Foster Wheeler - South East Plant - University of Minnesota
Comprehensive Energy Assessment
In Compliance with 40 CFR Part 63 Subpart JJJJJJJJ

PREPARED FOR:

PROJECT NUMBER:

S14-015

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I. EXECUTIVE SUMMARY

As per the EPA, existing oil, biomass, and coal-fired boilers with a design heat input capacity of 10 MMBtu/hr or greater and categorized as an “Area Source” emissions producer must conduct a one-time energy assessment performed by a qualified energy assessor by March 21, 2014 in order to be in compliance with the 40 CFR Part 63, Subpart JJJJJ (Boiler MACT) regulation. The regulation specifies that the energy assessment must contain, but is not limited to, seven (7) specific areas of focus.

1. Performance of a visual inspection of the boiler system to identify general condition, noting conditions such as cracks, corrosion, leaks, and insulation condition.
2. An evaluation of the operating characteristics of the affected boiler systems, specifications of energy use systems, operating and maintenance procedures, and unusual operating constraints.
3. An inventory of major systems consuming energy (i.e., energy use systems) from affected boiler(s) and which are under the control of the boiler owner or operator.
5. A list of major energy conservation measures that are within the facility’s control.
6. A list of the energy savings potential of the energy conservation measures identified.
7. A comprehensive report detailing the ways to improve efficiency, the cost of specific improvements, benefits, and the time frame for recouping those investments.

Foster Wheeler hired SourceOne to complete this energy assessment for its University of Minnesota facilities. On February 25th of this year, SourceOne performed an on-site energy assessment of the South East Plant located at 12-20 Sixth Ave. SE, Minneapolis, MN. SourceOne was assisted by Richard Lewis (Engineering Manager), Josh Svejcar (Chief Operator & Maintenance Supervisor), Paul Hostettler (EIC Supervisor), as well as several other plant personnel. The South East Plant has 23 employees. As part of this initiative, the SourceOne representatives have:

- Reviewed the documentation provided by the staff in response to SourceOne’s “Energy Assessment RFI” prior to arriving on-site
  - DEP Emissions Limits
  - Boiler Operating Procedures & Drawings
  - Boiler Fuel Usage Summary Tables
- Conducted an on-site “Kick-Off” meeting with plant personnel to review RFI response documents as well as site visit agenda
- Reviewed the distributed control system (DCS) functionality and graphics with Operations personnel
- Reviewed applicable drawings and documents
  - Boiler Data Sheets
  - Raw Water/City Water/Make-Up Water System
  - Water Treatment
  - Feedwater System
  - Boiler Blowdown System
  - Natural Gas System
  - #2 Fuel Oil System
  - Combustion Air System
Review Preventative Maintenance (PM) Program and Corrective Maintenance (CM) issues with plant Maintenance and Operations personnel
Conducted facility walkthroughs where a visual inspection of the boiler systems was conducted and the general condition and deficiencies were noted. The walkthroughs were limited to the boiler systems
Identified energy conservation measures (ECM’s) and potential energy conservation initiatives (ECI’s)
Conducted an on-site “Wrap-Up” meeting with Josh Svejcar to review findings, potential ECM’s & ECI’s, and non-energy conservation related recommendations.
Conducted off-site review of documentation provided by facility personnel
- Natural Gas and Fuel Oil Cost Summary Sheet
- Existing Outstanding Corrective Maintenance Issues
- Historic High Priority Corrective Maintenance Issues for the past few years
- Existing Preventative Maintenance Work Orders
- 2013 Emissions Statements
- 2013 Fuel Consumption Data
Analyzed potential ECM’s for financial feasibility and attractiveness as measured by “simple payback”
- Identified twenty-eight (28) energy conservation measures (ECM’s) that will conserve energy
- Identified one (1) energy conservation initiatives (ECI’s) that may conserve energy but require additional analysis outside the scope of this report to confirm energy savings and financial paybacks

ENERGY CONSERVATION MEASURES (ECM’S)

The implementation of the twenty-eight (28) aforementioned SourceOne ECM’s should result in the following energy savings:

Compressed Air System

S1-CAS-ECM-1: Replacement of 60 HP Air Compressor Motors with High Efficiency Equivalents
- Energy Savings: 16,584 kWh
- Capital Cost: $6,400
- Payback: 9.65 years

S1-CAS-ECM-2: Replacement of 150 HP Air Compressor Motors with High Efficiency Equivalents
- Energy Savings: 18,825 kWh
- Capital Cost: $14,700
- Payback: 9.76 years
Feedwater System

S1-BFW-ECM-1: Replacement of 600 HP Feedwater Pump Motors with High Efficiency Equivalents and Installation of VFDs
⇒ Energy Savings: 1,084,817 kWh
⇒ Capital Cost: $223,400
⇒ Payback: 2.57 years

S1-BFW-ECM-2: Replacement of 300 HP Feedwater Pump Motors with High Efficiency Equivalents and Installation of VFDs
⇒ Energy Savings: 324,692 kWh
⇒ Capital Cost: $114,800
⇒ Payback: 4.42 years

S1-BFW-ECM-3: Replacement of EU-005 Feedwater Pump Motors with High Efficiency Equivalents
⇒ Energy Savings: 961 kWh
⇒ Capital Cost: $27,000
⇒ Payback: 351 years (Not Cost Justifiable Based Upon Energy Savings Alone)

Water Treatment System

S1-WTS-ECM-1: Replacement of Raw Water Pump Motors with High Efficiency Equivalents
⇒ Energy Savings: 327 kWh
⇒ Capital Cost: $2,800
⇒ Payback: 107 years (Not Cost Justifiable Based Upon Energy Savings Alone)

S1-WTS-ECM-2: Replacement of Demineralized Water Pump Motors with High Efficiency Equivalents
⇒ Energy Savings: 6,804 kWh
⇒ Capital Cost: $6,400
⇒ Payback: 11.7 years (Not Cost Justifiable Based Upon Energy Savings Alone)

Combustion Air System

S1-CA-ECM-1: Replacement of EU-005 Forced Draft Fan Motor with High Efficiency Equivalent
⇒ Energy Savings: 291 kWh
⇒ Capital Cost: $4,100
⇒ Payback: 176 years (Not Cost Justifiable Based Upon Energy Savings Alone)

