PW103012-28

Energy Efficiency and Renewable Energy Initiative

City of Rapid City, South Dakota

Final - Revised
April 30, 2010

Stanley Consultants INC.
A Stanley Group Company
Engineering, Environmental and Construction Services - Worldwide

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I hereby certify that this report was prepared by me or under my direct personal supervision and that I am duly Registered Professional Engineer under the laws of the State of South Dakota.		
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Executive Summary

The City of Rapid City retained Stanley Consultants to provide professional engineering services for a review of existing city facilities to identify capital improvement opportunities that will improve energy efficiency and possibly utilize renewable energy. This report presents the results of the preliminary review phase of this project.

Stanley Consultants met with the facility managers of buildings operated by the Parks and Recreation Department, Fire Department, Police Department, Public Works Department, Airport Department, Library Department, and Civic Center during a one-week, onsite visit March 1–5, 2010. An initial screening audit was performed. The screening audit identified feasible energy efficiency or renewable energy projects based on achieving a less than 15-year payback.

For this study, actual electricity rates for each facility were used and escalated 20% to account for the expected Black Hills Power rate increases. The natural gas rate used in the study was $7.63/mmBTU. This rate is based on the actual February 2010 blended rate which includes the basic service charge, a distribution delivery service charge, and the cost of natural gas.

There are twenty-two opportunities identified in Section 5, Table 5-1 that had estimated paybacks of less than 15 years. These include electrical, mechanical, and renewable energy projects. Fifty percent of these projects have a capital cost of less than $10,000. Eighty-two percent of these projects have a capital cost of less than $50,000. The maximum capital cost of a single recommended project is $525,000.

There are seven opportunities identified in Section 5, Table 5-2 that were technically feasible, would provide energy reduction and/or provide renewable energy, but had paybacks in excess of 15 years. For each of these projects, the amount of a grant required to achieve a 15-year payback was calculated. The energy price to achieve a 15-year payback (without a grant) was also calculated. Regulation of carbon dioxide emissions in the future would likely make these projects financially viable.

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Section 1

Building Summaries

Water Reclamation Plant

The Water Reclamation Plant has several buildings including a newer administration office occupied ~6:00 AM–4:30 PM, M–F, Filter operations building, Machine Shop, UV building, and smaller miscellaneous process buildings.

The administration office building is heated and cooled via water source heat pumps located throughout the building and auxiliary electrical strip heaters. Heat is provided to the heat pump's water loop via an electric boiler and heat is rejected from the loop to treated wastewater effluent though a plate and frame heat exchanger. This method of heating and cooling is very efficient and a very good application for this facility.

The administration office building contains a lot of windows and skylights providing natural light. Plant staff indicated that the building overheats in the summer and that the heat exchanger is undersized. Another alternative to investigate is to add window films to decrease the solar heat gain penetrating through the windows. Depending on how undersized the heat exchanger is, reducing the solar gain by adding window films may reduce the cooling load enough that replacing the heat exchanger is not necessary. Window films would need to also be reviewed for acceptance by the building occupants and any additional lighting costs due to the decrease in transmittance of light.

The remaining buildings at the Water Reclamation Plant are heated to comfort levels only when occupied.

The administration building utilizes T8 fluorescent lamps. Because of the skylights in the corridors, many lights were turned off which is a great energy saver.

Material Recovery Facility and Co-Compost Buildings

The Material Recovery Facility is operated 7:00 AM–5:30 PM, M–F. It consists of several rooms including an office, the TIPS room, bailing room, a maintenance bay, and recycling room. The office is heated and cooled by packaged rooftop units. The remaining rooms are heated only with overhead gas fired radiant heating units. The heating units are used only for the coldest outdoor temperatures.

Adjacent to the Material Recovery Facility is the Co-Composting Building. The building is ventilated to eight air changes per hour. It is not heated unless it is below ~40°F outside when gas fired furnaces are used to raise the indoor temperature in order to keep the compost above minimum required temperatures.

The high bay areas utilize metal halide lighting fixtures. These fixtures do not have as good of efficiency as fluorescent fixtures. Fluorescent fixtures have come a long way in the last ten years to replace HID lighting indoors. The payback to replacing these light fixtures is investigated in the Electrical section.

Street Department Facilities

The Street Department has several buildings all located on a central campus. The office is occupied ~7:00 AM–3:30 PM, M–F, and the shops are occupied mainly during the week 7:00 AM–11:00 PM. However, the buildings can be occupied at all hours of the day or night depending on weather conditions. The office area is heated and cooled with a roof mounted packaged heat pump system. The shops are heated with a mix of gas fired unit heaters, overhead gas fired radiant heaters, and waste oil heaters.

The Water Department buildings adjacent to the Streets Department also consist of an office and utility maintenance building with similar operating hours as the Streets Department facilities. The office is heated and cooled with a split system (gas furnaces, electric condensing units) and auxiliary electric heaters. The Water Department maintenance and storage buildings are heated with a mix of unit heaters and overhead gas fired radiant heaters.

All street department sites utilize fluorescent lighting fixtures in the storage and maintenance bays.

Airport Facilities

The main airport terminal is operated ~4:30 AM–10:00 PM, 7 days a week. A remodel and expansion of the concourse is currently in planning stages. Also on the airport campus are maintenance buildings and the TSA office building.

The terminal is heated and cooled by two main air-handling units served from a central chilled water system and a central hot water system. The central chilled water system consists of a dual compressor water-cooled chiller and cooling tower. There are variable frequency drives (VFD) on the chiller compressors, chilled water pumps, condenser water pumps, and cooling tower fan. All chilled water equipment has been recently replaced. This type of "all variable speed" chilled water plant has the ability to be very efficient if operated properly. Heating is provided via a central boiler system. It appears to be original to the airport and the boilers are therefore close to

their expected service life. When they are replaced more efficient condensing boilers should be considered. The viability for energy savings will depend on the modifications necessary to lower the system temperatures. Condensing boilers are only more efficient than more traditional boilers at lower hot water temperatures.

The airport contains many T12 fluorescent lighting fixtures.

Airport maintenance buildings are heating by overhead gas fire radiant heating systems. The maintenance bay includes a gas fired makeup air unit and the break room areas are air conditioning by packaged split systems.

The TSA office building is a new building occupied ~5:00 AM–8:00 PM, 7 days a week. It is heated and cooled by split systems. The heating system includes condensing boilers.

Rushmore Plaza Civic Center

The Rushmore Plaza Civic Center consists of several types of entertainment venues including an arena, exhibition halls, meeting rooms, performance theatre, and professional ice rink. The original building was built in the mid 1970s and has had several additions since. Event usage ranges from ~200 days/year for the arena to ~300 days/year for the exhibition halls. The main offices have typical office hours; however, events and meetings regularly occur on nights and weekends.

The arena, exhibition halls, ice rink, and theatre have multiple constant volume air-handling units serving each respective area. Event schedules are entered into the HVAC control system so that only air handling equipment that is necessary for each event is used. This is a very good technique to minimize energy usage. The meeting rooms and offices have variable air volume (VAV) systems that use VAV boxes to modulate air as required for each zone.

Chilled water and hot water are generated at the central plant. A separate previous study has outlined plant improvements including improvements to decrease energy use.

The civic center includes a kitchen which is generally a major source of energy use. It is in operation ~325 days/year. All kitchen equipment is electric. Replacing kitchen equipment with equivalent gas fired models was briefly investigated, but does not pay back within 15 years based on current utility rates. If the kitchen undergoes a major remodel or equipment maintenance replacement program, converting to gas fired equipment should be reevaluated. The kitchen's ice making equipment consumes water for not only the ice itself, but also for heat rejection of the heat removed from the ice. The water is discharged to the sanitary sewer. See Section 2 for Energy Conservation Measure M-4 to replace ice machines with models that have remote condensers to reject heat to the exterior of the building. The kitchen coolers and freezer have condensers located on the top that reject heat into the kitchen. Replacing the condensers with remote models that reject heat to the exterior of the building should also be considered when the equipment reaches the end of its service life.

The Civic Center contains many incandescent lighting fixtures. Recommendations are made to replace these fixtures with more energy efficient technologies in the Electrical section.

Roosevelt Park Swim Center

The Roosevelt Park Swim Center includes a natatorium, office, and exercise facilities.

The natatorium is heated and cooled via a large central air-handling unit including an energy recovery wheel along with the heating and cooling coils. An air-cooled chiller with remote evaporator provides chilled water to the facility. Hot water is provided from a central heating plant consisting of gas-fired, forced-draft, cast iron boilers. An additional boiler has failed due to cracking of the internal cast iron sections. This is most likely caused by thermal shocking of the boiler due to low return water temperature. Operation must be carefully monitored to ensure the boiler return water is kept above manufacturers operational limits. If the existing boilers ever need to be replaced, boilers specifically designed for this application should be considered. The Laars boilers at the other city pool sites are one type of boiler better suited for the application. Pool heating is also served from the main heating plant through heat exchangers.

Maintenance staff indicated that one section of the main air handling unit heating coil is leaking and no longer in service. All equipment should be properly maintained and replaced, if necessary, to keep systems as efficient as possible and to avoid damaging other equipment.

Roosevelt Park Ice Arena

The Roosevelt Park Ice Area is similar to the swim center in that it is also a newer facility. Staff occupies the facility from ~6:00 AM–11:00 PM, 7 days a week. Full use of the facility occurs ~11:00 AM–11:00 PM.

Packaged roof top units and a dehumidifier heat and cool the facility. The refrigeration system is a custom system consisting of reciprocating compressors sized for both the current ice rink and a future rink. It includes an ice melt pit that uses the heat of rejection from the refrigeration system to melt waste ice. When the system reaches the end of its service life, new equipment should be sized for only the current rink for maximum efficiency since the future rink is no longer forecasted. The cooling tower and refrigeration system are in need of repair. All equipment should be properly maintained and replaced, if necessary, to keep systems as efficient as possible and to avoid damaging other equipment.

The Ice Arena also has an un-insulated coiling door. Door replacement was investigated, but does not pay back within 15 years with current utility rates.

The arena lighting utilizes 400W metal halide fixtures. Newer municipal ice arenas are now being designed using T5HO fluorescent lighting fixtures. They consume less energy and provide a more even and comfortable light. See the electrical section for an investigation to replace the metal halide fixtures.

Parks Department Maintenance Facilities

The Parks Department campus includes an office, maintenance buildings, and greenhouse.

The office is occupied ~7:30 AM–4:00 PM, M-F. It is a repurposed house heated and cooled with a split system (standard efficiency gas fire furnace and condensing unit). The office break area includes an under-counter refrigerator that should be replaced with a modern model.

The maintenance building consists of an old shop area and new shop area. The new shop area is ~1 yr old. It includes a split system for heating and cooling the office (high efficiency furnace and condensing unit) that also includes a heat recovery ventilator to provide outside air efficiently. The wood shop is heated with an overhead gas fired radiant heater. The old shop area is heated with overhead gas fired radiant heaters. Old gas fired unit heaters still in the space are not used. The old shop area has un-insulated overhead doors. Door replacement was investigated, but does not pay back within 15 years with current utility rates.

The greenhouse is heated with a standard efficiency boiler and finned tube around the perimeter. The piping is not insulated; however, staff indicates that the heat radiating from the piping is used to heat the office area offsetting energy used by a gas-fired heater located in the office area.

Parks department garages utilize T12 and T8 fluorescent lighting fixtures.

Halley Park Building

The Halley Park Building is an old stone building with a 1950s addition. It is heated by split systems (high efficiency gas fired furnaces and condensing units). They are located in the attic.

The attic contains a very small amount of insulation. Renovations have added a wall with windows on the interior side of the exterior wall making the windows two pane. The interior portion of the wall may contain insulation. However, due to the fact that the attic contains so little insulation, the wall insulation should be verified and upgraded, if necessary. A small hole in a storage room or closet can be bored to investigate the interior wall construction. Cavity walls can be filled with loose fill insulation blown into the cavity.

Swimming Pools

The outdoor swimming pools with the exception of Horace Mann are all newer facilities. They are all operated only during the summer. The pools are heated with specialty pool boilers well suited for the application. Buildings are heated with unit heaters.

The Horace Mann pool is much older than the other pools and due to severe cracking the pool leaks significantly. This facility should be evaluated to see if further investment is warranted. For each 1 gpm of leaks during summer months costs the city approximately $715/yr at current utility rates. The bathhouse is lit using all incandescent lighting fixtures. The incandescent lamps should be replaced with compact fluorescent.

All pools except for the Jimmy Hilton facility are drained for winter. Maintenance staff indicates that the Jimmy Hilton pool is not drained due to difficulty ensuring that all water is removed. Therefore, the pump building is heated year round. The cost to heat the building year round is

significant and further research should be conducted to investigate if modifications are possible to completely drain the pool system to avoid heating the pump building year round.

Mt View Cemetery

The Mt View Cemetery building includes an office and maintenance facility. The building has CMU block walls, single pane windows, and un-insulated overhead doors. Door and window replacement was investigated, but does not pay back within 15 years with current utility rates.

The office is cooled with a wall-mounted air conditioner and heated with a separate gas fired furnace. The maintenance part of the facility is heated with gas fired unit heaters.

Fire Stations

All fire stations are occupied 24 hours a day, 7 days a week.

The Main Fire Station #1 is heated and cooled with a Variable Air Volume (VAV) roof top unit. VAV boxes with heating coils are located throughout the facility. Two gas-fired boilers provide hot water to the VAV boxes. The apparatus bay is heated with overhead gas fire radiant heaters. A maintenance bay is included in the facility heated with a gas fired unit heaters. Windows in the office area are single pane. Window replacement was investigated, but does not pay back within 15 years with current utility rates.

The South Fire Station #4 was built in 1993. The dorm portion of the building is heated and cooled with two packaged roof top units. The apparatus bay is heated with overhead gas fire radiant heaters.

Fire Station #6 was built in 2004. The office portion of the building is heated and cooled with a packaged rooftop units mounted on grade. The dorm portion of the building is heated and cooled with split systems (high efficiency furnaces and condensing units). The apparatus bay is heated with a hot water radiant floor system served from a traditional cast iron boiler.

