requirements.

With the life-cycle cost analysis results, particularly the discounted payback period, it was very easy for the steering committee to see that spending money beyond what was life-cycle cost effective, to save energy costs, was not in the owners best interest. Some EEMs did not save money over the life of the project, with some cases costing more money than they saved, and provided no additional value to the University. The steering committee ultimately selected the EEM package with lowest lifecycle cost, resulting in approximately 27.3% annual energy cost savings, and provided a waiver that the project did not need to meet the University's requirement, due to the fact that they would be spending money to pursue LEED points.

Table 4 - Crocker Overall EEM Summary

Initial Cost Savings of Non-Cost Effective EEMs	EEMs Initial Capital Costs	EEM Average Annual Energy Cost Savings	EEM 40-year LCCA Savings (Future Value $)	EME Fee
$1,695,000	$877,978	$68,424	$3,292,654	$74,000

[15] http://www.usgbc.org/node/2614273

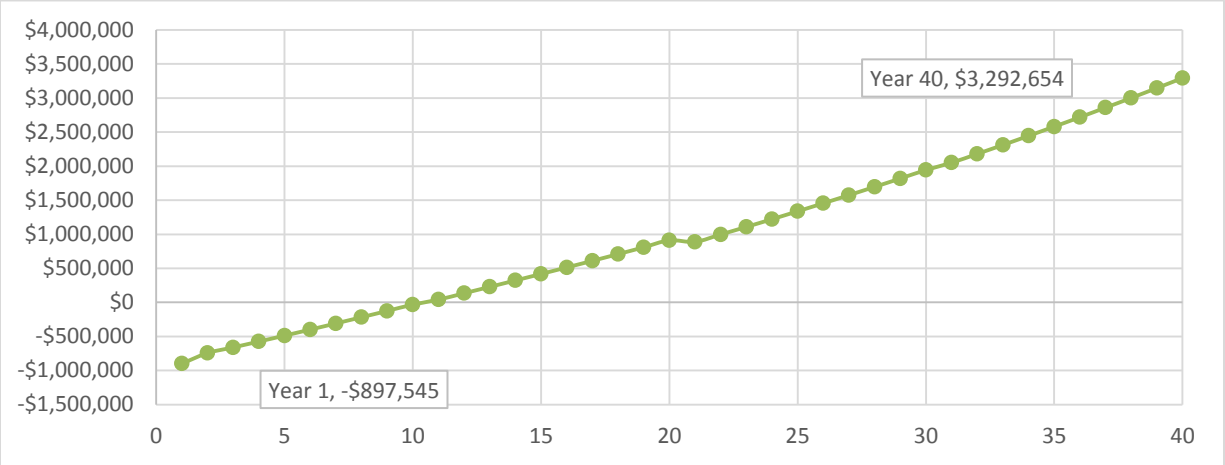

Figure 4 - Crocker Overall EEM LCCA Summary

Utah State University – Romney Stadium

Utah State University (USU) Romney Stadium (Romney) is a new 65,000 ft^2 football stadium. The new facility replaces the existing facility, adjacent to the football field, and is located on the main USU campus in Logan, Utah. The final project design includes 45,000 ft^2 of floor area intended to be occupied year round. These common areas include food services for the student athletes, as well as offices for the football coaching staff. The project also includes 20,000 ft^2 of floor area, including suites, concessions, and broadcast facilities, intended to be occupied only on game days. USU does not apply any design requirements beyond the HPBS, for energy performance, and therefore, the DFCM HPBS is the only requirement.

The game-day areas are estimated to be fully conditioned, for occupancy, approximately twelve days per year. The remaining 353 days of the year, the spaces are estimated to be conditioned only to a level to prevent freezing, and several outdoor concessions areas are completely shut off at the completion of the college football season.

Additionally, the project was significantly over budget. With the project budget, and limited use of a large portion of the building in mind, the design team suggested 21 specific EEMs to analyze on this project, including insulating beyond code minimum, a LED lighting system, and high performance HVAC system with evaporative cooling and condensing boilers. USU maintenance staff provided estimates regarding the labor and maintenance to assist the life-cycle cost analysis.

Romney – Envelope

The majority of the game-day-only areas are located at the exterior of the building, with the year round common areas occupying the interior of the project. With such a low estimated usage of the perimeter spaces, increasing the envelope beyond code minimum allowable levels provided no benefit to the owner. The results of the energy analysis showed that improved insulation, even orders of magnitude better, only provided an annual energy cost savings of less $1,000 per year. Initial project design documents indicated insulation that exceeded code minimum

levels. With the results of the LCCA, this additional insulation was removed from the project, because it provided little value to the owner.

Romney – HVAC

The project was located, relative to the central heating and cooling plants, such that the cost was prohibitive to route utilities from the central plant. Therefore the decision was made to include a local chiller and boiler, to serve the project. Due to the cooler climate in Logan, Utah,[16] cooling energy use is typically minimal, with 2,541 cooling degree days[17]. As a result of this climate, most cooling loads are served using economizers or evaporative cooling. The energy model showed that a water-cooled chiller would be more efficient than an air cooled chiller, but the additional installed cost and maintenance associated with a cooling tower would not be offset by the additional annual energy cost savings that a water-cooled chiller provided.