S1-CA-ECM-2: Replacement of EU-005 Over-Fire Air Fan Motor with High Efficiency Equivalent
⇒ Energy Savings: 273 kWh
⇒ Capital Cost: $3,200
⇒ Payback: 147 years (Not Cost Justifiable Based Upon Energy Savings Alone)

S1-CA-ECM-3: Replacement of EU-005 Induced Draft Fan Motor with High Efficiency Equivalent and Installation of VFD
⇒ Energy Savings: 961 kWh
⇒ Capital Cost: $13,500
⇒ Payback: 176 years (Not Cost Justifiable Based Upon Energy Savings Alone)
S1-CA-ECM-4: Replacement of EU-005 Baghouse Induced Draft Fan Motor with High Efficiency Equivalent
  ⇒ Energy Savings: 1,312 kWh
  ⇒ Capital Cost: $28,700
  ⇒ Payback: 273 years *(Not Cost Justifiable Based Upon Energy Savings Alone)*

S1-CA-ECM-5: Replacement of EU-001 Forced Draft Fan Motor with High Efficiency Equivalent and Installation of VFD
  ⇒ Energy Savings: 1,352,201 kWh
  ⇒ Capital Cost: $209,000
  ⇒ Payback: 1.93 years

S1-CA-ECM-6: Replacement of EU-001 Blower Motor with High Efficiency Equivalent
  ⇒ Energy Savings: 6,025 kWh
  ⇒ Capital Cost: $2,600
  ⇒ Payback: 5.39 years

S1-CA-ECM-7: Replacement of EU-001 Induced Draft Fan Motor with High Efficiency Equivalent and Installation of VFD
  ⇒ Energy Savings: 946,541 kWh
  ⇒ Capital Cost: $127,500
  ⇒ Payback: 1.68 years

S1-CA-ECM-8: Replacement of EU-002 Forced Draft Fan Motor with High Efficiency Equivalent and Installation of VFD
  ⇒ Energy Savings: 621,357 kWh
  ⇒ Capital Cost: $112,700
  ⇒ Payback: 2.27 years

S1-CA-ECM-9: Replacement of EU-003 Forced Draft Fan Motor with High Efficiency Equivalent and Installation of VFD
  ⇒ Energy Savings: 797,057 kWh
  ⇒ Capital Cost: $112,700
  ⇒ Payback: 1.77 years

**Coal Handling System**

S1-CHS-ECM-1: Replacement of Belt Drive Motor with High Efficiency Equivalent
  ⇒ Energy Savings: 1,255 kWh
  ⇒ Capital Cost: $1000
  ⇒ Payback: 9.96 years

S1-CHS-ECM-2: Replacement of 40 HP Crusher Drive Motor with High Efficiency Equivalent
  ⇒ Energy Savings: 1,408 kWh
  ⇒ Capital Cost: $2,150
  ⇒ Payback: 19.1 years *(Not Cost Justifiable Based Upon Energy Savings Alone)*

S1-CHS-ECM-3: Replacement of Bucket Drive Motor with High Efficiency Equivalent
  ⇒ Energy Savings: 570 kWh
  ⇒ Capital Cost: $800
  ⇒ Payback: 17.5 years *(Not Cost Justifiable Based Upon Energy Savings Alone)*
S1-CHS-ECM-4: Replacement of Conveyor Drive Motor with High Efficiency Equivalent
- Energy Savings: 680 kWh
- Capital Cost: $670
- Payback: 12.3 years (Not Cost Justifiable Based Upon Energy Savings Alone)

Fuel Oil System

S1-FOS-ECM-1: Replacement of Fuel Oil Pump Motors with High Efficiency Equivalents
- Energy Savings: 3,536 kWh
- Capital Cost: $6,400
- Payback: 22.6 years (Not Cost Justifiable Based Upon Energy Savings Alone)

Lube Oil System

S1-STG-ECM-1: Replacement of Lube Oil Pump Motors with High Efficiency Equivalents
- Energy Savings: 14,793 kWh
- Capital Cost: $5,200
- Payback: 4.39 years

Condensate System

S1-CND-ECM-1: Replacement of Condensate Pump (P-104A) Motor with High Efficiency Equivalent
- Energy Savings: 20,234 kWh
- Capital Cost: $10,800
- Payback: 6.67 years
S1-CND-ECM-2: Replacement of Condensate Pump (P-104B) Motor with High Efficiency Equivalent
- Energy Savings: 712 kWh
- Capital Cost: $10,800
- Payback: 190 years (Not Cost Justifiable Based Upon Energy Savings Alone)

Cooling Water System

S1-CW-ECM-1: Replacement of Cooling Tower Fan Motors with High Efficiency Equivalents and Installation of VFDs
- Energy Savings: 39,150 kWh
- Capital Cost: $16,000
- Payback: 5.11

Limestone Handling System

S1-LSH-ECM-1: Replacement of Limestone Blower Motor with High Efficiency Equivalent
- Energy Savings: 1,703 kWh
- Capital Cost: $1,800
- Payback: 13.2 years (Not Cost Justifiable Based Upon Energy Savings Alone)
Ash Handling System

S1-AHS-ECM-1: Replacement of Ash Blower Motor with High Efficiency Equivalent
⇒ Energy Savings: 715 kWh
⇒ Capital Cost: $7,350
⇒ Payback: 128 years \(\text{(Not Cost Justifiable Based Upon Energy Savings Alone)}\)

S1-AHS-ECM-2: Replacement of Fly-Ash Re-Injection Pump Motor with High Efficiency Equivalent
⇒ Energy Savings: 1,703 kWh
⇒ Capital Cost: $1,800
⇒ Payback: 13.2 years \(\text{(Not Cost Justifiable Based Upon Energy Savings Alone)}\)

As can be seen above, many of the twenty-eight (28) ECM’s investigated are not cost justifiable based upon energy savings alone and are not recommended. Refer to Section IX where all ECM’s and calculations are described in detail.