The Southwest Fire Station #5 was built in 1980. The dorm portion of the building is heated and cooled with split systems (high efficiency furnaces and condensing units). The apparatus bay is heated with gas fired unit heaters. The apparatus bay includes uninsulated overhead doors with single pane windows. Door replacement was investigated, but does not pay back within 15 years with current utility rates.

The West Side Fire Station #3 was built in 2006. The dorm portion of the building is heated and cooled with a split system (high efficiency furnace and condensing unit) and includes a heat recovery ventilator to preheat outside air from exhaust air. The apparatus bay is heated with a hot water radiant floor system served from a high efficiency condensing boiler and a gas fired unit heater.

Meadowbrook Golf Course

The Meadowbrook Golf Course Clubhouse was renovated in 2002. It is heated and cooled by a split system (high efficiency air handling unit and duct furnace, high efficiency condensing unit) located in the attic space.

The Meadowbrook maintenance building is 1950s era building currently in the city queue for replacement. The building has little to no insulation, single pane windows, and old heating/cooling equipment. This building is in need of replacement and any energy efficiency upgrades are not practical considering the remaining expected service life of the building.

The adjacent storage building and irrigation pump building are additional facilities at the golf course. The storage building should be renovated with insulated overhead doors, new building insulation, and more efficient heating equipment if the building is part of the adjacent construction project to replace the maintenance building. However, improving the building based on energy efficiency alone will not pay back within a 15-year period.

Executive Golf Course

The Executive Golf Course has a maintenance building and a clubhouse. The maintenance building is used ~5:00 AM–1:30 PM. It is a simple metal building heated with a gas fired unit heater. The clubhouse is a house repurposed as a clubhouse. It is used only during golf season, but heated all year long. Since the clubhouse is not used year round the plumbing systems should be investigated to determine if they can be winterized to avoid heating year round.

The clubhouse is heated and cooled with a split system (older standard efficiency gas fired furnace and condensing unit). The attic contains a small amount of insulation. Adding additional insulation to the attic was investigated but does not pay back within 15 years with current utility rates. If the building is winterized payback would be even longer. If the building is not winterized and utility rates rise, adding additional attic insulation should be reevaluated.

Downtown Library

The Downtown Library is operated from 9:00 AM–8:00 PM Mon.–Thurs., 9:00 AM–6:00 PM Fri.–Sat., and 12:00 AM–6:00 PM Sun. It was built in 1972, but expanded and renovated in 2002.

The original part of the building is heated and cooled from two main multi-zone air-handling systems. The new addition is served from a roof top unit with VAV boxes with heating coils throughout. Hot water is generated from two traditional gas fired cast iron boilers. Chilled water is generated with a packaged air-cooled chiller. The boilers, chillers, and water distribution systems were replaced in the 2002 renovation.

The new addition to the library has many windows, and because they are south facing, allows a lot of light through. This is very noticeable in the upper children's library and stairway. Day lighting controls can be utilized to save energy.

Dahl Arts Building

The Dahl Arts Building is operated from 11:00 AM–5:00 PM, Tues.–Sat., with additional hours of 5:00 PM–7:00 PM on Friday evenings. It includes an addition and recent renovation.

It is cooled by a variable air volume (VAV) system. VAV boxes with reheat coils are located throughout the facility. Ceiling hot water radiant heating panels and finned tube convectors provide additional heat. A VAV roof top unit provides air and cooling to the VAV boxes and includes high efficiency air filtration. High efficiency condensing boilers and hot water pumps with VFDs generate hot water to heat the building.

An uninsulated coiling overhead door has excessive infiltration directly into the gallery. Overhead door replacement was investigated, but does not pay back within 15 years with current utility rates. Additional weather stripping should be provided for the opening to improve comfort and protect artwork from possible damage.

The lighting in the exhibit areas are mainly incandescent and halogen fixtures. Some museums today are choosing to go with LED technology for lighting. The American Museum of Natural History and the Chicago Field Museum both chose a track head fixture by Lumelex to light some of the museum displays. Speaking with one of the local lighting reps in Minneapolis, Zumtobel lighting was recommended as a high quality museum light fixture. Both fixtures allow adjustment of light level and cool/warm tones.

This study will not make a recommendation as to whether the existing lighting should be changed out to a more energy efficient light. To make this type of recommendation, a much more in-depth study would be required to investigate lighting quality along with energy efficiency.

LED lighting is an emerging technology. White light LEDs have only been in existence since the late 1990's. LED lighting quality varies greatly as standards for these types of lights are being developed. Through my discussions with local lighting reps and facility owners, I received a very mixed opinion on whether LED lighting is mature enough to make the investment. Some lighting reps cautioned me due to LED color changing over time and lamp life not meeting the 50,000hr advertized life. Other reps told me that many fixture manufacturers in the industry have corrected these issues.

Current LED technology uses about 1/3 the energy usage of incandescent/halogen. LED lights also do not produce UV or IR wavelengths in the lighting spectrum. LED fixtures do cost substantially more than incandescent or halogen. A museum quality LED track head will cost between $250 and $500. For the Dahl, changing out track lighting has a potential saving 50W for each track head which would achieve an electrical savings of $1,455/yr. If we consider that each new LED track light will cost $325, the investment to upgrade the system is $65,000. This gives a simple payback of 45years.

Police Evidence, Transportation, and Traffic Building

The Police Evidence, Transportation, and Traffic Building was recently remodeled in 2008. The building is heated with gas fired unit heaters. Vehicle bays include ventilation systems with carbon monoxide and nitrogen dioxide sensors. The office areas are heated and cooled by packaged roof top units. The traffic office area includes a very old refrigerator that should be replaced with a modern model.

Lighting throughout the facility utilizes T8 fluorescent fixtures.

Milo Barber Transportation Center

The Milo Barber Transportation Center is currently under being renovated. It includes new windows, a new roof, new lighting, and new HVAC equipment. The new HVAC equipment consists of a packaged VAV roof top unit, VAV boxes throughout the facility, a high efficiency condensing boiler, and hot water distribution pumps with VFDs. See Section 2 for general mechanical recommendations that apply to all buildings.

City School Administration Center

The City School Administrative Center is occupied 7:00 AM–5:00 PM M–F. Heating and Cooling is provided by water source heat pumps located throughout the facility. Outside air is supplied to the heat pumps from a central outdoor air fan and exhaust located in the basement. The outside air system includes an air-to-air heat recovery system. Heat is provided to the heat pump water loop, when necessary, from five cast iron boilers. Cooling is provided to the loop from a closed circuit cooling tower also located inside the basement.

The water source heat pumps are in process of being replaced along with a controls upgrade as the individual equipment reaches the end of its service life and as funds allow. When the boilers reach the end of their service life they should be replace with condensing boilers which are a good fit for this type of system. In addition the soil engineering area includes a very old refrigerator that should be replaced with a modern model. See Section 2 for general mechanical recommendations that apply to all buildings.

Parking

Covered parking areas have had lighting fixtures recently updated to LED type. The uncovered parking areas utilize pole-mounted HID fixtures for lighting. It is recommended that lighting in the uncovered parking areas remain as is. See the electrical section for an investigation of LED lighting fixtures for these areas.

Section 2

Mechanical Energy Conservation Measures

General Recommendations

The following recommendations are low cost items that can be implemented as part of normal maintenance budgets, as applicable. Also included are recommendations for energy efficiency improvements that can be implemented as equipment is replaced and buildings are renovated.

Building Envelope

Additional building insulation, higher efficiency windows, and higher efficiency doors beyond energy code minimums typically pay back in less than 15 years. Unfortunately, adding additional insulation is very difficult and does not pay back unless the building is new or being renovated that allows access to the interior of walls and roofs. Whenever a building is renovated, re-roofed, or equivalent improving the building envelope should be investigated.

Packaged Equipment

Packaged HVAC equipment is typically available in standard models that meet the current minimum energy code requirements and premium models that have higher efficiency. When packaged equipment reaches the end of its service life, high efficiency models should be considered as replacements.

Boilers

Cast iron boilers found in many of the city facilities have an efficiency of ~82%. In the past five years condensing boilers have become widespread and reliable. They are able to condense water out of the flue gas resulting in efficiencies as high as 98%. Unfortunately, they are only able to reach this efficient with lower than traditional hot water supply temperatures. When cast iron boilers reach the end of their service life, the building hot water system should be investigated to see if it is compatible with lower hot water supply temperatures and if so, condensing boilers should be considered along with a lower building hot water temperature.

Water source heat pump systems and radiant floor systems are almost always operating at compatible lower hot water temperatures. Air handling unit coils and VAV box coils can usually be accommodated by resetting the hot water supply temperature lower as outside air temperature rises. This allows the hot water supply temperature to remain at a higher temperature when the building coils need their peak capacity (cold outside), but save energy (lower pipe losses and higher boiler efficiency) when the coil needs only part of its capacity (warm outside).

Decrease Heating Temperature Setpoint

Many city storage and maintenance facilities that were not normally occupied had thermostat setpoints intended for comfort conditions (upper 60°F's). If facility heating is intended only to protect piping and equipment from freezing, often times the thermostat can be set at ~55°F and still maintain all parts of the facility above freezing temperatures.

Programmable Thermostats

Many of the small city facilities do not use central control systems. The HVAC systems for these buildings should be controlled with programmable thermostats wherever possible. The programmable thermostat can be installed for ~$300 resulting in a typical payback of less than 3 years. It is important that a champion is assigned to keep the thermostat programmed properly otherwise projected savings will not develop.

Energy Efficient Refrigerators

The Department of Energy estimates that Energy Star refrigerators save owners approximately $100/yr in electricity costs over models manufactured in the 1980's and $200/yr in electricity in costs over models manufactured in the 1970's. Therefore, a new energy star refrigerator purchased for $1000 will pay back in ~5 years if a 1970's era refrigerator is replaced and will pay back in ~10 years when a 1980's era refrigerator is replaced.

Kitchen Grease Exhaust Hoods

When kitchen grease exhaust hoods reach the end of their service life, new hood systems that include hood control systems incorporating Variable Frequency Drives (VFD) should be considered. New kitchen hood technology is available that includes controls, sensors, and VFDs that decrease the exhaust and supply airflow to ~80% of peak when the heat and smoke sensed in the exhaust airstream indicates that the kitchen equipment under the hood is not operating heavily. These systems are a viable way to save energy when the kitchen equipment is used intermittently.

Compressed Air

The Rushmore Civic Center and main Airport Terminal have compressed air systems for pneumatic HVAC control systems. All fire stations and city maintenance buildings also have compressed air systems for shop tools. Often overlooked for energy savings, optimized compressed air systems can result in savings from 20-50%. This includes checking the piping systems for leaks, running the system at the lowest possible pressure, and turning off compressors when not in use. Compressed air users should be notified of its costs so that users can properly limit compressor runtime and maintain piping systems properly.

M-1 Co-Composting Facility Heat Recovery System

Existing Conditions

The Co-Composting Facility must be ventilated to eight air changes per hour continuously and heated when the ambient air temperature drops below approximately 40°F. Heating the ventilation air is required in order to keep the compost warm.

Solution

Add heat recovery coils in the exhaust air stream and the two makeup unit airstreams. A pump circulates a glycol solution between the two coil sets moving heat from the exhaust airstream to the makeup airstream.

Savings

Assuming a 50% effectiveness of heat transfer, savings are estimated at approximately $34,502/yr. Detailed calculations are provided in Appendix A.

Investments

A heat recovery system including coils, pump, piping, insulation, controls, glycol, and engineering will cost approximately $169,950. Detailed calculations are provided in Appendix A.

Payback

Payback is approximately $169,950/($34,502/yr)= 4.9 yrs.

M-2 Light Vehicle Maintenance Facility Waste Oil Heater

Existing Conditions

The Light Vehicle Maintenance Facility is heated by a gas fired unit heater.

Solution

Adding an additional heater served by waste oil recovered from the vehicle maintenance function of the Streets Department can be used to heat the building instead of natural gas used by the unit heater.

Savings

Heating a maintenance building of the approximate size and construction of the Light Vehicle Maintenance Facility with a gas fire unit heater costs approximately $1591/yr. Detailed calculations are provided in Appendix A.

Investments

A waste oil heater to heat a facility of this size costs approximately $4650 to furnish and install.

Payback

Payback is approximately $4650/($1591/yr)= 2.9 yrs.

M-3 Rushmore Civic Center Supply Fan VFDs

Existing Conditions

The Air Handling Unit supply fans serving the meeting rooms and offices of the Rushmore Plaza Civic Center are modulated by moving inlet guide vanes in the supply fan inlet. This has the effect of decreasing the fan capacity to match the load in the building.

Solution

Remove the inlet guide vanes, replace the motors, provide Variable Frequency Drives (VFD), and controls. Controls monitor the duct pressure and decrease the fan speed as necessary to modulate the airflow to only what is required to match the load.

Savings

Savings for all three systems (SF-13, SF-14, and SF-9) are estimated at approximately $17,254/yr. Detailed calculations are provided in Appendix A.

Investments

Construction cost to furnish and install motors, VFDs, controls, and demolition is approximately $48,625. Detailed calculations are provided in Appendix A.

Payback

Payback is approximately $48,625/($17,254/yr)= 2.8 yrs.

M-4 Rushmore Civic Center Kitchen Ice Machines

Existing Conditions

The Rushmore Plaza Civic Center Kitchen includes ice machines that reject the heat removed from the ice to potable water and then discharge it to the sanitary sewer.

Solution

Replace ice machines with models that include remote air-cooled condensers that reject heat to the exterior of the building.

Savings

Assuming kitchen use of 325 days/yr and ice use of 1800 lbs/day, the savings are approximately $3194/yr. Detailed calculations are provided in Appendix A.

Investments

New ice machines to produce approximately 1800 lbs/day are estimated to cost approximately $20,000 to furnish and install.

Payback

Payback is approximately $20,000/($3194/yr)= 5.2 yrs.

M-5 Halley Park Building Roof Insulation

Existing Conditions

The Halley Park Building is an old structure that has very little attic insulation. The insulation is rock wool or equivalent that is approximately 2 inches thick.