The heating load in Logan, Utah can be significant, therefore, a condensing boiler was proposed for the project to maximize efficiency of burning natural gas. The energy model demonstrated that the increased efficiency of a condensing boiler offset the increased fan and pump energy to distribute and utilize the lower temperature water that condensing boilers require.

The project is served by two air handlers; one that serves the common spaces, and the other the game-day-only spaces. IDEC and DEC were EEMs considered for both air handlers. Due to the low use of the game-day-only space, and the time of year the game-day space was intended to be used (September – December), both IDEC and DEC saved less than $800 per year in energy costs in the game-day air handler. The additional maintenance costs, as well as capital costs were not offset by the calculated energy cost savings. The year round common areas air handler, showed that IDEC and DEC would save energy, but the additional costs of a dedicated cooling tower for IDEC would not be life-cycle cost effective. Therefore DEC was included in the design of the common areas air handler.

Romney – Lighting

USU has a design requirement[18] that all installed lighting be LED. The design team proposed a fluorescent lighting design as an alternative to LEDs. Due to the limited usage of the game-day-only spaces, the additional cost of LED lighting in those spaces was not life-cycle cost effective. The owner, realizing the initial and ongoing cost savings associated with a fluorescent design, and waved the LED requirement in the game-day spaces, to maximize the owner value, and help bring the project within budget. For reasons similar to the envelope design, automatic dimmers in the perimeter spaces, mostly game-day-only spaces, was a considerable expense with an insignificant annual energy cost savings.

Romney – Results

Due to the intended function of the project, no “package” of life-cycle cost effective EEMs could be found to reach the HPBS requirement. The HPBS does not require projects to spend money that is not life-cycle cost effective, and provides no value to the owner, or tax payer, in a way that other rating systems such as LEED potentially require. The project was initially significantly

[16] ASHRAE 90.1-2010 Climate Zone 6B
[17] ASHRAE 90.1-2010 Appendix D
[18] http://www.usu.edu/facilities/planning/designreq.cfm

over budget, and allocating devalued funds towards EEMs would have meant reducing building function or area, diminishing the value of the project to the owner considerably. The LCCA process informed several design aspects of the project that were over-designed for energy efficiency, which were actually costing more money than saving, thereby assisting to balance the project budget.

The design team selected the package of EEMs that was demonstrated to be lifecycle cost effective, and used the funds that were not wasted on inappropriate EEMs, and instead improved the project, by staying within the programming scope, thereby increasing the total project value, to the owner.

Table 5 - USU Romney Stadium Summary Results

Initial Cost Savings of Non-Cost Effective EEMs	EME Fee
$341,745	$50,000

Additional Case Studies

University of Utah Quinney College of Law

University of Utah Quinney College of Law, is a 155,000 ft^2 building, located on the University of Utah campus in Salt Lake City, Utah. The project incurred an energy engineering fee of $55,000. Several donor groups offered additional funding for energy efficiency strategies to be included on the project, that could not be funded within the initial construction budget. LCCA, per the HPBS, was used as justification to donors that the proposed EEMs would save an appreciable amount of energy over the life of the project. As a result, all proposed EEMs were funded by private donors, increasing the project budget by $1,300,000, and the project is expected to save $70,600 annually, which is considerably higher savings than typical projects, due to private donor funding.

Table 6 - University of Utah Quinney College of Law Summary Results

Annual Energy Cost Savings	Additional Donations Secured for the Project	EME Fee
$70,600	$1,300,000	$55,000

Unified State Labs Module 2

Unified State Labs Module 2 is a 95,000 ft^2 laboratory facility in Taylorsville, Utah. The project incurred an energy engineering fee of $35,000. The project is intended to house the state medical examiner's lab, state food borne illness lab, and state crime lab. Due to this intended function of the building, energy usage is considerable. During initial design of the project, eight specific EEMs were analyzed using the HPBS and LCCA process. All proposed EEMs were cost effective, and included in the design, estimated in the energy model to save the project more than $52,000 in annual energy costs. Once initial design was completed, the project was put on hold, for one year, due to funding issues, and during that year, a proprietary recovery system, Konvekta, was proposed to further increase energy savings.

The Konvekta system would require a redesign of the HVAC source equipment, and carried a considerable initial cost. The system was analyzed in the energy model and LCCA, results demonstrated that the additional cost would not be justified over the life of the building, saving the project redesign fees, as well as approximately $1,200,000 of initial cost for the system. The energy model and LCCA results were also used as proof, to eliminate a proprietary fan array system, which cost the project approximately $15,000 of incremental costs and an additional $6,800 in annual energy costs.