ENERGY CONSERVATION INITIATIVES (ECI’S)

In addition to these ECM’s, SourceOne identified one (1) other energy conservation initiative (ECI) that would probably conserve energy at the stations but whose cost savings evaluation and financial payback would require a much more detailed analysis than that afforded as part of our energy assessment. This ECI is as follows:

Blowdown System

S1-BDS-ECI-1: Installation of Conductivity Meter and Auto-Dump Valves on Blowdown System
⇒ This ECI is an upgrade of the Blowdown System on all boilers to conductivity meters and automatic control valves from a manually controlled system. Cost savings comes by way of increased efficiency of operations personnel, improved boiler water chemistry, a reduction in feedwater water dumped by the boiler, quenching water at blowdown tank, and less damage to the boiler tubes.
⇒ Capital Cost: $35,000

ADDITIONAL RECOMMENDATIONS

In an effort to more closely monitor steam production, consumption, and efficiency of the steam cycle of the plant, it is recommended that steam flow meters be installed on each boiler. This installation would increase accuracy of boiler efficiency calculations and provide sufficient data to indicate auxiliary load steam consumption within the plant.
II. FACILITY OVERVIEW

Foster Wheeler operates and maintains a combined heat and power plant ("the plant," "the facility") on its premises at 12-20 Sixth Ave. SE, Minneapolis, MN. The plant was constructed in 1903 and is a dedicated steam supplier to the East Bank and West Bank Campuses at the University of Minnesota ("the University"). The plant is owned by the University which uses the steam for heating and cooling (steam-absorption chillers), domestic hot water, and other process needs at the University campuses and its affiliated medical centers.

There are five (5) boilers, of which four (4) are operational, that produce the steam at the facility. Natural gas, coal, oil, and wood are all used as fuel sources. Steam is produced at various pressures of both saturated and superheated steam but steam is distributed to the University at approximately 210 psig (saturated). Total steam generation capacity is approximately 1,000 MMBtu/hr, which equates to almost 900 Mlbs/hr at the steam distribution pressure. This capacity well exceeds the present maximum steam requirements of the University of 500 Mlbs/hr.

Two (2) of the boilers produce superheated steam which is utilized by a steam turbine generator to produce power. Total power output of the steam turbine generator is 15 MW. The plant uses several megawatts in auxiliary loads and the remaining power is used by the University. Extraction steam from the turbine at 210 psig is also tied into the header along with the steam generated from the two (2) lower pressure boilers and is fed to the grid for which the University receives credit.

Table 1, shown on the following page, presents an overview of the applicable major energy consuming boiler system equipment at the facility. The equipment will be discussed in more detail in this section.
<table>
<thead>
<tr>
<th>Item</th>
<th>System</th>
<th>Unit Type</th>
<th>Equipment ID</th>
<th>Rating</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Compressed Air System</td>
<td>Air Compressor</td>
<td>#1, #2</td>
<td>150 HP; VFD</td>
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<tr>
<td>2</td>
<td>Compressed Air System</td>
<td>Air Compressor</td>
<td>#2, #3</td>
<td>60 HP</td>
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<tr>
<td>3</td>
<td>Compressed Air System</td>
<td>Atlas Copco Air Compressor</td>
<td>C-101A, C-101B</td>
<td>350 HP; 4000 V; 95.4% Efficient</td>
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<td>4</td>
<td>Feedwater System</td>
<td>Feedwater Pump</td>
<td>BFP-103A, 103B</td>
<td>600 HP; 4000 V; Prem. Efficiency</td>
</tr>
<tr>
<td>5</td>
<td>Feedwater System</td>
<td>Feedwater Pump</td>
<td>BFP-103C</td>
<td>Steam Turbine Driven</td>
</tr>
<tr>
<td>6</td>
<td>Feedwater System</td>
<td>Feedwater Pump</td>
<td>BFP-105A, 105B</td>
<td>300 HP; 4000 V</td>
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<tr>
<td>7</td>
<td>Feedwater System</td>
<td>Raw Water Pump</td>
<td>(EU-005) FWP-A, B</td>
<td>250 HP; 460 V</td>
</tr>
<tr>
<td>8</td>
<td>Feedwater System</td>
<td>Demin Water Pump</td>
<td>P-102A, 102B</td>
<td>60 HP; 460 V; 89.5% Efficient</td>
</tr>
<tr>
<td>9</td>
<td>Combustion Air System</td>
<td>Forced Draft Fan</td>
<td>(EU-005)</td>
<td>100 HP; 460 V; 93% Efficient; Mag Drive</td>
</tr>
<tr>
<td>10</td>
<td>Combustion Air System</td>
<td>Over-Fire Air Fan</td>
<td>(EU-005)</td>
<td>60 HP; 460 V; 91.7% Efficient</td>
</tr>
<tr>
<td>11</td>
<td>Combustion Air System</td>
<td>Induced Draft Fan</td>
<td>(EU-005)</td>
<td>250 HP; 460 V; 93% Efficient</td>
</tr>
<tr>
<td>12</td>
<td>Combustion Air System</td>
<td>Baghouse Induced Draft Fan</td>
<td>(EU-005)</td>
<td>500 HP; 460 V; Mag Drive</td>
</tr>
<tr>
<td>13</td>
<td>Combustion Air System</td>
<td>Forced Draft Fan</td>
<td>(EU-001) B-201</td>
<td>1000 HP; 4160 V</td>
</tr>
<tr>
<td>14</td>
<td>Combustion Air System</td>
<td>Blower</td>
<td>(EU-001) B-204</td>
<td>50 HP; 460 V; 92.4% Efficient</td>
</tr>
<tr>
<td>15</td>
<td>Combustion Air System</td>
<td>Induced Draft Fan</td>
<td>(EU-001) B-203</td>
<td>700 HP; 4160 V</td>
</tr>
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<td>16</td>
<td>Combustion Air System</td>
<td>Forced Draft Fan</td>
<td>(EU-002) B-210</td>
<td>600 HP; 4160 V; 94.5% Efficient</td>
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<tr>
<td>17</td>
<td>Combustion Air System</td>
<td>Forced Draft Fan</td>
<td>(EU-003) B-220</td>
<td>600 HP; 4160 V; 94.5% Efficient</td>
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<tr>
<td>18</td>
<td>Coal Handling System</td>
<td>Belt Drive Motor</td>
<td>#1</td>
<td>15 HP</td>
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<tr>
<td>19</td>
<td>Coal Handling System</td>
<td>Crusher Drive Motor</td>
<td>CM-1</td>
<td>40 HP; 460 V; 91.7% Efficient</td>
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<tr>
<td>20</td>
<td>Coal Handling System</td>
<td>Crusher Drive Motor</td>
<td>CM-2</td>
<td>125 HP; 460 V; 95.8% Efficient</td>
</tr>
<tr>
<td>21</td>
<td>Coal Handling System</td>
<td>Bucket Drive Motor</td>
<td>#1</td>
<td>10 HP; 460 V; 87.5% Efficient</td>
</tr>
<tr>
<td>22</td>
<td>Coal Handling System</td>
<td>Conveyor Drive Motor</td>
<td>#1</td>
<td>7.5 HP; 460 V</td>
</tr>
<tr>
<td>23</td>
<td>Fuel Oil System</td>
<td>Fuel Oil Pump</td>
<td>MP-115A, 115B</td>
<td>60 HP; 460 V; 93% Efficient</td>
</tr>
<tr>
<td>24</td>
<td>Turbine Generator</td>
<td>Lube Oil Pump</td>
<td>P-123, P-124</td>
<td>50 HP; 460 V; 93% Efficient</td>
</tr>
<tr>
<td>25</td>
<td>Condensate System</td>
<td>Condensate Pump</td>
<td>P-104A</td>
<td>200 HP; 460 V; 86% Efficient</td>
</tr>
<tr>
<td>26</td>
<td>Condensate System</td>
<td>Condensate Pump</td>
<td>P-104B</td>
<td>200 HP; 460 V; 95.8% Efficient; VFD</td>
</tr>
<tr>
<td>27</td>
<td>Cooling Water System</td>
<td>Cooling Water Pump</td>
<td>P-106A, 106B</td>
<td>75 HP; 460 V; 95.4% Efficient</td>
</tr>
<tr>
<td>28</td>
<td>Limestone System</td>
<td>Limestone Blower</td>
<td>#1, #2</td>
<td>30 HP; 460 V</td>
</tr>
<tr>
<td>29</td>
<td>Ash Handling System</td>
<td>Ash Blower</td>
<td>#1, #2</td>
<td>150 HP; 460 V; 95.4% Efficient</td>
</tr>
<tr>
<td>30</td>
<td>Ash Handling System</td>
<td>Fly-Ash Re-Injection Pump</td>
<td>#1</td>
<td>30 HP</td>
</tr>
</tbody>
</table>