Solution

Add additional insulation to the attic space by blowing in fiberglass insulation on top of the existing insulation. Considering the lack of roof insulation, wall insulation may not be much better and should be investigated further.

Savings

The savings are approximately $747/yr. Savings reflect additional attic insulation only. Detailed calculations are provided in Appendix A.

Investments

Twelve inches of blown fiberglass insulation costs approximately $1.75/SF. The building is approximately 4,590 SF. 4,590 SF*$1.75=$8,033.

Payback

Payback is approximately $8,033/($747/yr)=9.7 yrs.

Section 3

Electrical Energy Conservation Measures

E-1: Retrofit Kits for T12 Parabolic Light Fixtures at City/School Administration Building

Existing Conditions

The City has many T12 fluorescent fixtures. This older fluorescent technology is slightly less energy efficient than new technology T8 and T5 fixtures. Replacing existing T12 fixtures with new T8 or T5 fixtures rarely pay back in less than 10 years because the typical retrofit kit will cost around $100 installed and energy savings is only a few dollars each year. This report will not look at replacing T12 lighting fixtures in most building, even though new fixtures are more energy efficient, because of poor paybacks. The City and School Administration Building is the only building that has potential to replace the T12 fixtures and see a reasonable payback. The reason that this building will have a reasonable payback is that we can replace 4 lamp parabolic fixtures with a 2 lamp volumetric fixture saving fixture watts. This was the only building observed where the T12 fixtures could be replaced and save significant wattage. Also, there is a special retrofit kit for these T12 fixtures.

The City and School Administration Building has (362) 4-lamp, T12 parabolic fixtures and (289) 2-lamp U-tube T12 fixtures. Lithonia Lighting, along with other manufacturers like HE Williams, claims to be able to replace the 4-lamp fixture with a 2-lamp 28W T5 fluorescent fixture and achieve a comparable light level. They can do this because the new T5 fixtures are designed for more efficient light output, have higher lumen/watt lamps, and are overdriving the lamps to get additional light.

Prior to replacing all fixtures in the facility, it is recommended that a room or two be used as a testing area to see the comparison. We ran the photometrics on AGI32 software. We used mean lumens for all lamps. The T12 fixtures were set to an industry ballast factor of .88 and the T5 fixtures were set to a ballast factor of 1.15. Our comparison showed a 9% reduction in average light levels which would likely be acceptable. It should also be noted that by

eliminating the "cave effect" lighting of the parabolic fixtures, the lighting would probably appear to be brighter with the T5 lights.

Lithonia and other manufacturers sell a retrofit kit for around $90 per fixture. Lithonia's retrofit kit is the RT5 kit. It is estimated that each fixture could be retrofitted for around $10 in labor. Lithonia has stated that it takes less than 10 minutes per fixture. The cost is the same for the 2X4 and the 2X2 fixtures.

Parabolic T12 Fixture
Figure 3-1

Solution

Retrofit each T12 parabolic fixture with a new T5 fixture.

Savings

1. 4-lamp 2X4 Parabolic energy savings are estimated at $10,151/yr.
2. 2-lamp 2X2 U-lamp energy saving are estimated at $3,570/yr.

Investments

1. 4-lamp 2X4 Parabolic replacement: $36,200.
2. 2-lamp 2X2 U-lamp replacement: $28,900.

Payback

1. 4-lamp 2X4 Parabolic: The resulting payback is ($36,200/$10,151) 3.6 years.
2. 2-lamp 2X2 U-lamp: The resulting payback is ($28,900/$3,570) 8.1 years.

E-2: Rushmore Plaza Civic Center

Existing Conditions

Rushmore Plaza Civic Center was built in 1976. It has a wide mix of metal halide, fluorescent and incandescent fixtures. The facility supports varying performances and exhibits and houses an arena, auditorium, kitchen, ice arena, and conference halls.

Each space will be examined separately to determine any potential electrical savings.

1. Arena: The Civic Center Arena uses the following lighting types in the Arena area:
   - (32) 1000W metal halide fixtures over the arena floor for normal use.
   - (32) 1000W incandescent over the arena floor for normal use and dimming.
   - (32) 1000W metal halide fixture used only for televised events.
   - (30) 1000W incandescent fixtures over the seating area (rarely used).

   The arena is utilized around 200 event days each year. During a typical event, the (32) 1000W metal halide fixtures and (32) 1000W incandescent fixtures over the arena floor are on for 18 hrs each day. The (32) 1000W metal halide fixtures for televised events and the (30) 1000W incandescent fixtures of the seating area are rarely used.

2. Rushmore/Lacroix Halls A, B, C, D, and North:
   - The Rushmore and LaCroix halls have 140 dimmable quartz fixtures. These fixtures are in operation for approximately 300 event days each year and operate 18hrs each event day.

Rushmore Hall
Figure 3-2

3. Decorative Lighting:

- There are (18) 24-lamp pole mounted decorative posts, and (10) 8-lamp decorative wall fixtures. Each lamp is a 40-W incandescent and operates approximately 8 hours each day. Each lamp can be replaced one-for-one with a 1.5W to 5W LED lamp. It is suggested to try the replacement at one fixture to determine if the LED lamp meets expectations before performing a bulk replacement.

24-Lamp Decorative Pole Light
Figure 3-3

1.5W LED Replacement Lamps – Sam's Club
Figure 3-4

4. Corridor Lighting:
   - The corridor lighting is a mix if incandescent and metal halide. There metal halide downlights and uplights, incandescent downlights, and incandescent track lighting. This report will recommend replacing the incandescent lamps in the existing downlights with a compact florescent. The compact fluorescent lamp will screw into the existing downlight base. There are (62) 150W incandescent downlights in the corridor.
   - There are (38) 150W incandescent lamps in existing track lighting.
   - This is a total of (100) 150W incandescent lamps.
   - The corridor lighting is on an average of 12 hrs/day, 7 days/week.

Solution

1. Arena: Replace the (32) 1000W incandescent lamps over the arena floor with 175W metal halide fixtures. The fixture should utilize a shutter system to allow them to be dimmed.

   Although this write-up will not look at the 1000W incandescent light fixtures over the seating area, it needs to be noted that these fixtures are very inefficient. An incandescent lamp at this wattage uses approximately 10 times more energy than an equivalent fluorescent fixture. If these fixtures had large operating hours during the year, replacing them would pay back very quickly.

2. Rushmore/Lacroix Halls: Replace the dimmable quartz fixtures with dimmable fluorescent fixtures.

3. Replace 40W incandescent decorative lighting with 1.5W LED lighting. There are many LED lamp options out there. LED lamps are constantly improving and coming down in cost. The lamp chosen for this write-up is a 1.5W decorative LED lamp that costs around $3.50 each.

4. Replace the (100) incandescent lamps throughout the corridor with a 26W compact fluorescent lamp.

Savings

1. Arena: The energy savings is estimated at $9,861/yr.
2. Rushmore/LaCroix Halls: The energy savings is estimated at $32,680/yr.
3. Decorative Lighting: The energy savings is estimated at $844/yr.
   - The lamp replacement savings are estimated at $256/yr.
   - Total savings = $735/yr + $256/yr = $991/yr.
4. Corridor Lighting: The energy savings is estimated at $3,326/yr.

Investments

1. Arena: Each of the (32) watt incandescent fixtures will be replaced with a new 175W metal halide fixture with a shutter.
   - Total cost is 32 fixt * $600/fixt = $19,200
2. Replace 80 incandescent fixtures with 80 fluorescent dimmable fixtures with controls: Replacement cost is (Dimmable fluorescent fixture is $125 with $125 installation cost) $250/fixt.
   - Total cost is 80 fixt * $250/fixt = $35,000
3. Each LED lamp costs $3.50.
   - 512 lamps * $3.50/lamp = $1,792
4. Each lamps costs approximately $10
   - 100lamps * $10/lamp = $1,000

Payback

1. Arena: The resulting payback is ($19,200/$9,861) 1.9 years.
2. Rushmore/LaCroix Halls: The resulting payback is ($35,000/$32,680) 1.1 years.
3. Decorative Fixtures: The resulting payback is ($1,792/$1,100) 1.6 years.
4. Corridor Lighting: The resulting payback is ($1,000/$3,326) 0.3 years.

E-3: Replace HID High Bay Lighting with Fluorescent

Existing Conditions

The City of Rapid City is very good about using fluorescent lighting in high bay and low bay areas. Fluorescent fixtures are used in all of the maintenance facilities and fire stations that we visited.

Two sites were observed to have metal halide lighting. Material Recovery Facility and Roosevelt Ice Arena currently use metal halide fixtures. 15 years ago, Indoor high bay lighting was typically installed using HID. Metal halide lighting was very common in maintenance facilities, fire stations, and ice arenas.

With the increased performance of lamp and ballast technologies, fluorescent fixtures provide as good or better light levels while using less energy. Fluorescent fixtures should be considered for all new installations. And replacing existing HID fixtures will usually have an acceptable payback.

The Material Recovery Facility is operating from 7am to 5pm Monday through Friday.

The Roosevelt Arena lighting is operating from 11am to 11pm 7 days per week.

Material Recovery
Figure 3-5

Roosevelt Ice Arena
Figure 3-6

Solution

1. The Material Recovery facility uses metal halide lighting fixtures in its high bay areas. The Tip Floor uses 80 400W metal halides. The Bailer room uses 23 400-watt metal halides. The Recycling room uses 60 400W metal halides.

   This is a total of 163 metal halide fixtures. Each 400W metal halide fixture (26,500 mean lumens per lamp) can be replaced with one 4-foot, 6-lamp T4HO fixture (4,600 mean lumens per lamp).

2. The Roosevelt Ice Arena uses 64 400W metal halide fixtures. Each 400W metal halide fixture (26,500 mean lumens per lamp) can be replaced with one 4-foot, 6-lamp T4HO fixture (4,600 mean lumens per lamp).

Savings

1. Material recovery: The energy savings is the difference between the current usage and the proposed changes: $19,952/yr - $14,738/yr = $5,214/yr

2. Roosevelt Ice Arena7: The energy savings is the difference between the current usage and the proposed changes: $12,182/yr - $8,998/yr = $3,184/yr

Investments

1. Material Recovery Facility: Each of the 163 metal halide fixtures take (1) 6-lamp T5 fixtures. Each metal halide fixture will cost $440 ($250 material and $190 labor):
   - Total cost is 163 fixt * $440/fixt = $71,720
2. Roosevelt Ice Arena: Each of the 64 metal halide fixtures take (1) 6-lamp 4-foot T5 fixture. Each metal halide fixture will cost $440 ($250 material and $190 labor):
   - Total cost is 64 fixt * $440/fixt = $28,160

Payback

1. Material Recovery Facility: The resulting payback is ($71,720/$5,214) 13.8 years.
2. Roosevelt Ice Arena: The resulting payback is ($28,160/$3,184) 8.8 years.

E-4: Occupancy Sensors in Common Spaces

Existing Conditions

Occupancy sensors are a reliable way to make sure light fixtures are turned off. They work well in restrooms, break rooms, offices, laundry rooms, and classrooms.

While walking through the facilities, common space rooms with the lights on were noted. This write-up does not try to predict the occupants' habits since we were only seeing a snapshot. This write-up will rely on a study done by NEMA and the EPA on potential savings using occupancy sensors.

The NEMA and EPA study found that rooms with occupancy sensors have the potential for saving:

Table 3-1 EPA Findings of Occupancy Sensor Savings

Application	Energy Savings
Break Room	29%
Classroom	52%
Conference Room	39%
Private Office	28%
Restroom	47%

Solution

1. Provide occupancy sensor control of lighting fixtures in restrooms and break rooms.
   - Summary of rooms and sensors:

Table 3-2 Breakrooms

Building	# of Rms	Qnty of Fixtures Total	Watts	Qnty of Occ Sensors total
Material Recovery	1	(9). 4-lamp T8	1152	1 needed
Main Fire Station	1	(5) 2-lamp T8	320	1 needed
TSA	1	(3) 4-lamp T8	384	1 needed
Library	1	(9) 2-lamp T8	576	1 needed
Transportation Traffic Garages	1	(6) 4-lamp T8	768	1 needed

Table 3-3 Restrooms/Locker Rooms

Building	# of Rms	Qnty of Fixtures Total	Watts	Qnty of Occ Sensors total
Material Recovery	3	(6). 2-lamp T8 (3) 2-lamp T12	384	3 needed
Main Fire Station	1	(4) cfl	296	1 needed
Airport	6	(36) 2-lamp T12 U	2736	6 needed
TSA	2	(1) T8, (3) CFL	142	1 needed
Library	4	T8	1024	4 needed
Dahl	2	3-lamp T8	384	2 needed
Transportation Traffic Garages	3	T8 and Inc	1040	3 needed
City Hall	8	2-lamp T12	6080	8 needed

Savings

1. Savings are seen from having the lighting fixtures off while the room is not in use.
   - Break Rooms: $216/yr
   - Restroom/Lockers: $1,327/yr

Investments

1. Break Rooms:
   - 5 sensors * $100/sensor = $500
2. Restrooms/Lockers:
   - 28 sensors * $100/sensor = $2,800

Payback

- Breakrooms: The resulting payback is ($500/$216/yr) 2.3 years.
- Restroom/lockers: The resulting payback is ($2,800/$1,327/yr) 0.36 years.

E-5: Day Lighting Control

Existing Conditions

Daylight control is a technique used to turn off area lighting fixtures when enough sunlight is present to not be needed. Daylighting can be accomplished through roof-mounted skylights, or by turning off perimeter lighting near windows. Two facilities visited have some daylighting opportunity.

1. Public Library:

   The library was built in 1972. It utilizes fluorescent fixture with some recessed incandescent and compact fluorescent can fixtures.

   An addition was constructed in 2002. The addition is two stories with fluorescent light fixtures.

   Library hours are:
   9am–8pm M–Th
   9am–6pm F–S
   12pm–6pm Su

   Lights in the facility are controlled by a low voltage relay lighting control system. Lights are switched at two wall-mount stations. One station is located in the offices near the main entrance. The second station is located on the east wall in the main library.