Table 7 - Unified State Labs Module 2 Summary Results

Annual Energy Cost Savings	Initial Cost Savings of Non-Cost Effective EEMs	EME Fee
$18,035	$1,215,000	$35,000

USU Brigham City Regional Campus New Academic Building

The scope of USU Brigham City Regional Campus New Academic Building was intended to pursue a minimum LEED Silver rating, in order to comply with the State of Utah and Utah State University standards. The intent of the energy modeling was to determine which energy efficiency measures would be most beneficial to the project, by comparing initial costs with long term life cycle costs.
The modeling effort included evaluating energy efficiency measures, such as improved building envelope components, high efficient lighting, and different high efficient mechanical systems. The specific items that were modeled and evaluated included:

- Windows with a SHGC rating of 0.29 or better, and when using aluminum fames include a thermal break and an NFRC assembly U factor rating of 0.41 or better. This was compared to lesser performing glazing and shown that this level of glazing performance had a positive life cycle cost.
- Maintain less than 40% glazing, attempt less than 30% if possible without negatively affecting the building. Different options were run to show glazing impacts.
- Models were used to compare continuous insulation as opposed to batt insulation. Models showed that it was preferable to use continuous wherever possible.
- Evaluate envelope leakage rates. Evaluate the savings utilizing three different leakage rates to determine what level of commissioning and testing should be required for this project.
- Project included preliminary schematic level modeling to evaluate multiple mechanical systems, such as water cooled chiller, condensing boilers, direct and indirect evaporative cooling, heat pump chillers, displacement ventilation, chilled beams, improved envelope infiltration, water side economizer, and ice storage.
- Ice storage shows a potential approximate savings of 12%, but did not have a short enough payback to be incorporated.
- High efficiency water cooled chiller, with direct and indirect evaporative cooling, and high efficiency condensing boilers shows a potential approximate savings of 15%.
- Geothermal heat pump chillers show an approximate potential savings of 7%, which was not as significant as the 15%.
- An ultra-high efficiency chiller was analyzed and showed

- Water side economizer showed a potential savings of 2-3% which did not have sufficient payback to be included. Models indicated that the use of occupancy sensors and CO2 sensors to reduce ventilation when unoccupied had a positive payback.
- High efficiency LED lights were shown to have a positive payback

Summary: The energy efficiency measures that were incorporated estimate an energy cost savings of 42.9%, or approximately $49,500 in annual energy cost savings. Additionally, the energy modeling ruled out the options of an ultra-high efficiency chiller and water side heat exchanger that did not show enough energy savings to justify the initial cost, which resulted in an initial construction cost savings of approximately $75,000. The energy modeling fee for the project was $17,500.

Table 8 - USU Brigham City Regional Campus Summary Results

Annual Energy Cost Savings	Initial Cost Savings of Non-Cost Effective EEMs	EME Fee
$49,500	$75,000	$17,500

Utah School for the Deaf and Blind

Utah School for the Deaf and Blind targeted an energy improvement of 20-30% better than code to meet the High Performance Building Standard. The intent of the energy modeling was to determine which energy efficiency measures would be most beneficial to the project, by reducing initial costs wherever possible, without sacrificing long term life cycle costs.

The modeling effort included evaluating energy efficiency measures, such as improved building envelope components, high efficient lighting, and different high efficient mechanical systems. The specific items that were modeled and evaluated included:

- Options for different glazing performance, such as u-values, solar heat gain coefficients, etc.
- Different options were run to show different quantities of glazing and their impacts on energy cost.
- Evaluate envelope leakage rates. Evaluate the savings utilizing three different leakage rates to determine what level of commissioning and testing should be required for this project.
- Project included preliminary schematic level modeling to evaluate multiple mechanical systems, such as water cooled chiller, condensing boilers, direct and indirect evaporative cooling, VAV rooftop units, evaporatively cooled VAV rooftop units, variable refrigerant flow (VRF) and air cooled chiller. The evaporatively cooled rooftop units showed the best value for this building when balancing budget with life cycle performance.
- Models indicated that the use of occupancy sensors and CO2 sensors to reduce ventilation when unoccupied had a positive payback.
- High efficiency LED lights were shown to have a positive payback

Summary: The energy efficiency measures that were incorporated estimate an energy cost savings of 34%, or approximately $32,000 in annual energy cost savings. Additionally, the energy modeling ruled out the options of water cooled or air cooled chiller 4 pipe system, that

did not show enough energy savings to justify the initial cost, which resulted in an initial construction cost savings of approximately $50,000 – 75,000 depending on the system. The energy modeling fee for the project was $13,500.

Table 9 - Utah School for the Deaf and Blind Results Summary

Annual Energy Cost Savings	Initial Cost Savings of Non-Cost Effective EEMs	EME Fee
$32,000	$50,000	$13,500

Discussion of Results

The results show that, in every case, the energy engineering fees are paid back, sometimes by orders of magnitude, with just the initial savings to the project alone. If the initial savings are disregarded, the annual energy cost savings still payback the energy engineering fees within two years of project completion. As an additional benefit, the energy modeling and LCCA efforts were used to support overcoming initial project budget issues, ongoing annual energy cost savings requirements, and assist towards receiving various utility rebate incentives. The HPBS process provides a method of verifiable documentation that can be applied to future projects, rather than conjecture and perception.

Credit for all of the annual energy cost savings has been attributed to the energy engineer, in the results presented in this report. An explicit breakdown of what exactly was saved by the energy modeling efforts and HPBS process, versus what the design team would have saved, is not available and is beyond the scope of this report. In general, more experienced design teams and simple projects will reach a higher level of energy performance value, than less experienced design teams or complex projects.