**Table 1: Major Energy Consuming Boiler System Equipment**

The rest of this section will detail the equipment comprising each boiler system and its operation. Some of the equipment is common to all boilers and some equipment is dedicated. A process flow diagram for the plant can be found in the appendix of the report as “Attachment – i”. 
City Water / Raw Water

Figure 1: Raw Water Entering Plant

Raw water, untreated, enters the plant and is sent out to the Fire Water, Water Treatment, and Cooling Water Systems. As can be seen from Figure 1 above, prior to being sent to the Water Treatment System, Raw water enters the plant and passes through two (2) Raw Water Pumps (MP-P101A&B), shown in Figure 2 below. Water pressure is typically around 110 psig and the pumps are only required when the pressure drops below 80 psig.

Figure 2: Raw Water Pumps (P-101A&B)
Water Treatment System / Make-Up Water System

The Water Treatment System consists of two (2) trains of cation and anion tanks used to remove mineral salts from the raw water. From these tanks the deionized water is sent to the Demineralization (Demin) Storage Tanks (TK-101A&B) until one of the two (2) Demin Pumps (P102A&B), shown in Figure 3 below, send the treated water to one of the two deaerators (DH101, DH102) as make-up water. The Demin Pumps (P102A&B) are controlled by a level control valve (LCV) on the make-up water line going to the deaerator.

![Figure 3: Demineralization Pumps (P-102A&B)](image)

Condensate

Condensate returns from the University between 155 and 190 deg F. The University condensate and that from the plant is collected by a number of condensate receiver tanks and returned by local pump-sets. Condensate is sent from the condensate receivers to the Condensate Surge Tank (TK-107). It is then pumped using the Condensate Pumps (P-104A&B) to the Condensate Polisher (CP). The Condensate Pumps are controlled by a pressure transmitter that regulates P-104B which has a VFD controller. The CP utilizes ion exchange technology to remove trace dissolved minerals. Following the CP, condensate is then sent to the deaerator (DH-102). If the condensate supply is insufficient to maintain deaerator level, make-up water is sent to the deaerator.
Feedwater System

From the main deaerator (DH-102), shown in Figure 4, two (2) sets of constant speed feedwater pumps distribute feedwater to the boilers (EU-001, EU-002, and EU-003) and desuperheaters (DS-101 and DS-102) at different pressures. Recirculation lines allow excess flow to return to the deaerator.

![Figure 4: Deaerator (DH-102)](image)

The High Pressure Feedwater Pumps (P-103A,B,&C) send the Feedwater to boilers EU-001 and EU-003. P-103C is the only steam turbine driven pump in this pump set; P-103A&B are motor driven. The electric motor driven pumps can be controlled in manual mode and all three pumps can be controlled by the DCS. When steam demand is low, the pump discharge is recirculated back into the deaerator to maintain a minimum flow through the pump.

The Medium Pressure Feedwater Pumps (P-105A&B) send the Feedwater to boiler EU-002 and to two (2) Export Steam Desuperheaters (DS-101, DS-102). These desuperheaters reduce the temperature of the superheated steam from boilers EU-001 and EU-003 for use in steam injection into the deaerator (DH-102) and desuperheats the extraction steam from the turbine prior to exporting the steam to the Campus. Both of these pumps can be operated in manual mode or controlled from the DCS. When steam demand is low, the pumps discharge is recirculated back into the deaerator to maintain a minimum flow through the pump.

An older deaerator (DH-101) is only used on the rare occasion that Boiler EU-005 is online. This deaerator has three (3) feedwater pumps (BFP-1,2,&3) that supply medium pressure feedwater to EU-004 and EU-005.
Boilers

The plant has five (5) boilers that burn various fuel sources including natural gas, #2 fuel oil, coal, and wood. There are two (2) high pressure boilers and two (2) medium pressure boilers in the plant. One of the boilers, Boiler EU-004, is no longer operational, though not officially retired. All boilers produce steam that is sent to the site directly, desuperheated, or sent to the steam turbine where extraction steam is then sent to the site. The steam is used for heating, steam-absorption chillers (air conditioning) and other process needs in the University and medical centers. The boilers each have several names by which they are known in various documents and by plant personnel but are referred to officially by their emissions unit numbers (EUs) from the EPA and DEP documents. These boiler names (EU-001, EU-002, EU-003, EU-004, & EU-005) will be used throughout the report.