   On the second level of the new addition, there is ample sunlight through the windows on the south facing wall. Meter readings of 70 footcandles were measured 15-feet from the south wall. Because of the large window surface area, light fixtures along the perimeter of the south facing wall could be turned off during the day to save energy. This approach can also be taken at the main stairway and second level conference area.

   Light meter readings were taken at 9am. It would be expected that the light levels during the time we visited were not even as bright as it would be at mid-day.

Public Library – Second Level New Addition
Figure 3-7

Light Meter Reading 10-Feet from Windows
Figure 3-8

Main Entry
Figure 3-9

Main Entry Footcandle Reading at 9am
Figure 3-10

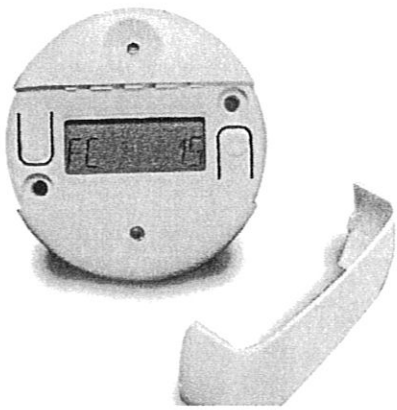
2. Airport:
   - The airport has a lot of window area along the concourse. Lights in this area are currently controlled by a lighting control system. The lighting control system has the ability to turn off perimeter lighting in the concourse space based on time of day control.
   - The lighting in the concourse, at one time, did provide time of day control to turn off perimeter light fixtures. This control has been lost and on-site staff are not familiar enough with the controller to program the system in order to re-implement this control.
   - It is recommended that an outside technician be hired to add the programming to control the perimeter lights.

Solution

1. Add a photo sensor in each space that daylighting control is desired. One sensor to be placed in the second level library, one in the second level conference area, and one in the main entry.

   When the light sensor reads 65 foot-candles or higher, it can turn off the fixtures it controls. Eighteen perimeter 4-lamp parabolic fixtures can be turned off in the upper library area. Ten 3-lamp suspended fixtures can be turned off in the stairway and upper conference area. Five 2-lamp parabolic fixtures can be turned off in the main entry vestibule.

   The light sensor that will be used in this write-up is the LS-101 by Watt Stopper. There are other light sensors on the market that could be used as well. The light sensor works with a relay pack. The sensor is adjustable and sends a signal to the relay pack to turn on and off the light fixtures.



Light Sensor
Figure 3-11

The budget quote for the light sensor and relay pack from the local Watt Stopper representative (Davis and Associates) is $140.

2. Hire a technician for a day to re-program the lighting controls.

Savings

1. Public Library
   - Upper Library Area energy savings is estimated at $417/yr
   - Stairway and upper conference area energy savings is estimated at $174/yr
   - Main Entry Vestibule area energy savings is estimated at $58/yr
   - Total Savings:

     $417/yr + $174/yr + $58/yr = $648/yr

2. Airport
   - Savings, seen by turning off approximately (50) 70W fluorescent fixtures for 6hrs each day, 365 days per year on average, is estimated at $715/year

Investments

1. The cost for daylight controller installations at each of the hangars is as follows:

Library

Item	Units	Unit Qnty	Equip Cost/Unit	Labor Cost/Unit	Item Cost
Daylight sensor	ea	3	140	70	$630
conduit/wire (60ft X 6)	lf	120	2.26	4.26	$782
Total					$1,412

2. Assume a technician cost of $125/hr * 8hrs = $1,000.

Payback

1. The resulting payback is ($1,412/$648) 2.2 years.
2. The resulting payback is ($1,000/715) 1.4 yrs.

E-6: Replace Incandescent Lighting

Existing Conditions

For the most part, the city is lit using fluorescent lighting. Although most of the fluorescent lighting is T12 lighting, it is still fairly efficient. New lighting installations today would use a T8 or T5 fluorescent lamp.

Incandescent lighting is seen in a few buildings. It is mainly seen in the Rushmore Plaza Civic Center.

Other facilities that have very small amount of incandescent lighting are: Fire Station #6, Fire Station #3, Meadowbrook Golf Clubhouse. Horace Mann Pool will be looked at as the example because it has a large number of fixtures.

1. Horace Mann Pool: The Horace Mann Pool is open in the summer for 3-months from 1pm to 6pm, 7-days each week. The facility has very low operating hour for the year, but the incandescent lamps are high in energy use. The facility has (70) 100W incandescent lamps in the shower and changing areas.

Solution

1. Horace Mann: Replace the (70) 100W incandescent lamps with 26-watt compact fluorescent lamps in the same fixture.

Savings

1. Horace Mann: The energy savings is estimated at $456/yr.

Investments

1. Horace Mann: Each 26W compact fluorescent lamp costs around $10.
   - Total cost is 70 lamps * $10/lamp = $700.

Payback

1. Horace Mann: The resulting payback is ($700/$456) 1.5 years.

E-7 Aeration Blower VFDs

Existing Conditions

One-half of the flow through the City of Rapid City wastewater treatment plant (WWTP) is treating aerobically using a suspended growth active sludge system. The oxygen required by this system for treatment is provided by one of three 300 hp blowers. The WWTP currently runs only one blower at a time. The operational blower is run a full capacity. The dissolved oxygen concentration in the activated sludge basins is controlled by opening a vent valve in the discharge piping of the blower. Therefore, the blower energy consumption is greater than required by the activated sludge system.

Solution

Providing variable frequency drives (VFDs) for the blower motors will allow for the blower to adjust its power consumption to the oxygen demand in the activated sludge basins. Published reports have shown that this approach can reduce the air flow by an average of 25% which corresponds to 57% reduction in power consumption by the blower.

Savings

It is estimated that the VFDs will reduce the blower electrical power consumption by 749,000 kW-hr/yr. This corresponds to an estimated avoided cost of $69,900/yr.

Investments

The installed cost of three 300 hp VFDs is $396,000.

Payback

The payback is calculated at 5.7 years.

E-8: Refrigerated Vending Machine Control for Energy Savings

Existing Conditions

Standard refrigerated vending machines consume between 7 and 11 kWh/day (9kWh/day will be used as average). This type of machine operates 24 hours per day and 365 days per year. With a blended electricity rate of $.0933/kWh, each machine has an average electrical cost of (9kWh/day * 365days/year * $.0933/kWh) $306/yr.

Refrigerated Vending Machines
Figure 3-12

Solution

The preferred solution when receiving a new machine is to negotiate the option of Energy Star rated equipment. An Energy Star rated machine uses between 1 and 2 kWh/day. This should reduce energy costs to around $68/yr.

Many times however, the building manager does not have control over the types of machines that are received. As well, the buildings already have machines that are not energy star rated and can benefit from energy controls to reduce the current energy consumption.

Products are made that control the energy usage of standard refrigerated vending machines. One of these products is the Vending Miser by Optimum Energy Products Ltd. This product plugs into the vending machine's outlet, which allows it to turn the unit 'off' and 'on'. The Vending Miser (unit) utilizes a passive infrared sensor to detect when the room is occupied. During unoccupied times, the unit powers down the vending machine. It automatically turns the machine back on during occupied times. The unit uses logic to learn the occupied habits of the space and modifies the shutdown time accordingly. Even during unoccupied times, the unit cycles the vending machine on and off based on space temperature to maintain a cold product. The unit also monitors the electrical current used by the vending machine so that it will never power down the vending machine while a compressor is running, or during a cooling cycle.

Vending Miser by Optimum Energy Products Ltd
Figure 3-13

Savings

The Vending Miser reduces electrical energy consumption by an average of 46%. This means that instead of $306 each year per machine, each machine will cost ($306 - .46*$306) $165/yr to operate. This provides a savings of $141 per year per machine.

Investments

Each Vending Miser costs $180.

It is assumed that two Vending Miser units can be installed in one labor hour. Assuming a labor cost of $30/hr, each unit will cost $15 to install.

Each unit costs $195 for installation

Payback

The resulting payback is $195/$141 = 1.4 years.

The following table notes the refrigerated vending units observed.

Table 3-4 Refrigerated Vending Units

Bldg Name	No. of Mach.
Main Fire Station	2
Airport	7
Rushmore Plaza Civic Center	6
Haley Park Building	1
Library	1
Dahl Arts Center	1
City /School Administration	5
Milo Barber Transportation	1
Totals	**24**

E-9: Roadway and Parking Lot Lighting. Compare LED to HID

Existing Conditions

Although Current LED technology does not have a reasonable payback as compared to HID fixtures, it is widely believed that LED's will replace HID fixtures as the standard in the future. This technology should be followed by the City as a possible future roadway and parking light source.

LED lighting is an emerging technology that has the possibility of replacing most light sources used today. The technology is changing rapidly while costs are coming down. Currently, LED technology is fairly expensive compared to fluorescent and HID. A LED lamp that compares to a T8 fluorescent lamp costs around $150. A LED outdoor roadway fixture that compares to a 150W-HID fixture costs around $1500.

Energy savings using an LED lamp can be seen today. The current LED lamps are around 60 lumens/watt. This is much better than an incandescent and compares well to a compact fluorescent. As the technology improves, the upcoming LEDs that will soon be in fixtures are each around 120 lumens/watt. This exceeds the most common lighting sources used today such as fluorescent and HID. You must be careful in choosing a LED fixture since quality and efficacy are highly variable.

People are yet skeptical about the performance and longevity of LED fixtures. LED fixture life is very susceptible to heat. Under the hot sun, and without a well-designed heat dissipation housing, LED lamps can be reduced from the 50,000 hr lamp life to a number much lower.

The City of Rapid City currently has many different types of roadway fixtures. Most residential lighting is 100W High Pressure Sodium. Other fixtures types include 250W, 400W, and 1000W HPS, 150W, 175W, and 400W Metal Halide.

This analysis will compare installing new roadway fixtures using LED rather than HID. LED fixtures do cost more than HID, but have a much longer lamp life and lower energy usage.

This analysis will use the Beta Edge roadway fixture. This fixture was recently installed on the re-built 35W bridge in Minneapolis and outperforms most other LED roadway fixtures.

LED Fixture
Figure 3-14

Solution

1. Instead of installing new 150W HPS fixtures for new roadway projects, install LED equivalent fixtures. A 150W MH fixture uses 190W and provides 7,200 lumens. The fixture Beta recommends for replacement is an 80 LED fixture which uses 104W and provides 6,460 lumens. A 150W MH fixture has rated life of 15,000 hours. The Beta fixture has a rated life of 100,000 hours.

   For this analysis, it is assumed that the cost of the pole, concrete base, and wiring will be exactly the same for either HID or LED. Because of this, only the cost of the fixtures will be used in determining a payback.

   The cost for the LED fixture as given by the local Beta rep is $1,500. The cost for a 150W MH cobra head style fixture is $275.

   This analysis will use only one fixture in determining payback.

2. Another option that may be considered is induction fluorescent lighting. I have very little personal experience with induction lighting. Induction lighting lamp can be obtained up to a 150W HPS lamp. They are physically larger in size than their HID equivalents. They can be placed in cold weather and have a lamp life of 100,000 hours.

3. A third option is to provide a self-contained, solar powered roadway light. A solar powered fixture uses a photovoltaic cell with batteries to power an LED fixture. They are designed to operate the LEDs on battery power for ten 5-day periods in case of inclement weather. During the inclement weather period, the system dims the light output to get time.

Savings

1. The savings for both the energy usage, and reduced lamp replacement is estimated at $34.5/yr.

2. Induction lighting uses 100 watts for an equivalent fixture brightness. The savings is the same as the LED fixture of $34.5/yr.

   Savings can also be seen by reduced maintenance cost. The City of Rapid City pays an outside service to maintain the roadway fixtures. The outside service costs $1.29/mo for each fixture. It is not expected that this would change with the different fixture type, so reduced maintenance will not be considered.

Investments

1. The investment is the difference between fixture costs.
   - $1,500 - $275 = $1,225
2. Induction fixtures are the same as LED above for savings.
3. Solar power savings is the total HID energy usage of $76/yr

Payback

1. The resulting payback is ($1,225/$34.5) 35.5 years.
   - Note that for the payback to be 5 years to use LED fixtures, the fixture cost would need to be $453 per fixture
2. The resulting payback for Induction is ($225/$34.5) 6.5 years.
3. Resulting payback for solar lighting is ($1,525/$76) = 20 years.

Section 4

Renewable Energy Opportunities

Energy use (type and quantity) and available resources for energy conversion were evaluated and renewable energy opportunities were identified. The City of Rapid City has several source of renewable energy: solar, woody biomass, waste vegetable oil, landfill gas, and biogas from the wastewater treatment plant. Biomass energy production was not considered in this study since it had been previously evaluated for a district energy system and was determined to not meet financial return goals. The other renewable energy sources will be described below. An implementation concept is presented with each renewable opportunity along with an estimated financial return.

REO-1 Landfill Gas

Existing Conditions

In 2010, the City of Rapid City plans to install wells within the landfill for landfill gas recovery. The volume and quality of the landfill gas will be observed over a 6 to 12 month period. The City plans to solicit a third party developer for beneficial use of the gas. Previous studies of the landfill estimated that 100,000 mmBTU/yr of landfill gas could be recovered from the landfill. The capital cost for the gas recovery and cleanup system to allow for offset of natural gas in an industrial boiler was $2,384,700. The annual operations and maintenance cost for the landfill gas recovery and cleanup was $282,000/yr.

Solution

The Material Recycling Facility uses an estimated 16,000 mmBTU/yr of natural gas to heat the co-composting building. This natural gas use could be offset with landfill gas. This represents 16% of the estimated landfill gas production.

Savings

The annual avoided natural gas cost was estimated at $103,000/yr.

Investments

The cost of a landfill gas recovery and cleanup system to provide 16,000 mmBTU/yr was estimated at $378,000. The operations and maintenance cost for this system was estimated at $44,700/yr.

Payback

The payback was estimated at 6.5 years.