The success of the HPBS process relies considerably upon the support of all involved parties, including, the design team, building users, owner, cost estimator and general contractor. A couple design teams have resisted the HPBS process, and the energy cost savings results were considerably less than the optimized EEM results. In some cases these projects struggled to document energy code compliance. The owner bears the burden of initiating, driving, and sustaining holistic integrated design toward energy performance. Otherwise, a fragmented or compartmentalized approach results in less than achievable energy performance.

The HPBS process has optimized the realized energy savings per dollar spent, to ensure that each project and owner are realizing the most value per dollar spent. The results have been used to justify additional funding, either from private parties or, where life-cycle cost effective, tax dollars, to improve the quality and value, without missed opportunities or reduced potential towards energy savings.

The results of each of these projects are well documented, and have been used to justify or eliminate EEMs on future projects. By having this information available for future projects, the potential for duplicating work, and analyzing the same EEMs on different projects, is reduced.

Additionally, DFCM and State of Utah project managers are able to make more accurate project budget estimates, as well as future budgeting, master planning and the supporting documentation can even be used to support future design standards.

Table 10 - Overall Projects Summary

	Initial EMEs Cost	Initial Capital Cost Savings	Annual Energy Cost Savings	Year 1 Savings including initial savings (Future $)	Year 40 Savings including initial savings (Future $)
UofU Crocker	$73,621	$1,695,000	$68,424	$1,689,803	$6,854,256
USU Romney Stadium	$50,000	$267,000	$2,556	$220,198	$459,726
UofU Quinney College of Law	$55,000	$0	$70,601	$15,601	$5,323,404
Unified State Labs Module 2	$34,627	$1,215,000	$13,522	$1,193,895	$2,234,576
USU – Brigham	$17,500	$75,000	$49,500	$107,000	$2,087,000
USDB	$13,500	$50,000	$32,000	$68,500	$1,348,500

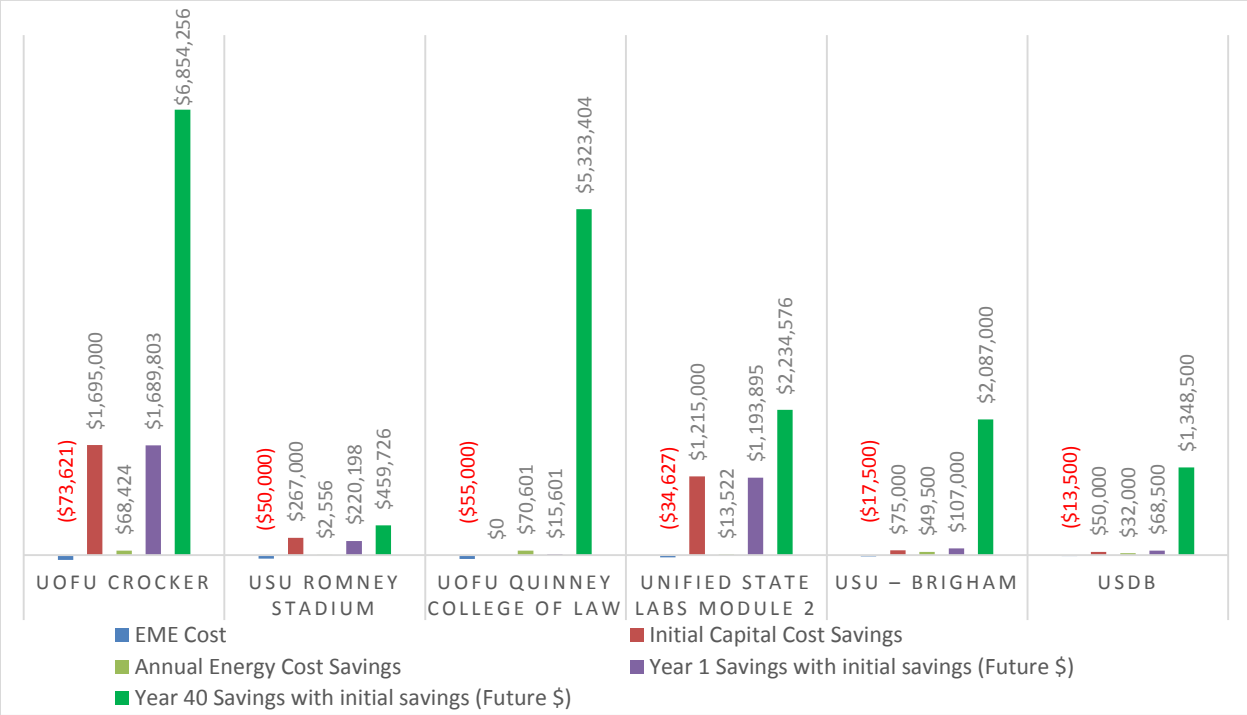

Figure 5 - Overall Projects Results

UofU Crocker Science Energy & LCCA Analysis Summary
June 10, 2015
Colvin Engineering