EU-001

Boiler EU-001 (Boiler No. 5, SG-201) is a Foster Wheeler circulating fluidized bed (CFB) boiler and is capable of burning natural gas, coal, and coal/wood chip mixtures. It is a high pressure boiler with a superheated steam discharge pressure of 930 psig and temperature of 900 deg F. The maximum steam flow of this boiler is 200,000 lbs/hr. This boiler also has limestone injection to reduce sulfur emissions.

Two (2) separate desuperheaters (DS-201, DS-202) reduce the temperature of the steam as it passes between all three (3) stages of superheaters on the boiler. The steam, at 900 deg F is then sent to the main high pressure steam header.

This boiler has both an FD fan and ID fan as part of the combustion air and flue gas system. The FD fan (B-201) supplies combustion air and the ID fan Figure (x) maintains a light negative pressure (-0.5") on the boiler combustion chamber.

EU-002

Boiler EU-002 (Boiler No. 7, SG-202) is a Foster Wheeler D-type package boiler and is capable of burning gas and oil. It is a medium pressure boiler with a steam discharge pressure of 265 psig and a temperature of 420 deg F. The maximum steam flow of this boiler is 250,000 lbs/hr on gas and 225,000 lbs/hr on oil. This boiler also utilizes induced flue gas recirculation to recycle the flue gas and burn any unused fuel and any excess O2 in the flue gas stream. There is no pollution control equipment installed on this boiler though it is monitored for NOx, O2, and opacity.

Boiler pressure is maintained at positive pressure and controlled with a forced draft fan (B-210) and an exhaust damper.
EU-003

Boiler EU-003 (Boiler No. 6, SG-203) is a Foster Wheeler D-type package boiler and is capable of burning gas and oil. It is a high pressure boiler with a steam discharge pressure of 930 psig and a temperature of 900 deg F. The maximum steam flow of this boiler is 200,000 lbs/hr. This boiler also utilizes induced flue gas recirculation to recycle the flue gas and burn any unused fuel. There is no pollution control equipment installed on this boiler though it is monitored for NOx, O2, and opacity.

Boiler pressure is maintained at positive pressure and controlled with a forced draft fan (B-220) and an exhaust damper.

EU-004 (Not Operational)

Although not officially retired, this boiler is not currently operable.

Boiler EU-004 (Boiler No. 3) is a pulverized coal fired boiler and is capable of burning coal or oil but is presently not operational. It is a medium pressure boiler with a superheated steam discharge pressure of 440 psig and a temperature of 750 deg F. The maximum steam flow of the boiler is 150,000 lbs/hr when using high grade bituminous coal and 110,000 lbs/hr when using sub-bituminous coal.

This boiler has a forced draft fan, induced draft fan, and baghouse induced draft fan to control furnace pressure.

This boiler utilizes a limestone slurry (calcium hydroxide) injection system for the removal of sulfur oxide (SOx) emissions used when coal firing as well as a baghouse for further particulate removal.

EU-005

Boiler EU-005 (Boiler No. 4) is a B&W natural ventilation, stoker boiler built in 1948 and is capable of burning coal, oil, and wood. It is a medium pressure boiler with a steam discharge pressure of 440 psig and a temperature of 850 deg F. The maximum steam flow of the boiler is 160,000 lbs/hr but, due to emissions restrictions, each fuel type has reduced maximum steam flows. When burning coal, the maximum is 131,000 lbs/hr and when burning oil, the maximum permitted steam load is limited to 30% of the maximum continuous rated capacity, which is about 54,000 lbs/hr. During boiler start-up, the boiler is typically ignited with wood and rags soaked in kerosene. Once the boiler is ignited, coal or oil is used.

This boiler has a forced draft fan, induced draft fan, baghouse induced draft fan and an over-fire air fan to control combustion air as well as furnace and baghouse draft.

This boiler also utilizes a limestone slurry (calcium hydroxide) injection system for the removal of sulfur oxide (SOx) emissions used when coal firing as well as a baghouse for further particulate removal.
Distributed Control Systems

There are two distributed control systems (DCS) currently used to control the boilers and other auxiliary systems.

Boilers EU-001, EU-002, EU-003, and their auxiliary systems are controlled by a Moore Products DCS (Figure 5). Operators control these boilers from two PCs located in the “new” control room that provide schematic displays of the process with real time data. Operational data from the boilers and auxiliary equipment as well as steam flow data from this DCS is collected and stored by a Moore data acquisition system.

Figure 5: Moore Products Distributed Control System (DCS) Screen Shot

Boilers EU-004 and EU-005 are controlled by a Bailey Controls NET 90 DCS. Operators control the boilers from control stations located on the boiler control panel in the “old” control room. This DCS has three “stand-alone” systems for boiler control, emission equipment control and flame safeguard on Boiler EU-003. These systems are “stand-alone” because they do not communicate with the Moore Products DCS.
There are separate control panels for the turbine generator, coal system and water treatment system that do not communicate with the DCS.

**Blowdown**

The plant utilizes a cascade blowdown system on the high pressure boilers (EU-001 and EU-003). Blowdown is first sent to a flash tank, where pressure is reduced and flashed steam is sent to the deaerator and to a header for plant heating. Blowdown condensate at 250 deg F is sent to idle boilers and circulated. The blowdown is then discharged to the low pressure blowdown tank and finally quenched from 180 down to 140 deg F.

The boiler blowdown tanks are common to all five boilers. Continuous blowdown (CBD) is sent to the CBD Drum (D-101) from all boilers and is manually controlled by a hand-valve which is left open to a certain percentage for each boiler. Intermittent blowdown (IBD) is sent to the IBD Drum (D-102) from Boilers EU-002, EU-003, Deaerator DH-102, as well as from the Continuous Blowdown Drum (D-101). Intermittent blowdown is performed on a daily basis based on chemistry.

The plant Cooling Water System also has a blowdown line that taps off the return header. The valve on the line is manually operated to control flow before it is discharged to the process waste water sumps and then to the sewer. The cooling tower also has a blowdown line which is automatically controlled by a conductivity meter on the hot return line.

**Desuperheaters**

There are two desuperheaters (DS-101, DS-102) used in the plant to reduce the temperature of the superheated steam from boilers EU-001 and EU-003. DS-102 is used upstream of the steam injection into the Deaerator DH-102 and DS-101 is used on the extraction steam from the turbine prior to exporting the steam to the University. Feedwater injection for each of these desuperheaters is fed from Feedwater Pumps P-105A&B.