REO-2 Photovoltaic (PV) Solar Energy

Existing Conditions

Many of the City of Rapid City buildings and facilities operate during daylight hours. The National Renewable Energy Laboratory solar radiation evaluation tool, PVWatts, predicts that City of Rapid City could recover 14.5 kW-hr/ft^2-yr for roof mounted PV panels.

Solution

Roof mounted PV panels could be installed on any facilities with flat, un-shaded roof space. Examples would include Fire Station #1, Airport (FAA approval required), Roosevelt Park Aquatics Center, Roosevelt Park skating rink, the Civic Center, etc. The default system size used by NREL's PVWatts program, 4 kW, was used for this evaluation. This system includes approximately 22 PV panels and covers 377 ft^2.

Savings

A 4.0 kW PV solar system in Rapid City is expected to produce 5,500 kW-hr of electrical power annually. This would be an annual avoided electrical cost of $616.

Investments

Roof mounted PV systems are estimated to cost between $6 and $8 an installed watt of capacity. Therefore, this 4.0 kW system would cost between $24,000 and $32,000 installed.

Payback

A simple payback for this system would be 40–60 years. In order to meet a 15-year payback, a grant of $15,000 to $23,000 would be required to pay down the capital cost of the project. Alternatively, a rate of $0.34/kW-hr would be required to achieve a 15-year payback.

This analysis would apply to any facility with 377 ft^2 of available area for the 22 PV panels, producing 4 kW. This 4 kW system would have a capital cost of between $24,000 and $32,000 and would provide an annual avoided electrical cost of $616 for the facility it was installed on. This type of system could achieve a 15 year payback, only if capital was paid down with a grant or a rate of $0.34/kW-hr were available.

REO-3 Wastewater Treatment Plant Biogas

Existing Conditions

The City of Rapid City's wastewater treatment plant (WWTP) currently processes all its primary sludge and half of its secondary sludge using anaerobic digestion. Some of the biogas is used to heat the anaerobic digesters and the remainder of the biogas is burned in a flare. Though the actual volume of biogas generated is not measured, it is estimated at 45 million British thermal units (mmBTU) per day. This volume of biogas assumes that plant operations are modified so that both primary and secondary sludges are digested in order to maximize the available biogas.

Solution

A reciprocating engine (design to run a mixture of biogas and natural gas) driven electrical generator could be installed at the WWTP. A 191 kW generating set could use all of the biogas and 16.5 mmBTU/day of natural gas to produce 1,670,000 kW-hr/yr.

Savings

The avoided electricity cost would be $187,040 annually. The natural gas would cost $46,351/yr. The operations and maintenance for the generating system is estimated at $27,500/yr. The annual net savings is $114,000.

Investments

The installed cost of this electrical generating set, including desulfurization of the biogas, is $525,000.

Payback

The payback is estimated at 4.6 years.

REO-4 Solar Thermal Water Heating

Existing Conditions

Heating swimming pools is the largest natural gas load for City of Rapid City facilities. At the indoor pools, this heating load is relatively constant throughout the year. For the outdoor pools, it is only during the summer.

Solution

The swimming pool water can be heated using solar energy. Solar water heating panels can be installed on the roof and offset natural gas for maintaining pool water temperature. As an example, a base system consisting of 10 panels will be evaluated. This base system is estimated to produce an average of 0.25 mmBTU/day. This based system will require 400 ft^2 of flat roof space.

Savings

This base system would produce 91.25 mmBTU/yr. This would be an annual avoided cost of $696.

Investments

The base system has an estimated installed cost of $18,325.

Payback

The payback for the base system would be 26.3 years. A grant would be required for 43% of the installed cost ($7,885) in order to reduce payback to less than 15 years. Alternatively, a natural gas rate of $13.39/mmBTU would be required to achieve a 15-year payback.

This payback analysis was based on a generic 10 panel system, requiring 400 ft^2 of flat roof space. This analysis was done for indoor pools only, since these pools are used year round and maximize the months of solar collection for the payback. Outdoor pools were not evaluated, due the limitation of use during the summer months only. This reduced usage extends the payback beyond reason and there is only a payback in the offset natural gas usage, which is less applicable for an outdoor pool.

REO-5 Waste Vegetable Oil Recovery (biodiesel)

Existing Conditions

The food service division at the Civic Center generates three 55-gallon drums of waste vegetable oil (WVO) approximately 15 times per year. Disposal of a 55-gallon drum of the WVO costs $30. Therefore, the Civic Center produces 2,475 gallons of WVO annually with a disposal cost of $1,350.

Solution

This WVO can be converted into biodiesel, blended 5% in to petroleum diesel, and used in the City's maintenance vehicles. The WVO can be converted using commercially available biodiesel batch plants. The City of Rapid City could purchase a batch plant and produce biodiesel to offset the use of petroleum diesel. The waste glycerin for the biodiesel production could be disposed in the WWTP anaerobic digester.

Savings

Biodiesel requires WVO, methanol and sodium hydroxide. The WVO must be heated for the reaction to occur. The cost of the chemicals and electricity to convert WVO to biodiesel is estimated at $0.34/gal. The operating and maintenance cost for operating the batch facility are estimated at $0.54/gal. 2,475 gallons of WVO will produce the same number of gallons of biodiesel. The net savings from biodiesel production is estimated at $6,102/yr.

Investments

There are several companies that sell small-scale batch biodiesel plants. The University of Central Oklahoma has a design for such available free on their website. The installed cost of a batch plant is estimated at $10,000.

Payback

The payback for a biodiesel batch plant is estimated at 1.6 years.

Section 5

Recommendations

The results of Stanley Consultants' review of the City of Rapid City's buildings and facilities for energy reduction and renewable energy opportunities are presented in the preceding sections. The City's benchmark was a payback of 15 years or less. The opportunities identified that meet or exceed this requirement are summarized in Table 5-1. These recommendations are prioritized by the estimated payback. These identified projects include electrical, mechanical, and renewable energy opportunities. The maximum capital cost of a single recommended project is $525,000. It should be noted that fifty percent (50%) of the recommended projects require a project investment of $10,000 or less. Eighty-two percent (82%) of the recommended projects require a project investment of less than $50,000.

There are seven, energy saving and renewable energy opportunities (e.g., LED lighting, PV solar electricity generation, and solar water heating) that were technically feasible, but had estimated paybacks of greater than 15 years. These opportunities are presented in Table 5-2. For each of these projects the grant necessary to pay down the project capital in order to achieve a 15-year payback is presented. Alternatively, the energy rate necessary to achieve a 15-year backpack without a grant is also presented. The financial viability of these projects could change should carbon dioxide become regulated by the US EPA or managed under climate change legislation.

Table 5-1 Energy Efficiency and Renewable Energy Recommendations

Project		Project Description	Facility	Capital Cost	Annual Savings	Payback (years)
Elect	2d	Corridor Lighting	Rushmore Civic Center	$1,000	$3,326	0.3
Elect	4b	Occupancy Sensors - Restrooms/Locker Rooms	Multiple Facilities	$2,800	$1,327	0.4
Elect	2b	Rushmore/Lacroix Halls Lighting	Rushmore Civic Center	$35,000	$32,680	1.1
Elect	8	Refrigerated Vending Machine Control	Multiple Facilities	$4,680	$3,384	1.4
Elect	5b	Day Lighting Control	Airport	$1,000	$715	1.4
Elect	6	Replace Incandescent Lighting	Horace Mann Pool	$700	$456	1.5
Elect	2c	Decorative Lighting	Rushmore Civic Center	$1,792	$1,100	1.6
REO	5	Waste Vegetable Oil Recovery as Biodiesel	Rushmore Civic Center	$10,000	$6,102	1.6
Elect	2a	Arena Lighting	Rushmore Civic Center	$19,200	$9,861	1.9
Elect	5a	Day Lighting Control	Library	$1,412	$648	2.2
Elect	4a	Occupancy Sensors - Break Rooms	Multiple Facilities	$500	$216	2.3
Mech	3	Supply Fan VFDs	Rushmore Civic Center	$48,625	$17,254	2.8
Mech	2	Waste Oil Heater	Light Vehicle Maintenance Center	$4,650	$1,591	2.9
Elect	1a	Retrofit Kit for T12 Parabolic Light Fixtures (4 lamp)	City School Administration Center	$36,200	$10,151	3.6
REO	3	Biogas to Electricity	Water Reclamation Facility	$525,000	$114,000	4.6
Elect	7	Aeration Blower VFDs	Water Reclamation Facility	$396,000	$83,900	4.7
Mech	1	Heat Recovery System	Material Recovery Facility	$169,950	$34,502	4.9
Mech	4	Kitchen Ice Machine	Rushmore Civic Center	$20,000	$3,194	5.2
REO	1	Landfill Gas for Co-Composting Building Heating	Material Recovery Facility	$378,000	$58,300	6.5
Elect	1b	Retrofit Kit for T12 Parabolic Light Fixtures (2 Lamp)	City School Administration Center	$28,900	$3,570	8.1
Elect	3	Replace HID High Bay Lighting	Roosevelt Ice Arena	$28,160	$3,184	8.8
Mech	5	Roof Insulation	Halley Park Building	$8,033	$828	9.7
TOTAL				**$1,721,602**	**$390,289**	**4.4**

Note: REO-1 does not include the cost of landfill gas collection.

Table 5-2 Energy Efficiency and Renewable Energy Projects with Greater Than 15-Year Payback

Project	Project Description	Facility	Capital Cost	Annual Savings	15-Year Payback Requirements	
					Capital Buy Down Grant	Energy Price
Mech - 5	Roof Insulation	Executive Golf Course Clubhouse	$2,625	$169	$90	$21.34/mmBTU
App A - Mech Calcs.	Overhead Door Replacement	Roosevelt Ice Arena	$2,634	$93	$1,239	$73.17/mmBTU
App A - Mech Calcs.	Window Replacement	Main Fire Station	$600	$19	$315	$33.33/mmBTU
REO-4	Solar Water Heating	(10 Panel System - Typical any Indoor Pool) Roosevelt Aquatic Center	$18,325	$696	$7,885	$13.42/mmBTU
REO-2	PV Solar Power	(4 kW System - Typical any Bldg.) Main Fire Station	$28,000	$616	$18,760	$0.34/kWhr
Elect 9-1	LED Fixtures (per fixture)	Roadways and Parking	$1,225	$35	$700	$0.26/kWhr
Elect 9-3	Solar Lighting Fixtures (per fixture)	Roadways and Parking	$1,525	$76	$385	$0.15/kWhr

Note: To get the project payback less than 15 years, only the capital buy down grant OR the higher energy price is required.

Appendix A

Mechanical Calculations

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JOB NO. 22593 PAGE NO. 1
SUBJECT: City of Rapid City
Mechanical Payback Calculations

MATERIAL RECOVERY FACILITY CO-COMPOST BUILDING
M-1 HEAT RECOVERY SYSTEM

HDD50	3473 °F*DAY/YR	ASSUMED HEAT RECOVERY WATER COIL TEMP DIFF	20 °F	HDD50 = HEATING DEGREE DAYS WITH 50°F BALANCE TEMPERATURE
GAS COST	$7.627 /DK	ASSUMED PUMP HEAD	50 FT	DK = DEKATHERM
CDD65	678 °F*DAY/YR	ASSUMED PUMP EFFICIENCY	0.60	CDD65 = COOLING DEGREE DAYS WITH 65°F BALANCE TEMPERATURE
ELECTRIC COST	$0.1120 /KWH	ASSUMED MOTOR EFFICIENCY	0.93	
		HOURS OF OPERATION (5 MO)	3,600 HRS	
		ASSUMED INCREASED COIL PRESSURE DROP	0.20 IN_{WG}	IN_{WG} = INCHES OF WATER GUAGE
		ASSUMED FAN EFFICIENCY	0.50	

	AIR QUANTITY CFM	HEAT RECOVERY EFFECTIVENESS	HEAT QTY BTU/YR	HEAT EFF	GAS QTY DK/YR	GAS COST $/YR	PUMP GPM	PUMP BHP	PUMP MOTOR KW	FAN BHP	FAN MOTOR KW	ELEC QTY KWH	ELEC COST $/YR	ENERGY COST $/YR	CONSTRUCTION COST $
EXISTING	100,000		9E+09	0.8	11,252.5	$85,822.97								$85,822.97	$0
NEW	100,000	0.50	4.5E+09	0.8	5,626.3	$42,911.49	388.8	8.2	11.8	6.3	9.1	75,111	$8,409.39	$51,320.88	$169,950
			SAVINGS ($/YR)											$34,502.09	
			SIMPLE PAYBACK (YRS)											4.9	

CONSTRUCTION COST DETAIL

ITEM	QTY	UNIT COST $/EA	TOTAL $	DESCRIPTION
EA COIL	3	$5,800	$17,400	51"X120"
OA COIL	4	$4,850	$19,400	51"X96"
EA PLENUM	1	$15,000	$15,000	CUSTOM PLENUM, SUPPORT STEEL
OA PLENUM	2	$7,750	$15,500	CUSTOM PLENUM, SUPPORT STEEL
PIPING	400	$50	$20,000	4" SCH 40 WELDED
INSULATION	400	$11	$4,280	1-1/2" THICK, 4" PIPE
JACKET	400	$8	$3,080	7" PVC JACKETED
PUMP	1	$5,250	$5,250	10 HP BASEMOUNTED END SUCTION
STARTER	1	$1,200	$1,200	
WIRING	1	$2,000	$2,000	100 FT
CONTROLS	1	$15,000	$15,000	
GLYCOL	130	$14	$1,840	50% PROPYLENE GLYCOL, GAL
ENGINEERING	1	$20,000	$20,000	
MISC	1	$20,000	$30,000	
TOTAL			$169,950	

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JOB NO. 22593 PAGE NO. 2
SUBJECT: City of Rapid City
Mechanical Payback Calculations

STREETS DEPT LIGHT VEHICLE MAINTENANCE FACILITY
M-2 WASTE OIL HEATER

HDD65	7027 °F*DAY/YR	HDD65 = HEATING DEGREE DAYS WITH 65°F BALANCE TEMPERATURE
GAS COST	$7.627 /DK	DK = DEKATHERM
CDD65	678 °F*DAY/YR	CDD65 = COOLING DEGREE DAYS WITH 65°F BALANCE TEMPERATURE
ELECTRIC COST	$0.1120 /KWH	