EEM Number	Design Element / EEM	Alternative Description & Modeled Parameter / Efficiency	Notes	Annual Utility Cost Δ (USD/Year)	Initial installed Cost Δ (USD)	Annual O&M Cost Δ (USD)	Overhaul / Replacement Cost (USD)	Utility Rebate (USD)	40-year LCCA Savings (USD)	LCCA Discounted Payback	Included in EEM Package Option Number
Envelope (Existing and New)											
	Roof										
1	Existing	(Baseline) R-5 metal seemed roof and R-21 membrane		-0-	N/A	$0	$0	$0	N/A	N/A	
2		Upgrading R-5 metal roof to match existing R-21 membrane		$814	$27,747	$0	$0	$0	-$6,234	40+ years	
3		Upgrading entire existing roof from Baseline to R-30		$952	$32,000	$0	$0	$144	-$7,348	40+ years	
4	New	(Baseline) R-20	ASHRAE 90.1-2010 minimum	-0-	N/A	$0	$0	$0	N/A	N/A	
5		Upgrading new roof to R-30	Most of the new roof area is covered with mechanical. Not a lot of insulated roof to improve.	$170	$22,914	$0	$0	$1,661	-$17,247	40+ years	
6		Upgrading new roof to R-36	Most of the new roof area is covered with mechanical. Not a lot of insulated roof to improve.	$172	$36,662	$0	$0	$1,661	-$30,803	40+ years	
	Exterior Walls										
7	Existing	(Baseline) R-4.3	Uninsulated stone panels, sheeting, and with plaster. Based on existing drawings, and site walkthrough.	-0-	N/A	$0	$0	$0	N/A	N/A	
8		Upgrade existing walls from Baseline to code minimum (R-15.6)		$20,828	$532,000	$0	$0	$0	$50,300	36 years	9
9		Upgrade existing walls from Baseline to R-20		$21,446	N/A	$0	$0	$0	N/A	N/A	
10	New	(Baseline) R-15.6	ASHRAE 90.1-2010 minimum	-0-	N/A	$0	$0	$0	N/A	N/A	
11		Upgrade new envelope from Baseline to R-20	Savings is minimal and therefore not likely to be life-cycle cost effective.	$190	N/A	$0	$0	$0	N/A	N/A	
	Below Grade Walls										
12	Existing and New	(Baseline) Existing uninsulated concrete, New R-7.5	ASHRAE 90.1-2010 minimum	-0-	N/A	$0	$0	$0	N/A	N/A	
13		Upgrade existing envelope from Baseline to R-7.5 to match new	Savings is minimal and therefore not likely to be life-cycle cost effective.	$958	N/A	$0	$0	$0	N/A	N/A	
	Glazing										
14	Existing	(Baseline) Existing uninsulated single pane U-1.25 SHGC-0.82	Per ASHRAE 90.1-2010 Appendix A based on site walkthrough.	-0-	N/A	$0	$0	$0	N/A	N/A	1,5
15		Upgrade existing window pane with new pane. U-0.927 SHGC-0.702	Calculations per LBNL Window 6	$3,403	$146,500	$0	$0	$0	-$53,732	40+ years	
16		Replace existing windows with new insulated window assemblies. U-0.435 SHGC-0.223	Existing frames may not be large enough for insulated assemblies. Solarban 70xl with insulated frame assumed. Infiltration issues with existing windows is also assumed to be fixed. Existing window units have asbestos that requires abatement.	$36,045	$541,500	$0	$0	$0	$431,917	19 years	4,8,9,10
17		Provide storm windows at building interior (single pane)	Assumes assembly U-0.70 and SHGC-0.68	$6,715	$395,000	$0	$0	$0	-$212,886	40+ years	2,6
18		Provide storm windows at building interior (double pane)	Assumes assembly U-0.60 and SHGC-0.60	$8,587	$395,000	$0	$0	$0	-$124,470	40+ years	3,7
19	New	(Baseline) New windows Solarban 60. U-0.435 SHGC-0.383	Savings shown is compared to ASHRAE 90.1-2010 code minimum.	$686	N/A	$0	$0	$0	N/A	N/A	
20		Upgrade new windows from Solarban 60 to Solarban 70xl. U-0.433 SHGC-0.223		$3,360	$7,983	$0	$0	$0	$86,596	3 years	1,2,3,4,5,6,7,8,9,10
21		Provide 40% frit on 100% of new glazing assuming Solarban 60 assembly. U-0.381 SHGC-0.313	Calculations of frit per LBNL Window 6	$887	$7,093	$0	$0	$0	$18,010	9 years	
	Shading Devices										
22		(Baseline) No Shading with Solarban 60 glazing on new		-0-	N/A	$0	$0	$0	N/A	N/A	
23		Option 1 - Deep horizontal mullions at south façade		$5,458	$18,495	$0	$0	$0	$128,817	4 years	1,2,3,4,5,6,7,8,9,10
24		Option 2 - Light shelf at south facing glazing		$5,851	$37,200	$0	$0	$0	$118,574	8 years	
25		Option 3 - Louvers on interior side of new glazing assembly		$5,553	$62,100	$0	$0	$0	$87,248	13 years	
	Infiltration										
26		(Baseline) Existing - 0.31 CFM/ft2 of envelope area New - 0.1 CFM/ft2 of envelope area	Existing infiltration rate is assumed based on existing drawings and site walkthrough. New infiltration rate is assumed based on DFCM Design Requirements	-0-	N/A	$0	$0	$0	N/A	N/A	
27		Upgrade Existing envelope to DFCM Design Requirements of 0.1 CFM/ft2 of envelope		$6,050	Potentially part of other EEMs	$0	$0	$0	N/A	N/A	
Ventilation / Lab ACH											
28		(Baseline) 10 ACH reduced to 5 during unoccupied hours		-0-	N/A	$0	$0	$0	N/A	N/A	
29		Research Labs - 8 ACH Teaching Labs - 6 ACH. All reduced to 3 ACH during unoccupied hours	This EEM has already been coordinated and accepted by the owner, and included in all other EEM calculations. It has been included here to demonstrate potential savings of reduced outside airflow.	$20,512	N/A	$0	$0	$0	N/A	N/A	1,2,3,4,5,6,7,8,9,10
Domestic Hot Water											
30	DHW	(Baseline) Campus High temperature hot water with HX to create DHW		-0-	N/A	$0	$0	$0	N/A	N/A	
31		Local natural gas boiler and storage tank within the building. 80% Et		$600	$31,600	$0	$0	$0	-$13,500	40+ years	
32		Solar HW	Assumed 20% reduction in DHW heating energy.	$600	$93,000	$0	$0	$0	-$74,900	40+ years	
Lighting											
33	Fluorescent Lighting	(Baseline) Fluorescent lighting design based on Electrical Engineer sample spaces	Savings shown is compared to ASHRAE 90.1-2010 code maximum. Overall 25% reduction in lighting power consumption	$7,139	N/A	$0	$0	$7,491	N/A	N/A	
34	LED Lighting	LED lighting design based on Electrical Engineer sample spaces	Overall 48% reduction in lighting power consumption	$9,524	$75,000	$0	$0	$9,596	$132,950	9 years	1,2,3,4,5,6,7,8,9,10
35	Daylighting Controls	Assumes 60% VT on glazing and controls in all exterior spaces		$2,579	$25,000	$0	$0	$4,341	$33,342	13 years	1,2,3,4,5,6,7,8,9,10
Equipment											
36	LAB Equipment - Elec.	(Baseline)	Baseline - COMNET Appendix A	-0-	N/A	$0	$0	$0	N/A	N/A	
37	LAB Equipment - NG										
38	Office Equipment (Elec.)										
39	Energy Star Equipment	Required by the University of Utah Design requirements	Reduction based on Energy Star calculator for office equipment. No reduction assumed for lab equipment.	$1,009	$0	$0	$0	$0	$21,775	Immediate	1,2,3,4,5,6,7,8,9,10
40	Elevators	Regenerative Elevator Drives	Savings vary considerably based on elevator usage. Assumes 20 year life span of elevator drives	$640	$14,000	$0	$14,000	$0	-$21,751	Never	