**Steam Turbine Generator**

A steam turbine generator (TG-101) produces 15 MW at 13.8 kV and receives high-pressure steam from both EU-001 and EU-003 at 930 psig and 900 deg F. The steam exhausts at 20 psig saturated steam and is used as pegging steam for the deaerators. Extraction steam at 210 psig ties into the main steam distribution header and is sent with steam produced from the medium pressure boilers to the University. Maximum flow at 15 MW is 400,000 lbs/hr. Several megawatts are consumed by the plant and the remaining power, which is fed back to the grid and is net metered.
The cooling water system is an open, recirculating type cooling system. It is used to remove heat gained from the turbine, Boiler EU-001 ash coolers and fan bearings, sample coolers, HVAC, air compressors, feedwater pump bearings, various components of Boilers EU-004 and EU-005, and other miscellaneous users.

The system consists of a cooling tower, two (2) cooling water pumps (P-106A&B), two (2) heat exchangers and flow control valves (FCVs) which regulate flow through each heat exchanger. The pumps are constant speed 100% capacity centrifugal pumps connected to the outlet of the cooling tower and are controlled by balance valves which assure optimum system flow at minimum pump operating horsepower. Cooling Water Pumps MP-106A&B are shown in Figure 7 below.
Because the cooling water system is “open”, it experiences evaporation at the cooling tower and requires occasional make-up water. A city water connection is controlled by a float level switch in the cooling tower. The cooling tower heat exchangers contain a low pressure steam connection (130 psig) used to maintain sump water temperature above 40 deg F. The Cooling Tower (CT-101) is shown in Figure 8 below.

Compressed Air

Compressed air for the plant is provided by a set of six (6) units. There are two (2) 60 HP compressors and two (2) 150 HP compressors. Recently, the plant installed two (2) “new” Atlas Copco compressors and two oil-injected, screw type compressors. Air is discharged from the compressors and is sent to a receiver tank. From the tank, the air is directed through a desiccant drying system that aids in the removal of particulate, compressor oil, and moisture. Most control valves are air operated and pressure is normally maintained between 90 and 115 psig.
Fuel Systems

There are three (3) fuel sources at the steam plant: Coal, Natural Gas, and No. 2 Fuel Oil.

Coal System

Coal is delivered and unloaded by rail or truck at the Coal Unloading Facility and transferred to the coal bunker at the plant by a series of conveyors in the steam service tunnel. The coal is piled over the reclaim feed ports and is gravity fed to the reclaim conveyor where it is then routed to the coal crusher. The crusher discharges to the bucket elevator which dumps into a shoot where a diverter gate sends coal to either the feeder or tripper conveyor. The feeder sends coal into a second crusher, then to a second bucket elevator, and finally to the tripper conveyor. The tripper conveyor sends coal to Boiler EU-004 and EU-005 coal bunkers as well as the Boiler EU-001 coal silos.
Figure 10: Coal Handling System
Figure 11: Coal Conveyor in Coal Tunnel

Natural Gas System

The Natural Gas System consists of a single line entering the plant that supplies gas to the following users:

- EU-001 (No. 5, CFB, SG-201) Igniter, Duct Burner, Over-Fire Burners, Bed Lance Burners
- EU-002 (No. 7, MP, SG-202) Igniter, Burner
- EU-003 (No. 6, HP, SG-203) Igniter, Burner

Fuel Oil System

The Fuel Oil System consists of three (3) tanks that store No. 2 fuel oil in two different areas of the plant. Two (2) of the tanks are located at the main plant and the other is located at the S.E. Steam Service Facility. Two (2) fuel oil transfer pumps send fuel oil from the main plant tanks to the S.E. Steam Service Facility tank. Two (2) fuel oil pumps then supply Boilers EU-002 burners, EU-003 burners, EU-004 igniters and burners, and EU-005 igniters and burners.
Steam Distribution

Steam is produced at several pressures but steam distributed to the University must remain at or below 210 psig and 395 deg F. As mentioned above, the steam feeds various processes including heating, steam-absorption chillers (air conditioning) and other process needs in the University. A network of tunnels connects the plant to the University and totals several miles of piping.

Lighting

Lighting at the plant is mainly mercury vapor with T-12 4ft lamps in the office areas. Lighting load is minimal.
III. ELECTRICITY, NATURAL GAS, COAL, AND FUEL OIL CONSUMPTION

The electrical supplier and distributor for the South East plant is X-Cel Energy. The South East Plant import consumption is linked with the Saint Paul Plant as well as the University of Minnesota. The plant consumption is metered and invoiced by the University of Minnesota. A rate between 7 and 8 cents per kWh is quite common but can rise to as much as 11 cents per kWh in summer months. Table 2 and Table 3 below include consumption and rates associated with the import of electricity for 2012 and 2013, respectively.

<table>
<thead>
<tr>
<th>South East Plant 2012 Electricity Costs</th>
<th>South East Plant 2013 Electricity Costs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Month</td>
<td>Import Consumption (kWh)</td>
</tr>
<tr>
<td>-------</td>
<td>--------------------------</td>
</tr>
<tr>
<td>Jan-12</td>
<td>NA</td>
</tr>
<tr>
<td>Feb-12</td>
<td>NA</td>
</tr>
<tr>
<td>Mar-12</td>
<td>1,401,882</td>
</tr>
<tr>
<td>Apr-12</td>
<td>738,158</td>
</tr>
<tr>
<td>May-12</td>
<td>647,394</td>
</tr>
<tr>
<td>Jun-12</td>
<td>657,455</td>
</tr>
<tr>
<td>Jul-12</td>
<td>951,903</td>
</tr>
<tr>
<td>Aug-12</td>
<td>1,191,425</td>
</tr>
<tr>
<td>Sep-12</td>
<td>1,041,986</td>
</tr>
<tr>
<td>Oct-12</td>
<td>1,414,810</td>
</tr>
<tr>
<td>Nov-12</td>
<td>1,513,051</td>
</tr>
<tr>
<td>Dec-12</td>
<td>1,728,240</td>
</tr>
<tr>
<td>Total</td>
<td>11,286,304</td>
</tr>
</tbody>
</table>

Table 2: South East Plant 2012 Electricity Cost and Rates  
Table 3: South East Plant 2013 Electricity Cost and Rates
Center Point Energy provides natural gas to the South East plant. The consumption and cost for 2013 can be seen in Table 4 below.