	DESCRIPTION		R VALUE	U VALUE BTU/(HR*°F*FT^2)	AREA FT^2	HEAT QTY BTU/YR	HEAT EFF	GAS QTY DK/YR	GAS COST $/YR	CONSTRUCTION COST $
EXISTING	GAS UNIT HEATER	WALL (~40'WX60'LX12'H)	1.5	0.67	1,200	134,918,400	0.82	164.5	$1,254.91	$0
		ROOF	11	0.09	2,360	36,182,662	0.82	44.1	$336.54	$0
								TOTAL	$1,591.45	
NEW	WASTE OIL UNIT HEATER								$0	$4,650
						SAVINGS ($/YR)			$1,591.45	
						SIMPLE PAYBACK (YRS)				2.9

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JOB NO. 22593 PAGE NO. 3
SUBJECT: City of Rapid City
Mechanical Payback Calculations

ELECTRIC COST $0.1120 /KWH
HOURS OF OPER. 3,120 /YR

12 HRS/DAY, 5 DAYS/WK, 52 WKS/YR

RUSHMORE PLAZA CIVIC CENTER
M-3 REPLACE VARIABLE INLET GUIDE VANES ON SUPPLY FAN WITH VFDs

	DESCRIPTION	HP	VFD SPEED REDUCTION	HP REDUCTION	MOTOR EFF	MOTOR POWER KW	ELEC QTY KWH	ELEC COST $/YR	CONSTUCTION COST MOTOR $	VFD $	CONTROLS $	DEMO $	TOTAL $
EXISTING	SF-13	15	1.00	1.00	0.89	22.6	70,488	$7,891.87					
EXISTING	SF-14	15	1.00	1.00	0.89	22.6	70,488	$7,891.87					
EXISTING	S-9	25	1.00	1.00	0.89	37.7	117,480	$13,153.12					
							TOTAL ($/YR)	$28,936.86					
NEW	SF-13	15	0.75	0.42	0.93	9.1	28,458	$3,186.18	$1,100	$3,425	$10,000	$1,000	$15,525
NEW	SF-14	15	0.75	0.42	0.93	9.1	28,458	$3,186.18	$1,100	$3,425	$10,000	$1,000	$15,525
NEW	S-9	25	0.75	0.42	0.93	15.2	47,430	$5,310.31	$1,700	$4,875	$10,000	$1,000	$17,575
							TOTAL ($/YR)	$11,682.67					$48,625

SAVINGS ($/YR) $17,254.18
SIMPLE PAYBACK (YRS) 2.8

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JOB NO. 22593 PAGE NO. 4
SUBJECT: City of Rapid City
Mechanical Payback Calculations

ELECTRIC COST $0.1120 /KWH
WATER COST $0.00356 /GAL

BASED ON SEWER CHARGE $2.66/100 CF

RUSHMORE PLAZA CIVIC CENTER
M-4 KITCHEN ICE MACHINES

ICE LBS/DAY	DAYS	ICE LBS	CONDENSER WATER CONSUMPTION GAL/100 LBS	CONDENSER WATER CONSUMPTION GAL	WATER COST	ADDITIONAL ELEC KWH/100 LB	ELEC KWH	ELEC COST $/YR	CONSTUCTION COST $
1,800	325	585,000	185	1,082,250	$3,848.64	-1	-5,850	-$654.97	$20,000.00

SAVINGS ($/YR)	$3,193.68
SIMPLE PAYBACK (YRS)	5.2

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JOB NO. 22593 PAGE NO. 5
SUBJECT: City of Rapid City
Mechanical Payback Calculations

HALLEY PARK BUILDING
M-5 ROOF INSULATION

HDD65	7027	°F*DAY/YR
GAS COST	$7.627	/DK
CDD65	678	°F*DAY/YR
ELECTRIC COST	$0.1120	/KWH

HDD65 = HEATING DEGREE DAYS WITH 65°F BALANCE TEMPERATURE
DK = DEKATHERM
CDD65 = COOLING DEGREE DAYS WITH 65°F BALANCE TEMPERATURE

	DESCRIPTION	R VALUE IN	R VALUE PER INCH	R VALUE	U VALUE BTU/(HR*°F*FT^2)	AREA FT^2	HEAT QTY BTU/YR	HEAT EFF	GAS QTY DK/YR	GAS COST $/YR	COOL QTY BTU/YR	SEER BTU/(HR*W)	ELEC QTY KWH	ELEC COST $/YR	ENERGY COST $/YR	CONSTRUCTION COST $/FT^2	CONSTRUCTION COST $
EXISTING	ROCK WOOL	2	3.5	7	0.14	4,590	110,584,903	0.92	120.2	$916.77	10,669,783	12	889.1	$99.55	$1,016.32	0	$0
NEW	BLOWN FIBERGLASS ON TOP OF EXISTING	12	3.15	37.8	0.03	4,590	20,478,686	0.92	22.3	$169.77	1,975,886	12	164.7	$18.44	$188.21	1.75	$8,033
							SAVINGS ($/YR)			$747.00				$81.11	$828.11		
							SIMPLE PAYBACK (YRS)								9.7		

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JOB NO. 22593 PAGE NO. 6
SUBJECT: City of Rapid City
Mechanical Payback Calculations

HOURS	2,160 HRS
GAS COST	$7.627 /DK
WATER COST	$0.00356 /GAL

DK = DEKATHERM
BASED ON SEWER CHARGE $2.66/100 CF

HORACE MANN POOL
WATER LOSS

WATER LOSS GPM	TEMP POOL °F	MAKEUP WATER TEMP °F	BTU/HR	HEAT QTY BTU/YR	HEAT EFF	GAS QTY DK/YR	GAS COST $/YR/GPM	WATER GAL	WATER COST $/YR/GPM	TOTAL COST $/YR/GPM
1	80	50	15,000	32,400,000	0.82	39.5	$301.36	129,600	$460.88	**$762.24**

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JOB NO. 22593 PAGE NO. 7
SUBJECT: City of Rapid City
Mechanical Payback Calculations

EXECUTIVE GOLF COURSE CLUBHOUSE
ROOF INSULATION

HDD65	7027	°F*DAY/YR
GAS COST	$7.627	/DK
CDD65	678	°F*DAY/YR
ELECTRIC COST	$0.1120	/KWH

HDD65 = HEATING DEGREE DAYS WITH 65°F BALANCE TEMPERATURE
DK = DEKATHERM
CDD65 = COOLING DEGREE DAYS WITH 65°F BALANCE TEMPERATURE

	DESCRIPTION	IN	R VALUE PER INCH	R VALUE	U VALUE BTU/(HR*°F*FT^2)	AREA FT^2	HEAT QTY BTU/YR	HEAT EFF	GAS QTY DK/YR	GAS COST $/YR	COOL QTY BTU/YR	SEER BTU/(HR*W)	ELEC QTY KWH	ELEC COST $/YR	ENERGY COST $/YR	CONSTRUCTION COST $/FT^2	CONSTRUCTION COST $
EXISTING	FIBERGLASS BATT	3.5	3.15	11.025	0.09	1,500	22,945,306	0.82	28.0	$213.42	2,213,878	10	221.4	$24.79	$238.21	0	$0
NEW	BLOWN FIBERGLASS ON TOP OF EXISTING	12	3.15	37.8	0.03	1,500	6,692,381	0.82	8.2	$62.25	645,714	10	64.6	$7.23	$69.48	1.75	$2,625
							SAVINGS ($/YR)			$151.17				$17.56	$168.73		
							SIMPLE PAYBACK (YRS)								15.6		

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JOB NO. 22593 PAGE NO. 8
SUBJECT: City of Rapid City
Mechanical Payback Calculations

OVERHEAD DOOR REPLACEMENT

HDD50	3473	°F*DAY/YR
GAS COST	$7.627	/DK
CDD65	678	°F*DAY/YR
ELECTRIC COST	$0.1120	/KWH

HDD50 = HEATING DEGREE DAYS WITH 50°F BALANCE TEMPERATURE
DK = DEKATHERM
CDD65 = COOLING DEGREE DAYS WITH 65°F BALANCE TEMPERATURE

	DESCRIPTION	R VALUE	U VALUE BTU/(HR*°F*FT^2)	AREA FT^2	HEAT QTY BTU/YR	HEAT EFF	GAS QTY DK/YR	GAS COST $/YR	COOL QTY BTU/YR	SEER BTU/(HR*W)	ELEC QTY KWH	ELEC COST $/YR	ENERGY COST $/YR	CONSTRUCTION COST $/FT^2	CONSTRUCTION COST $
EXISTING	12'X12' UNINSULATED	1	1.00	144	12,002,688	0.82	14.6	$111.64	0	10	0.0	$0.00	$111.64	0	$0
NEW	12'X12' INSULATED	6	0.17	144	2,000,448	0.82	2.4	$18.61	0	10	0.0	$0.00	$18.61	1.75	$2,634
					SAVINGS ($/YR)			$93.03				$0.00	$93.03		
					SIMPLE PAYBACK (YRS)								28.3		

Stanley Consultants INC.

COMPUTED BY: Kenton Graves
CHECKED BY:
REVIEWED BY:

DATE: April 8, 2010
DATE:
DATE:

JOB NO. 22593 PAGE NO. 9
SUBJECT: City of Rapid City
Mechanical Payback Calculations

MAIN FIRE STATION/ CEMETARY OFFICE
WINDOW REPLACEMENT

HDD65	7027	°F*DAY/YR
GAS COST	$7.627	/DK
CDD65	678	°F*DAY/YR
ELECTRIC COST	$0.1120	/KWH

HDD65 = HEATING DEGREE DAYS WITH 65°F BALANCE TEMPERATURE
DK = DEKATHERM
CDD65 = COOLING DEGREE DAYS WITH 65°F BALANCE TEMPERATURE

	DESCRIPTION	R VALUE	U VALUE BTU/(HR*°F*FT^2)	AREA FT^2	HEAT QTY BTU/YR	HEAT EFF	GAS QTY DK/YR	GAS COST $/YR	COOL QTY BTU/YR	SEER BTU/(HR*W)	ELEC QTY KWH	ELEC COST $/YR	ENERGY COST $/YR	CONSTRUCTION COST $/FT^2	CONSTRUCTION COST $
EXISTING	SINGLE PANE	0.9	1.11	15	2,810,800	0.82	3.4	$26.14	271,200	10	27.1	$3.04	$29.18	0	$0
NEW	DOUBLE PANE	2.5	0.40	15	1,011,888	0.82	1.2	$9.41	97,632	10	9.8	$1.09	$10.50	40	$600
					SAVINGS ($/YR)			$16.73				$1.94	$18.68		
					SIMPLE PAYBACK (YRS)								32.1		

Appendix B

Electrical Calculations

Electrical Rates

The following table shows a list of the existing electrical rates at each facility. A column is added to show what the electrical rate will be with the upcoming 20% rate increase. This column, with the 20% increase, will be used for the calculations.

Electric Rate ($/kWh)	Facility	Electric Rate X 20% ($/kWh)
0.0933	St Joseph St/5Th St Parking Lot	0.112
0.0933	Main St/6th St Parking Lot	0.112
0.0933	Main St/6th St Parking Lot	0.112
special	Main St/7th St Parking Lot	
0.0933	Main St/8th St Parking Lot	0.112
0.0933	6th St Parking Ramp	0.112
5.41	6th St Parking Ramp	6.492
0.0933	6th St Parking Ramp	0.112
0.0808	6th St Parking Ramp	0.097
0.0715	6th St Parking Ramp	0.086
0.0933	Memorial Park Tennis Courts	0.112
0.0808	Memorial Park Tennis Courts	0.097
special	Wilson Park Tennis Courts	
0.0933	Stevens High School Tennis Courts	0.112
0.0808	Stevens High School Tennis Courts	0.097
0.0933	Mt View Cemetery Office	0.112
0.0933	Mt View Cemetery Shop	0.112
	Meadowbrook Golf Course Maintenance Shop	
5.41	Southwest Fire Station #5	6.492
0.0933	Southwest Fire Station #5	0.112
0.0808	Southwest Fire Station #5	0.097
0.0933	Halley Park Building	0.112
0.0808	Halley Park Building	0.097
0.0715	Halley Park Building	0.086
5.41	South Side Fire Station #4	6.492
0.0933	South Side Fire Station #4	0.112
0.0808	South Side Fire Station #4	0.097
0.0715	South Side Fire Station #4	0.086
	Meadowbrook Golf Course Carpenter Shop	
5.41	West Side Fire Station #3	6.492
0.0933	West Side Fire Station #3	0.112
0.0808	West Side Fire Station #3	0.097
0.0715	West Side Fire Station #3	0.086
	Airport TSA Building	
5.41	Fire Station #6	6.492
0.0933	Fire Station #6	0.112
0.0808	Fire Station #6	0.097
0.0715	Fire Station #6	0.086
5.41	Milor Barber Transportation	6.492
0.0933	Milor Barber Transportation	0.112

Electric Rate ($/kWh)	Facility	Electric Rate X 20% ($/kWh)
0.0808	Milor Barber Transportation	0.097
0.0715	Milor Barber Transportation	0.086
0.0933	Parkview Pool & Bathhouse	0.112
	Airport SRE Maintenance Facility	
0.0933	Horace Mann Park Pool & Bathhouse	0.112
	Water Reclamation Plant	
5.41	Main Fire Station #1	6.492
0.0933	Main Fire Station #1	0.112
0.0808	Main Fire Station #1	0.097
0.0715	Main Fire Station #1	0.086
0.0585	Main Fire Station #1	0.070
0.089	City/School Administration Center	0.107
0.0933	Police Evidence, Transportation & Traffice Building	0.112
0.0855	Roosevelt Park Swim Center	0.103
0.0938	Public Library	0.113
	Airport Terminal	
0.885	Material Recovery Facility & Co-Compost Buildings	1.062
0.089	Rushmore Plaza Civic Center	0.107

E-1: Retrofit Kits for T12 Parabolic Light Fixtures at City/School Administration Building.