Mechanical											
	Mechanical HVAC Systems										
41	VAV	(Baseline)		-0-	N/A	$0	$0	$0	N/A	N/A	
42	DEC w/ VAV	Direct Evaporative Cooling serving lab and non-lab spaces		$10,681	$50,000	$2,000	$20,000	Custom TBD	$109,005	7 years	1,2,3,4,5,6,7,8
43	IDEC w/ VAV	Indirect Direct Evaporative Cooling (IDEC) serving lab and non-lab spaces		$18,679	$245,000	$8,000	$90,000	$28,918	-$47,540	40+ years	9,10
44	IDEC w/ Chilled Beams	IDEC serving lab spaces, Chilled beams serving non-lab spaces		$6,551	$327,000	$8,000	$90,000	Custom TBD	-$385,164	40+ years	
	Central Plant Equipment										
45	Central Plant steam / high temp	(Baseline) - Use central plant HTHW for steam and building heating		-0-	N/A	$0	$30,000	$0	N/A	N/A	5,6,7,8
46	Central Plant steam / local boiler	Assumes 96% efficient local boiler with VAV system		$14,186	$138,000	$4,000	$83,000	$0	$153,743	15 years	1,2,3,4,9,10
47	Local steam / local boiler	Assumes 96% efficient local boiler with VAV system	Savings for increased efficiency heating at Stewart have not been included.	$14,186	$196,500	$8,000	$106,000	$0	-$12,172	40+ years	
	HVAC EEMs	HVAC EEMs assume IDEC VAV system serving lab and non-lab spaces.									
48	Oversized Ducts	Reduced fan power by 10%		$1,945	$81,500	$0	$0	$0	-$39,522	40+ years	
49	Oversized Pipe	Reduced pump power by 10%		$1,317	$54,000	$0	$0	$0	-$25,581	40+ years	
50	Oversized Coils	Reduced fan power by 10%		$1,945	$22,000	$0	$0	$0	$19,978	15 years	1,2,3,4,5,6,7,8,9,10
51	Aircuity	Reduces ventilation required to the space based on measured contaminants in the air.	Reduced airflow calculated based on Aircuity calculation spreadsheet.	$28,519	$204,000	$26,000	$0	$38,441	-$1,205,559	Never	10
52	Standard ERV	Assumes coil run around loop with 30% sensible efficiency. 10% increase in fan power.	Per Mechanical Engineer, energy recovery systems are to be designed in parallel with systems that do not include energy recovery, to get more accurate pricing data.	$12,030	TBD	TBD	$0	Custom TBD	TBD	TBD	1,2,3,4,5,6,7,8,9,10
53	Enhanced ERV	Assumes coil run around loop with 70% sensible efficiency.		$21,960	TBD	TBD	$0	Custom TBD	TBD	TBD	
54	ERV Konvekta Brand	Assumes coil run around loop with 90% sensible efficiency.		TBD	TBD	TBD	TBD	TBD	TBD	TBD	

General Notes:

1. Energy cost savings results of each EEM are not additive. Selected EEMs must be evaluated as a whole for final energy cost savings.
2. Some EEMs may require variances from UofU design standards.
3. Baseline budget and EEM pricing is at a conceptual phase only. Equipment and system selections have not been finalized.