<table>
<thead>
<tr>
<th>South East Plant 2013 Natural Gas Costs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Month</td>
</tr>
<tr>
<td>-------</td>
</tr>
<tr>
<td>Jan-13</td>
</tr>
<tr>
<td>Feb-13</td>
</tr>
<tr>
<td>Mar-13</td>
</tr>
<tr>
<td>Apr-13</td>
</tr>
<tr>
<td>May-13</td>
</tr>
<tr>
<td>Jun-13</td>
</tr>
<tr>
<td>Jul-13</td>
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<tr>
<td>Aug-13</td>
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<tr>
<td>Sep-13</td>
</tr>
<tr>
<td>Oct-13</td>
</tr>
<tr>
<td>Nov-13</td>
</tr>
<tr>
<td>Dec-13</td>
</tr>
<tr>
<td>Total</td>
</tr>
</tbody>
</table>

Table 4: South East Plant Natural Gas Usage and Rates

River Trading Company is the coal supplier for the South East Plant. The average cost of coal per ton for 2013 was $74.06. The consumption data can be seen for 2013 in Table 5 below.

<table>
<thead>
<tr>
<th>South East Plant 2013 Coal Costs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Month</td>
</tr>
<tr>
<td>-------</td>
</tr>
<tr>
<td>Jan-13</td>
</tr>
<tr>
<td>Feb-13</td>
</tr>
<tr>
<td>Mar-13</td>
</tr>
<tr>
<td>Apr-13</td>
</tr>
<tr>
<td>May-13</td>
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<tr>
<td>Jun-13</td>
</tr>
<tr>
<td>Jul-13</td>
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<tr>
<td>Aug-13</td>
</tr>
<tr>
<td>Sep-13</td>
</tr>
<tr>
<td>Oct-13</td>
</tr>
<tr>
<td>Nov-13</td>
</tr>
<tr>
<td>Dec-13</td>
</tr>
<tr>
<td>Total</td>
</tr>
</tbody>
</table>

Table 5: South East Plant Coal Usage and Rates
Yocum Oil is the #2 Fuel Oil supplier for the South East plant. The South East plant has two (2) 20,000 gallon storage tanks and an average cost of #2 Fuel Oil per gallon of $2.37. The consumption data for 2013 are summarized in Table 6 below.

<table>
<thead>
<tr>
<th>Month</th>
<th>Consumption (Gallons)</th>
<th>Total Cost ($)</th>
<th>Average Cost ($/Gallon)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jan-13</td>
<td>16,183</td>
<td>$38,353</td>
<td>$2.37</td>
</tr>
<tr>
<td>Feb-13</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>Mar-13</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>Apr-13</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>May-13</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>Jun-13</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>Jul-13</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>Aug-13</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>Sep-13</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>Oct-13</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>Nov-13</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>Dec-13</td>
<td>277</td>
<td>$659</td>
<td>$2.38</td>
</tr>
<tr>
<td>Total</td>
<td>16,459</td>
<td>$39,011</td>
<td>$2.37</td>
</tr>
</tbody>
</table>

**Table 6: South East Plant #2 Fuel Oil Usage and Rates**

As can be seen from the data above and Figure 13 below, the consumption of #2 Fuel Oil and Coal is only a small portion of the total fuel consumed of the plant. Fuel Oil is used only as a primer for coal.

![South East Plant Fuel Source Breakdown](image-url)
IV. STEAM SENDOUT PRODUCTION

Table 7 below presents the 2013 steam production values for the South East Plant. The data shows the production values of each individual boiler for each month. These values were obtained from data supplied by the plant. The values from the individual boilers were calculated based on fuel consumption and average heating values for the quantity of fuel consumed. These values are estimates.

The Total Steam Production column is a representation of the sum of the production of all boilers. The Total Steam Sendout is a representation of the total steam distributed to the University. The Total Condensate Return is a representation of the total condensate returning from the University.

It was observed that there are variations in the Total Steam Production (TSP) values from all of the boilers at the steam sendout pressure and the Total Steam Sendout (TSS) values. At times, the TSP values are less than the TSS. The variations in these values can be attributed to inaccurate estimates of the fuel heating values.

In addition, Total Steam Sendout values should be less than the Total Steam Production Values as there are auxiliary steam loads and losses within the plant. These loads are estimated at 5-10%. The installation of steam flow meters on each boiler would certainly improve steam flow management.

<table>
<thead>
<tr>
<th>Month</th>
<th>EU-001 (Mlbs)</th>
<th>EU-002 (Mlbs)</th>
<th>EU-003 (Mlbs)</th>
<th>EU-004 (Mlbs)</th>
<th>EU 005 (Mlbs)</th>
<th>Variation in Meter Data (Mlbs)</th>
<th>Total Steam Production (Mlbs)</th>
<th>Total Steam Sendout (Mlbs)</th>
<th>Total Condensate Return (Mlbs)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jan-13</td>
<td>85,775</td>
<td>56,972</td>
<td>48,759</td>
<td>0</td>
<td>3,020</td>
<td>6,852</td>
<td>194,525</td>
<td>201,377</td>
<td>186,675</td>
</tr>
<tr>
<td>Feb-13</td>
<td>79,668</td>
<td>19,322</td>
<td>62,780</td>
<td>0</td>
<td>0</td>
<td>10,701</td>
<td>161,770</td>
<td>172,471</td>
<td>158,698</td>
</tr>
<tr>
<td>Mar-13</td>
<td>80,343</td>
<td>3,346</td>
<td>66,651</td>
<td>0</td>
<td>0</td>
<td>12,433</td>
<td>150,340</td>
<td>162,773</td>
<td>148,392</td>
</tr>
<tr>
<td>Apr-13</td>
<td>68,136</td>
<td>0</td>
<td>50,975</td>
<td>0</td>
<td>0</td>
<td>2,602</td>
<td>119,111</td>
<td>121,713</td>
<td>108,002</td>
</tr>
<tr>
<td>May-13</td>
<td>68,113</td>
<td>99</td>
<td>7,038</td>
<td>0</td>
<td>0</td>
<td>8,819</td>
<td>75,250</td>
<td>84,069</td>
<td>72,756</td>
</tr>
<tr>
<td>Jun-13</td>
<td>35,664</td>
<td>6,851</td>
<td>25,482</td>
<td>0</td>
<td>0</td>
<td>4,545</td>
<td>67,997</td>
<td>72,542</td>
<td>63,773</td>
</tr>
<tr>
<td>Jul-13</td>
<td>0</td>
<td>56,033</td>
<td>16,402</td>
<td>0</td>
<td>0</td>
<td>-5,924</td>
<td>72,435</td>
<td>66,510</td>
<td>57,637</td>
</tr>
<tr>
<td>Aug-13</td>
<td>0</td>
<td>48,196</td>
<td>31,091</td>
<td>0</td>
<td>0</td>
<td>-5,299</td>
<td>79,287</td>
<td>73,987</td>
<td>65,182</td>
</tr>
<tr>
<td>Sep-13</td>
<td>0</td>
<td>57,213</td>
<td>16,050</td>
<td>0</td>
<td>0</td>
<td>-6,499</td>
<td>73,263</td>
<td>66,763</td>
<td>58,106</td>
</tr>
<tr>
<td>Oct-13</td>
<td>0</td>
<td>75,637</td>
<td>25,810</td>
<td>0</td>
<td>0</td>
<td>-8,257</td>
<td>101,447</td>
<td>93,189</td>
<td>80,578</td>
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<tr>
<td>Nov-13</td>
<td>64,421</td>
<td>11,142</td>
<td>62,871</td>
<td>0</td>
<td>0</td>
<td>1,894</td>
<td>138,434</td>
<td>140,328</td>
<td>121,541</td>
</tr>
<tr>
<td>Dec-13</td>
<td>95,522</td>
<td>51,917</td>
<td>79,733</td>
<td>0</td>
<td>2,954</td>
<td>-9,075</td>
<td>230,126</td>
<td>221,051</td>
<td>198,571</td>
</tr>
<tr>
<td>Total</td>
<td>577,641</td>
<td>386,728</td>
<td>493,642</td>
<td>0</td>
<td>5,974</td>
<td>12,791</td>
<td>1,463,985</td>
<td>1,307,604</td>
<td>1,319,915</td>
</tr>
<tr>
<td>Total %</td>
<td>39.5%</td>
<td>26.4%</td>
<td>33.7%</td>
<td>0.0%</td>
<td>0.41%</td>
<td>0.87%</td>
<td>100%</td>
<td>89.3%</td>
<td>90.2%</td>
</tr>
</tbody>
</table>