Assumptions:
a. A 4-lamp T12 parabolic uses 148W, or .148kW of electricity with the magnetic ballast.
b. A 2-lamp T5 fixtures uses 64W or .064kW of electricity with a 1.15 ballast factor.
d. A 2-lamp T12 U-fixture uses 76W, or .076kW of electricity with the magnetic ballast.
e. 2-lamp T5 fixtures uses 39W or .039kW of electricity with a 1.15 ballast factor.
f. Fixtures are on typically 12hrs each day M-F.
g. The electrical rate that will be used for this facility is $.107/kWh. This accounts for the expected rate increase by BHP.

1. 4-lamp 2X4 Parabolic: The savings is seen as the difference in fixture wattage of (.148kW - .064kW) 0.084kW per fixture
.084kW/fixt * 362fixt * 12hrs/day * 5dys/wk * 52wks/yr = 94,873kWh/yr
94,873kWh/yr *$0.107/kWh = $10,151/yr

2. 2-lamp 2X2 U-lamp: The savings is seen as the difference in fixture wattage of (.076kW -.039kW) 0.037kW per fixture
0.037kW/fixt * 289fixt * 12hrs/day * 5dys/wk * 52wks/yr = 33,362kWh/yr
33,362kWh/yr *$0.107/kWh = $3,570/yr

Investments

1. 4-lamp 2X4 Parabolic: 362fixt * $100/fixt = $36,200

2. 2-lamp 2X2 U-lamp: 289fixt * $100/fixt = $28,900

Payback

1. 4-lamp 2X4 Parabolic: The resulting payback is ($36,200/$10,151) 3.6 years.

2. 2-lamp 2X2 U-lamp: The resulting payback is ($28,900/$3,570) 8.1 years.

E-2: Rushmore Plaza Civic Center.

Savings

Assumptions:
a. A 1000W incandescent fixture uses 1000W, or 1kW and delivers 12,000 lumens.
b. A 175W metal halide fixture uses 200W, or 0.2kW and delivers 12,800 mean lumens.
c. A 500W quartz fixture delivers 10,000 lumens
d. A 3-lamp T8 fluorescent fixture delivers 9000 lumens and uses 96W, or 0.096kW
e. The electrical rate that will be used for this facility is $.107/kWh. This accounts for the expected rate increase by BHP.

1. Arena: The savings is the difference between the wattage of the incandescent fixtures and the wattage of the metal halide fixtures. 1kW – 0.2kW = 0.8kW

Savings: .8kW/fixt * 32fixt * 18hrs/day * 200dys/yr = 92,160kWh/yr
92160kWh/yr *$0.107/kWh = $9,861/yr

2. Rushmore/LaCroix Halls: Energy savings is seen by the difference between the quartz fixture and the fluorescent fixture. .5kW – 0.096kW = .404kW/fixt
0.404kW/fixt * 140fixt * 18hrs/day * 300dys/yr = 304,424kWh/yr
305,424kWh/yr *$0.107/kWh = $32,680/yr

3. Decorative Lighting: The savings is seen in the wattage difference between the two lamps. .040kW - .0015kW = 0.0385kW/lamp
0.0385kW/lamp * 512 lamps * 8hrs/dy * 7dys/wk * 50 wks/yr = 7,885kWh/yr
7,885kWh/yr * $0.107/kWh = $844/yr

We will also consider the lamp replacement savings. Each lamp runs an estimated 2,800 hrs each year. A 40W incandescent lamp has a 2000hr lamp life. A 1.5W LED lamp has a 30,000 hr lamp life. For this estimate, we will include the cost to replace each incandescent lamp once a year as a savings. $0.50/lamp will be used as cost.
512 lamps * $.50/lamp = $256/yr

Total savings = $844/yr + $256/yr = $1,100/yr

4. Corridor Lighting: The savings is seen in the wattage difference between the two lamps. 100W – 26W = 74W, or 0.074kW of savings.
0.074kW/lamp * 100 lamps * 12hrs/dy * 7dys/wk * 50wks/yr = 31,080kWh/yr
31,080kWh/yr * 0.107/kWh = $3326/yr

Investments

1. Arena: Each of the (32) watt incandescent fixtures will be replaced with a new 175W metal halide fixture with a shutter.

Total cost is 32 fixt * $600/fixt = $19,200

2. Replace 80 incandescent fixtures with 80 fluorescent dimmable fixtures with controls: Replacement cost is (Dimmable fluorescent fixture is $125 with $125 installation cost) $250/fixt.

Total cost is 80 fixt * $250/fixt = $35,000

3. Each LED lamp costs $3.50.
512 lamps * $3.50/lamp = $1,792

4. Each lamps costs approximately $10
100lamps * $10/lamp = $1,000

Payback

1. Arena: The resulting payback is ($19,200/$9,861) 1.9 years.

2 Rushmore/LaCroix Halls: The resulting payback is ($35,000/$32,680) 1.1 years.

3. Decorative Fixtures: The resulting payback is ($1,792/$1,100) 1.6 years.

4. Corridor Lighting: The resulting payback is ($1,000/$3,326) 0.3 years.

E-3: Replace HID high bay lighting with fluorescent.

Savings

Assumptions:
a. A 1000W MH fixture uses 1100W, or 1.1kW of electricity with the magnetic ballast.
b. A 6-lamp T5 fixtures use 325W or .325kW of electricity.
d. A 400W MH fixture uses 440W, or 0.44kW of electricity with the magnetic ballast.
e. The Material Recovery facility is in operation 10hrs each day, 5dys per week.
f. The ice arena is in operation 12hrs each day, 7dys per week.
g. The electrical rate that will be used for the material recovery facility is $.107/kWh. This accounts for the expected rate increase by BHP.
eg The electrical rate that will be used for this facility is $.103/kWh. This accounts for the expected rate increase by BHP.

1. Material recovery: Current Usage: .44kW/fixt * 163fixt * 10hrs/day * 5dys/wk * 52wks/yr = 186,472kWh/yr
186,472kWh/yr *$0.107/kWh = $19,952/yr

Proposed changes:
0.325kW/fixt * 163fixt *10hrs/day * 5dys/wk * 52wks/yr = 137,735kWh/yr
137,735kWh/yr * $0.107/kWh = $14,738/yr

The savings is the difference between the current usage and the proposed changes:
$19,952/yr - $14,738/yr = $5,214/yr

2. Roosevelt Ice Arena7: Current Usage: 0.44kW/fixt * 64fixt * 12hrs/day * 7dys/wk * 50wks/yr = 118,272kWh/yr
118,272kWh/yr *$0.103/kWh = $12,182/yr

Proposed changes:
0.325kW/fixt * 64fixt *12hrs/day * 7dys/wk * 50wks/yr = 87,360kWh/yr
87,360kWh/yr * $0.103/kWh = $8,998/yr

The savings is the difference between the current usage and the proposed changes:
$12,182/yr - $8,998/yr = $3,184/yr

Investments

1. Material Recovery: Each of the 163 metal halide fixtures take (1) 6-lamp T5 fixtures. Each metal halide fixture will cost $440 ($250 material and $190 labor):

Total cost is 163 fixt * $440/fixt = $71,720

1. Roosevelt Ice: Each of the 64 metal halide fixtures take (1) 6-lamp 4-foot T5 fixture. Each metal halide fixture will cost $440 ($250 material and $190 labor):

Total cost is 64 fixt * $440/fixt = $28,160

Payback

1. Material Recovery: The resulting payback is ($71,720/$5,214) 13.8 years.

2. Roosevelt Ice: The resulting payback is ($28,160/$3,184) 8.8 years.

E-4: Occupancy Sensors in Common Spaces

Savings

Assumptions:

a. Occupancy sensor cost is $75. Labor cost is $25. Total cost per occupancy sensor is $100.
b. Because many different buildings are considered in this write-up, an average of $0.0933/kWh will be used in the savings calculations.

1. Savings are seen from having the lighting fixtures off while the room is not in use.

The following will be used for typical hours: 10hrs/day, 5dys/wk, 50wks/yr.
10hrs/dy * 5dys/wk * 50wks/yr = 2,500hrs/yr.

Break Rooms:
3.2kW * 2500hrs/yr * 29% = 2,320kWh/yr
2,320kWh/yr * $0.0933/kWh = $216

Restroom/Lockers:
12.1kW * 2500hrs/yr * 47% = 14,218kWh/yr
14,218kWh/yr * $0.0933/kWh = $1,327/yr

Investments

1.

Break Rooms:
5 sensors * $100/sensor = $500

Restrooms/Lockers:
28 sensors * $100/sensor = $2,800

Payback

1. Breakrooms: The resulting payback is ($500/$216/yr) 2.3 years.

Restroom/lockers: The resulting payback is ($2,800/$1,327/yr) 0.36 years.

Bldg 7424: The resulting payback is ($1,680/$3,385/yr) 2.1 years.

L-5: Day Lighting Control.

Savings

Assumptions:
a. A 4-lamp T8 parabolic fixture uses 128W, or .128kW of electricity with an electronic ballast.
b. A 2-lamp T8 parabolic fixture uses 64W, or 0.064kW of electricity with an electronic ballast.
c. A 3-lamp fluorescent fixture uses 96W, or -.096kW of electricity with an electronic ballast.
d. Savings is seen by having the daylight sensor turn off light fixtures.
e. Assume 200 days of sunshine each year allowing the sensor to de-energize fixtures for 8-hours each of those days.
f. The electrical rate that will be used for the Public Library is $.113/kWh. This accounts for the expected rate increase by BHP.
e. The electrical rate that will be used for the Airport is $.0933/kWh. This rate is an average of the local rates and will be used since the rate at the Airport is unknown.

Savings: kW/fixt * #fixt * 8hrs/day * 200dys/yr = kWh/yr
kWh/yr *$0.0933/kWh = $/yr in savings

1. Library
Upper Library Area:
0..128kW/fixt * 18fixt *8hrs/day * 200dys/yr = 3686kWh/yr
3686kWh/yr * $0.113/kWh = $417/yr

Stairway and upper conference:
0.096kW/fixt * 10fixt *8hrs/day * 200dys/yr = 1536kWh/yr
1536kWh/yr * $0.113/kWh = $174/yr

Main Entry Vestibule:
0.064kW/fixt * 5fixt *8hrs/day * 200dys/yr = 512kWh/yr
512kWh/yr * $0.113/kWh = $58/yr

Total Savings:
$417/yr + $174/yr + $58/yr = $648/yr

2. Airport

Savings is seen by turning off approximately (50) 70W fluorescent fixtures for 6hrs each day, 365 days per year on average.
50 fixt * 0.07kW/fixt * 6hrs/dy * 365dys/yr = 7,665kWh/yr
7,665kWh/yr * 0.0933/kWh = $715/year

Investments

1. The cost for daylight controller installations at each of the hangars is as follows:

Library					
ITEM	**Units**	**Unit Qnty**	**Equip Cost/Unit**	**Labor Cost/Unit**	**Item Cost**
Daylight sensor	ea	3	140	70	$ 630
conduit/wire (60ft X 6)	lf	120	2.26	4.26	$ 782
Total					$ 1,412

2. Assume a technician cost of $125/hr * 8hrs = $1,000

Payback

1. The resulting payback is ($1,412/$648) 2.2 years.

2. The resulting payback is ($1,000/715) 1.4 yrs.

E-6: Replace Incandescent Lighting

Savings

1. Horace Mann: The savings is the difference between the wattage of the two fixtures. 0.1kW – 0.026kW = 0.074kW

Savings: .074kW/lamp * 70lamps * 8hrs/day * 100dys/yr = 4,144kWh/yr
4,144kWh/yr *$0.11/kWh = $456/yr

Investments

1. Horace Mann: Each 26W compact fluorescent lamp costs around $10

Total cost is 70 lamps * $10/lamp = $700

Payback

1. Horace Mann: The resulting payback is ($700/$456) 1.5 years.

E-8: Refrigerated Vending Machine Control for Energy Savings

The following table notes the refrigerated vending units observed

Bldg Name	No. of Mach.
Main Fire Station	2
Airport	7
Rushmore Plaza Civic Center	6
Haley Park Building	1
Library	1
Dahl Arts Center	1
City /School Administration	5
Milo Barber Transportation	1
Totals	**24**

Savings

The Vending Miser reduces electrical energy consumption by an average of 46%. This means that instead of $306 each year per machine, each machine will cost ($306 - .46*$306) $165/yr to operate. This provides a savings of $141 per year per machine.

Total savings of $141 * 24units = $3,384/yr

Investments

Each Vending Miser costs $180.

It is assumed that 2 Vending Miser units can be installed in 1 labor hour. Assuming a labor cost of $30/hr, each unit will cost $15 to install.

Each unit costs $195 for installation

Total Investment is $195 * 24units = $4,680

Payback

The resulting payback is $4,680/$3,384 = 1.4 years.

E-9: Roadway and Parking Lot Lighting. Compare LED to HID

Savings

Assumptions:
a. a 150W MH fixture uses 190W (0.19kW). A LED or Induction Fixture fixture uses 104W (0.104kW)
b. Light fixtures are on 10hrs per day on average throughout the year.

1. The savings is seen in both the energy usage, and reduced lamp replacement. The energy savings is the difference in wattage during lamp use. (0.19kW – 0.104kW = 0.086kW).

   .086kW * 10hrs/dy * 365dys/yr = 314kWh/yr
   314kWh/yr * $0.11/kWh = $34.5/yr.

   Savings can also be seen by reduced maintenance cost. The City of Rapid City pays an outside service to maintain the roadway fixtures. The outside service costs $1.29/mo for each fixture. It is not expected that this would change with the different fixture type, to reduced maintenance will not be considered.