EEM Package Options	Summary of EEMs	Annual energy cost savings percent	LEED v4 Optimize energy performance points (w/o Cogen)	Project Budget implications	Notes:
Option 1	Suggested design + Local boiler + Untouched windows (EEMs 14,20,23,29,34,35,39,42,46,50,52)	16.0%	7	+$248,000	
Option 2	Suggested design + Local boiler + Single Pane Storm window to existing (EEMs 17,20,23,29,34,35,39,42,46,50,52)	18.0%	8	+$401,000	
Option 3	Suggested design + Local boiler + Double Pane Storm window to existing (EEMs 18,20,23,29,34,35,39,42,46,50,52)	18.7%	8	+$401,000	Does not include cost estimations for double pane storm windows
Option 4	Suggested design + Local boiler + Replace existing windows (EEMs 16,20,23,29,34,35,39,42,46,50,52)	27.3%	12	+$789,500	Option requires existing windows to be replaced with matching new windows, could be a major cost increase.
Option 5	Suggested design + HTHW central plant + Untouched windows (EEMs 14,20,23,29,34,35,39,42,45,50,52)	6.8%	2	-$28,000	
Option 6	Suggested design + HTHW central plant + Single Pane Storm windows to existing (EEMs 17,20,23,29,34,35,39,42,45,50,52)	9.1%	3	+$263,000	
Option 7	Suggested design + HTHW central plant + Double Pane Storm windows to existing (EEMs 18,20,23,29,34,35,39,42,45,50,52)	10.6%	4	+$263,000	Does not include cost estimations for double pane storm windows
Option 8	Suggested design + HTHW central plant + Replace existing windows (EEMs 16,20,23,29,34,35,39,42,45,50,52)	18.9%	8	+$651,500	Option requires existing windows to be replaced with matching new windows, could be a major cost increase.
Option 9	Reach UofU's project design requrements (13 points) Cheapest Ongoing Cost - Suggested design + Local boiler + Replace existing windows + Upgrade existing walls + IDEC (EEMs 8,16,20,23,29,34,35,39,42,43,46,50,52)	30.2%	13	+$1,438,812	Option requires existing windows to be replaced with matching new windows, could be a major cost increase. Renovating the existing walls is not recommended by the design team. Includes IDEC EEM that is not life-cycle cost effective.
Option 10	Reach UofU's project design requrements (13 points) Cheapest First Cost - Suggested design + Local boiler + Replace existing windows + Aircuity + IDEC (EEMs 16,20,23,29,34,35,39,42,43,46,50,51,52)	30.1%	13	+$1,110,812	Option requires existing windows to be replaced with matching new windows, could be a major cost increase. Includes IDEC and Aircuity EEMs that are not life-cycle cost effective. Aircuity requires annual maintenance agreement of ~$26,000.

COLVIN ENGINEERING ASSOCIATES

Project: Utah State University Romney Stadium
Date: March 20, 2015

Purpose:

DFCM high performance building standard requires all projects to achieve 20% annual energy cost savings, if life-cycle cost effective. Utah State University has required that the project achieve LEED silver, which requires, at a minimum, 10% annual energy cost savings. The design team has proposed energy efficiency measures (EEMs), at project coordination meetings, to consider in this life-cycle cost analysis (LCCA). A summary of the cost effective EEMs is offered below.

Results:

Cost estimations for all EEMs have not be supplied, therefore, this report is still missing cost estimations for several proposed measures. These omissions in cost estimations have been indicated in yellow on the attached spreadsheet. Refer to the attached spreadsheet which shows each of the EEMs in greater detail, including LCCA cost, discounted payback years, and general notes towards the analysis.

Cost effective EEMs:

- None of the proposed EEMs, for which the analysis has been completed, are life-cycle cost effective.

EEMs that are not cost effective:

- Upgrade roof to R-30
- Upgrade roof to R-36
- Upgrading exterior walls to R-20
- Installing direct evaporative cooling on the common areas air handling unit (AHU)
- Installing direct evaporative cooling on the game day areas AHU
- Installing indirect-direct evaporative cooling on all AHUs
- Installing a water cooled chiller in lieu of an air cooled chiller

Discussion:

Due to the building's primary function as a football stadium, the majority of the building floor area is intended to be utilized approximately 8-12 times per year. As a result of the primary intended function of the building, all EEMs currently analyzed are not life-cycle cost effective, due to minimal use, and therefore, minimal opportunity for savings.