2. Induction fixtures are the same as LED above for savings.

3. Solar power savings is the total HID energy usage.

   0.19kW * 10hrs/dy * 365dys/yr = 693.5kWh/yr
   693.5kWh/yr * $0.11/kWh = $76/yr

Investments

1. The LED investment is the difference between fixture costs.
$1,500 - $275 = $1,225

2. The Induction investment cost is the difference between fixture costs.
$500 - $275 = $225

3. It is difficult to determine the standard of quality for the solar powered light. There are many solar powered fixture manufacturers on the market. This analysis will use the same LED fixture as recommended in part one to base the quality along with a $300 adder for the solar package. Total fixture cost is $1,800. The investment cost is the difference between the solar fixture and the HID. $1,800 - $275 = $1,525.

Payback

1. The resulting payback for LED is ($1,225/$34.5) 35.5 years.

Note that for the payback to be 5 years to use LED fixtures, the fixture cost would need to be 5yr = ($X - $275) / $35.5
$X = 5ry * $35.5 + $275
$453 per fixture

2. The resulting payback for Induction is ($225/$34.5) 6.5 years.

3. The resulting payback for solar lighting is ($1,525/$76 = 20 years.

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PROJECT NAME:	City of Rapid City
PROJECT NUMBER:	22593.01.00
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DATE COMPUTED:	4/8/10
CHECKED BY:	
DATE CHECKED:	
APPROVED BY:	
DATE APPROVED:	
REVISION:	

CALCULATION SHEET

AERATION BLOWER VFD EVALUATION (E-7)

REVISIONS

None

DESCRIPTION

Determine the payback based on energy savings for installing VFDs on the activated sludge aeration blowers at the City of Rapid City wastewater treatment plant.

REFERENCES

1.Midwest City Saves Money by Controlling Dissolved Oxygen in Aeration Basin", Water & Wastes Digest, May 2002
2.ISTC Fact Sheet, TN10-097, "Reducing Energy Usage in Water and Wastewater Treatment Facilities: A Tale of Two Cities"

GIVEN

The WWTP has three 300 hp aeration blower with 150 kW motors.The WWTP runs one blower at full load.

Dissolved oxygen control can reduce air flow to activated sludge systems by and average of 25%. This can be done using variable frequency drives.

Reducing blower load by 25% will reduce electrical power requirement by 57%.

VFD for 300 hp motor is $44,000. The installation cost was assumed to be twice the equipment cost. Therefore, the installed cost of a single VFD is $132,000.

$$Capex := 3 \cdot 132000 = 3.96 \times 10^{5} \text{ dollars}$$

$$electricity := 0.112 \frac{\text{dollars}}{\text{kWhr}}$$

CALCULATION

$$Electricity_Use := 150 \cdot 24 \cdot 365 = 1.31 \times 10^{1} \frac{\text{kWhr}}{\text{yr}}$$

$$Electricity_Savings := Electricity_Use \cdot 0.57 = 7.49 \times 10^{5} \frac{\text{kWhr}}{\text{yr}}$$

$$Cost_Savings := Electricity_Savings \cdot electricity = 8.39 \times 10^{4} \ \frac{dollars}{yr}$$

$$Payback := \frac{Capex}{Cost_Savings} = 4.72 \quad years$$

Appendix C

Renewable Energy Calculations

Stanley Consultants INC.

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PROJECT NAME:	City of Rapid City
PROJECT NUMBER:	22593.01.00
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CALCULATION SHEET

Landfill Gas for Heating Composting Buidling (REO-1)

REVISIONS

none

DESCRIPTION

The landfill and the composting facility are located adjacent to each other. The composting facility uses natural gas to maintain building temperature and compost pile temperature. The landfill gas could replace natural gas for heating the composting building.

REFERENCES

1. *Landfill gas recovery project summary poster in Material Reclaimation Center Office*

GIVEN

Project description of lanfill gas recovery for industrial use.

$$Capex := 2384700 \quad dollars$$

$$OandM := 282000 \ \frac{dollars}{yr}$$

$$Revenue := 650000 \ \frac{dollars}{yr}$$

Natural gas price $Nat_Gas := 7.627 \ \frac{dollars}{mmBTU}$

$$Nat_Gas_Produced := \frac{Revenue}{Nat_Gas} = 8.52 \times 10^4 \ \frac{mmBTU}{yr}$$

In 2009 the Material Reclamation Center spend $103,000 on natural gas

CALCULATION

$$Nat_Gas_Use := \frac{103000}{Nat_Gas} = 1.35 \times 10^4 \ \frac{mmBTU}{yr}$$

$$Percent_Landfill_Gas_Recovery := \frac{Nat_Gas_Use}{Nat_Gas_Produced} = 0.16$$

Landifll gas recovery system needed to just meet the needs of heating the composting building would be 16% of the complete landfill gas recovery system.

$$Capex_Compost := Capex \cdot Percent_Landfill_Gas_Recovery = 3.78 \times 10^{5} \quad dollars$$

$$OandM_Compost := OandM \cdot Percent_Landfill_Gas_Recovery = 4.47 \times 10^{4} \quad \frac{dollars}{yr}$$

$$Revenue_Compost := Revenue \cdot Percent_Landfill_Gas_Recovery = 1.03 \times 10^{5} \quad \frac{dollars}{yr}$$

$$Annual_Savings := Revenue_Compost - OandM_Compost = 5.83 \times 10^{4} \quad \frac{dollars}{yr}$$

$$Payback := \frac{Capex_Compost}{Annual_Savings} = 6.48 \quad years$$

Stanley Consultants INC.

A Stanley Group Company
Engineering, Environmental and Construction Services - Worldwide

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PROJECT NUMBER:	22593.01.00
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CALCULATION SHEET

Photovoltaic (PV) Solar Power Generation (REO-2)

REVISIONS

None.

DESCRIPTION

Evlauate the payback of PV solar electricty generation in Rapid City, South dakota

REFERENCES

1. PVWatts by National Renewable Energy Laboratory
2.Personal communciation with Mario Monesterio, Principal, Westwood Renewables
3. SolarWorld SW220/225/230 specification sheet

GIVEN

Using PVWatts; 35 m2 of PV panels (i.e., 4,000 Wdc system) in Rapid City, SD will produce 5,500 IWhr/yr

Small roof mounted solar PV systems cost $6 to $8 per Wdc installed

Use 4 kW system from PVWatts for analysis

$$\text{Electricty} := 0.112 \quad \frac{\text{dollars}}{\text{kWhr}}$$

CALCULATION

$$\text{Capex_low} := 4000 \cdot 6 = 2.4 \times 10^4 \quad \text{dollars}$$

$$\text{Capex_High} := 4000 \cdot 8 = 3.2 \times 10^4 \quad \text{dollars}$$

$$\text{Energy_Savings} := 5500 \cdot \text{Electricty} = 616 \quad \frac{\text{dollars}}{\text{yr}}$$

$$\text{Payback_low} := \frac{\text{Capex_low}}{\text{Energy_Savings}} = 38.96 \quad \text{years}$$

$$Payback_high := \frac{Capex_High}{Energy_Savings} = 51.95 \quad years$$

How much do you need to buy down the capex to get to a 15 year payback?

$$Buydown_Low := Capex_low - (Energy_Savings \cdot 15) = 1.48 \times 10^4 \quad dollars$$

$$Buydown_High := Capex_High - (Energy_Savings \cdot 15) = 2.28 \times 10^4 \quad dollars$$

Elect

$$electricty_rate := \frac{\left(\frac{Capex_low + Capex_High}{2}\right)}{5500 \cdot 15} = 0.34 \quad \frac{dollars}{kWhr}$$

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PROJECT NAME:	City of Rapid City
PROJECT NUMBER:	22593.01.00
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CALCULATION SHEET

Beneficial Biogas Use at Wastewater Treatment Plant (REO-3)

REVISIONS

A - change in natural gas and electrical cost

DESCRIPTION

The City of Rapid City wastewater treatment plant currently processes all primary sludge and half of the secondary treatment sludge through anaeorbic diegstion. There is no measurement of the amount of biogas produced. The biogas is currently used to maintain temperature in the digesters with the excess biogas flared. This calculation estimates the amount of biogas produced and the amount of electricty that could be produced form the biogas.

REFERENCES

1. *Caterpillar G3412 specification sheet*
2. *Wastewater Engineering:Treatment and Reuse, Metcalf & Eddy fourth edition*

GIVEN

City fo Rapid City wastewater tretament plant processes 8 - 9 MGD of flow which represents 80,000 to 90,000 population equivalents.

Anerobic digestion of primary sludge produces 0.6 - 0.8 scf/capita-day of biogas

Anaerobic digestion of primary and secondary sludges produces 1 scf/capita-day of biogas

Biogas is 600 BTU/scf

G3412 genset requires 2.5 mmBTU/hr of fuel

G3412 genset produces 191 kW at full load.

$Engine_Capex := 275000 \quad dollars$

Engine O&M is assuemd to be 10% of the equipment cost

$OandM := Engine_Capex \cdot 0.1 = 2.75 \times 10^4 \quad dollars$

$Nat_Gas := 7.627 \quad \frac{dollars}{mmBTU}$

$Electricity := 0.112 \quad \frac{dollars}{kWhr}$

CALCULATION

Estimate of Biogas Production (assuming 85,000 population equivalents)

$$\text{Biogas_Production} := (85000 \cdot 0.7) + \left[\left(\frac{85000}{2}\right) \cdot 0.3\right] = 7.22 \times 10^4 \ \frac{\text{SCF}}{\text{day}}$$

$$\text{Biogas_Energy} := \text{Biogas_Production} \cdot \frac{600}{10^6} = 43.35 \ \frac{\text{mmBTU}}{\text{day}}$$

$$\text{Biogas_Heat_Rate} := \frac{\text{Biogas_Energy}}{24} = 1.81 \ \frac{\text{mmBTU}}{\text{hr}}$$

$$\text{Nat_Gas_Augment} := (2.5 - \text{Biogas_Heat_Rate}) \cdot 24 \cdot 365 = 6077.25 \ \frac{\text{mmBTU}}{\text{yr}}$$

$$\text{Electrical_Production} := 191 \cdot 24 \cdot 365 = 1.67 \times 10^6 \ \frac{\text{kWhr}}{\text{yr}}$$

$$\text{Net_Energy_Savings} := \text{Electrical_Production} \cdot \text{Electricity} - \text{OandM} - \text{Nat_Gas_Augment} \cdot \text{Nat_Gas} = 1.14 \times 10^5 \ \frac{\text{dollars}}{\text{yr}}$$

Mechical instalation and electrical interconnect are estimated to cost an addition $150,000.
Desulfurization unit is assuemd to be $100,000 installed.

$$\text{Project_Capex} := \text{Engine_Capex} + 150000 + 100000 = 5.25 \times 10^5 \ \text{dollars}$$

$$\text{Payback} := \frac{\text{Project_Capex}}{\text{Net_Energy_Savings}} = 4.62 \ \text{years}$$

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CALCULATION SHEET

Solar Water Heating (REO-4)

REVISIONS

None

DESCRIPTION

Calculating the payback for a solar hot water heating system.

REFERENCES

1. *Means HVAC Section D3010, page 500-501*
2. *Solar Skies Manufacturing, Solar Collector Certification and Rating*

GIVEN

1. *Temperature data from City of Rapid City: Average Annual high: 59.6 oF*
   Average Annual Low: 34 oF
   Average Annual: 46.8 oF

Solar Skies Operational Data (BTU/day-panel)

	36 oF	46.8 oF	90 oF
Clear	42000	38600	25000
Mildly Cloud	29000	25800	13000
Cloudy	16000	13400	3000
Average	29000	25933	13666

$$Heat_Rate := 25000 \quad \frac{BTU}{day \cdot panel}$$

2. *Means cost for installation of a 10 panel water heating system is $18,325*
3. *Cost analysis will be based on a 10 panel system*
4. *A system coudl be sized to meet speicifc building needs simply as a multiple of the 10 panel system*
5. *Natural gas price $7.627/mmBTU*

CALCULATION

$$Annual_Energy_Savings := \frac{10 \cdot 25000 \cdot 365}{10^6} = 91.25 \quad \frac{mmBTU}{yr}$$

$$Annual_Cost_Savings := Annual_Energy_Savings \cdot 7.627 = 695.96 \quad \frac{dollars}{yr}$$

$$Payback := \frac{18325}{Annual_Cost_Savings} = 26.33 \quad years$$

How much do you need to buy down the capex to get a 15 year payback

$$Buydown := 18325 - (Annual_Cost_Savings \cdot 15) = 7885.54 \quad dollars$$

$$Percent_Project_Buydown := \frac{Buydown}{18325} = 0.43$$

Natural Gas price for 15 year payback

$$NG_price := \frac{18325}{Annual_Energy_Savings \cdot 15} = 13.39 \quad \frac{dollars}{mmBTU}$$

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CALCULATION SHEET

Waste Vegetable Oil to Biodiesel (REO-5)

REVISIONS

None

DESCRIPTION

This calculation shows the amount of biodiesel that coudl be produced by the City of Rapid City and a simple financial payback from converting waste vegetable oil to biodiesel

REFERENCES

1.Singh, A. et al., "Biodiesel Process Selection: Rendered Products vs. Soybean Oil", Render, Feb 2007.

GIVEN

1. *Rushmoore Civic Center food services division produces 45 55-gallon drums of waste vegetable oil each year*
2. *The cost for disposal of waste vegetable oil is $30/drum*
3. *A 175 gallons/batch skid mounted biodiesel process costs $10,000*
4. *Operation, maintenance, and chemical (OMC) cost are $0.88/gallon produced*
5. *Diesel price is $2.80/gallon*

CALCULATION

$$\text{Annual_WVO_Production} := 45 \cdot 55 = 2475 \ \frac{\text{gallons}}{\text{yr}}$$

$$\text{Annual_Cost_Savings} := [(30 \cdot 45) + (2475 \cdot 2.80)] = 8280 \ \frac{\text{dollars}}{\text{yr}}$$

$$\text{OMC} := 2475 \cdot 0.88 = 2178 \ \frac{\text{dollars}}{\text{yr}}$$

$$\text{Net_Savings} := \text{Annual_Cost_Savings} - \text{OMC} = 6102 \ \frac{\text{dollars}}{\text{yr}}$$

$$\text{Simple_Payback} := \frac{10000}{\text{Net_Savings}} = 1.64 \ \text{years}$$