All portions of the LCCA are estimations, as the results could vary based on the final equipment selections and layout of the building. With the project in the design development phase, explicit equipment selections have not been made, and detailed drawings are not available.

The LCCA was conducted using the methods outlined in 10 CFR 436 subset A as required by the DFCM High Performance Building Standard. The EEMs analyzed were proposed by the design team at the project coordination meeting on December 16, 2014. All EEMs were submitted by January 26, 2015.

Annual utility costs were predicted using ASHRAE 90.1-2010 Appendix G modeling protocol, as required by the DFCM High Performance Building Standard. Initial installed costs, and replacement costs were provided by the CMGC. Annual O&M cost for HVAC EEMs were estimated by the energy engineer.

Conclusion:

Costs for all missing data should be submitted to the design team, so the LCCA analysis can be completed. The design team should coordinate with the cost estimator to finalize any information needed to complete cost estimations.

The design team, DFCM, and USU, should evaluate each EEM and make a selection of which to include in the final design of the project, if any. Once direction is given to the design team, of EEMs to include in the project, an energy model will be created with all selected EEMs included, to determine an estimated final annual energy cost savings, and LEED points.

None of the proposed EEMs are life-cycle cost effective, however, due to LEED silver being a requirement for the project, LEED requires the project must obtain 10% annual energy cost savings. To meet the 10% annual energy cost savings required by LEED, EEMs that are not life-cycle cost effective may need to be included in the project.

USU Romney Stadium LCCA Analysis Summary
March 20, 2015
Colvin Engineering

Design Element / EEM	Alternative Description & Modeled Parameter / Efficiency	Notes	Annual Utility Cost Δ (USD/Year)	Initial installed Cost Δ (USD)	Annual O&M Cost Δ (USD)	Overhaul / Replacement Cost (USD)	Utility Rebate (USD)	40-year LCCA Savings (USD)	LCCA Discounted Payback
Envelope (Existing and New)									
Roof									
	(Baseline) R-20	ASHRAE 90.1-2010 minimum	0	$0	$0	$0	$0	$0	-
	Upgrading roof from Baseline to R-30		$252	$27,946	$0	$0	$894	-$21,175	40+ years
	Upgrading roof from Baseline to R-36		$374	$55,893	$0	$0	$2,011	-$41,451	40+ years
Exterior Walls									
	(Baseline) R-15.6	ASHRAE 90.1-2010 minimum	0	$0	$0	$0	$0	$0	-
	Upgrade opaque envelope from Baseline to R-20		$755	$86,798	$0	$0	$1,487	-$59,713	40+ years
Exposed Floor Slab									
	(Baseline) R-30		$0	$0	$0	$0	$0	$0	-
	Upgrade floor slab from Baseline to R-35		$66	$11,820	$0	$0	$0	-$9,468	40+ years
Glazing									
	(Baseline) New windows Solarban 60. U-0.435 SHGC-0.383	Savings shown is compared to ASHRAE 90.1-2010 code minimum.	$1,108		$0	$0	$0		
	Upgrade new windows from Solarban 60 to Solarban 70xl. U-0.433 SHGC-0.223		$2,948		$0	$0	$0		
	Provide 40% frit on 100% of new glazing assuming Solarban 60 assembly. U-0.381 SHGC-0.313	Calculations of frit per LBNL Window 6	$2,424		$0	$0	$0		
Lighting									
Fluorescent Lighting	(Baseline) Fluorescent lighting design based on Electrical Engineer sample spaces	Savings shown is compared to ASHRAE 90.1-2010 code maximum. Overall 10% reduction in lighting power consumption	$893		$0	$0			
LED Lighting	LED lighting design based on Electrical Engineer sample spaces	Overall 14% reduction in lighting power consumption	$1,173		$0	$0			
Daylighting Controls	Assumes 60% VT on glazing and controls in all exterior spaces		$801		$0	$0			
Equipment									
Energy Star Equipment	Required by the DFCM HPBS	Reduction based on Energy Star calculator for office and kitchen equipment.	$130		$0	$0	$0		
Elevators	Regenerative Elevator Drives	Not available on hydronic elevators	N/A						
Mechanical									
Mechanical HVAC Systems									
VAV	(Baseline)		0	0		$0	$0	$0	-
DEC w/ VAV (common AHU)	Direct Evaporative Cooling serving common space		$2,556	$45,000	$2,000	$10,000	$1,500	-$28,125	40+ years
DEC w/ VAV (game day AHU)	Direct Evaporative Cooling serving game-day space		$791	$50,000	$2,000	$20,000	$3,780	-$72,035	Never
IDEC w/ VAV	Indirect Direct Evaporative Cooling (IDEC) serving common and game-day spaces		$3,778	$145,000	$6,500	$90,000	$7,932	-$247,048	Never
Water cooled chiller	Air cooled chiller replaced with water cooled chiller		$1,571	$227,000	$4,000	$168,000	$0	-$293,928	Never

General Notes:

1. Energy cost savings results of each EEM are not additive. Selected EEMs must be evaluated as a whole for final energy cost savings.
2. Utility rebates are conceptual only. Final utility rebates to be determined by utility.
3. Baseline budget and EEM pricing is at a conceptual phase only. Equipment and system selections have not been finalized.