Table 7: 2013 South East Plant Monthly Steam Production and Sendout (Mlbs)
V. EMISSIONS LIMITS AND PRODUCTION

Emissions limits for pollutants and heat consumption have been set for this facility by the Minnesota Department of Environmental Protection Bureau of Waste Prevention – Air Quality. These limits were obtained from the facility permit and are listed below in Table 8.

<table>
<thead>
<tr>
<th>Boiler</th>
<th>Opacity*</th>
<th>SO2</th>
<th>NOX</th>
</tr>
</thead>
<tbody>
<tr>
<td>EU001/SV001</td>
<td>Less than or equal to 20% except (1) six minute period per hour up to 27%</td>
<td>Less than or equal to 0.38 lbs/MMBtu and 90% or greater removal of potential SO2 emission based on a (1) hour average</td>
<td>Less than or equal to 0.222 lbs/MMBtu (coal) and less than or equal to 0.20 lb/MMBtu (gas) based on a 30 day rolling average</td>
</tr>
<tr>
<td>S.E. Boiler 5</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SG201 CFB</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>EU002/SV002</td>
<td>Less than or equal to 20% except (1) six minute period per hour up to 27%</td>
<td>Not Applicable</td>
<td>Less than or equal to 0.14 lbs/MMBtu based on a 30 day rolling average</td>
</tr>
<tr>
<td>S.E. Boiler 7</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SG202 MP</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>EU003/SV002</td>
<td>Less than or equal to 20% except (1) six minute period per hour up to 27%</td>
<td>Not Applicable</td>
<td>Less than or equal to 0.14 lbs/MMBtu based on a 30 day rolling average</td>
</tr>
<tr>
<td>S.E. Boiler 6</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SG203 HP</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>EU004/SV003</td>
<td>Less than or equal to 20% except (1) six minute period per hour up to 33%</td>
<td>Less than or equal to 0.34 lbs/MMBtu based on a (1) hour average</td>
<td>Not Applicable</td>
</tr>
<tr>
<td>S.E. Boiler 3</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>EU005/SV004</td>
<td>Less than or equal to 20% except (1) six minute period per hour up to 33%</td>
<td>Less than or equal to 0.34 lbs/MMBtu based on a (1) hour average</td>
<td>Not Applicable</td>
</tr>
<tr>
<td>S.E. Boiler 4</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 8: Plant Air Emission Limits of Continuously Monitored Pollutants

The annual limits in Table 9 below have been calculated from the total fuel consumption (MMBtu) by each boiler and the emission limits above.

<table>
<thead>
<tr>
<th>Boiler</th>
<th>Opacity*</th>
<th>SO2</th>
<th>NOX</th>
</tr>
</thead>
<tbody>
<tr>
<td>EU001/SV001</td>
<td>No Data Available</td>
<td>(Total) 693,169 MMBtu/yr Limit: 131.7 tons/yr</td>
<td>(Coal) 34,754 MMBtu/yr Limit: 3.86 Tons/yr</td>
</tr>
<tr>
<td>S.E. Boiler 5</td>
<td></td>
<td></td>
<td>(Gas) 470,141 MMBtu/yr Limit: 47.01 Tons/yr</td>
</tr>
<tr>
<td>SG201 CFB</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>EU002/SV002</td>
<td>No Data Available</td>
<td>Not Applicable</td>
<td>(Total) 470,141 MMBtu/yr Limit: 32.9 Tons/yr</td>
</tr>
<tr>
<td>S.E. Boiler 7</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SG202 MP</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>EU003/SV002</td>
<td>No Data Available</td>
<td>Not Applicable</td>
<td>(Total) 760,432 MMBtu/yr Limit: 53.23 Tons/yr</td>
</tr>
<tr>
<td>S.E. Boiler 6</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SG203 HP</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>EU004/SV003</td>
<td>No Data Available</td>
<td>Boiler Not Operable</td>
<td>Not Applicable</td>
</tr>
<tr>
<td>S.E. Boiler 3</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>EU005/SV004</td>
<td>No Data Available</td>
<td>(Total) 4,982 MMBtu/yr Limit: 0.009 Tons/yr</td>
<td>Not Applicable</td>
</tr>
<tr>
<td>S.E. Boiler 4</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 9: Plant Air Emission Limits of Continuously Monitored Pollutants Based on 2013 MMBtu
The following tables display the actual emissions data for the plant for including total emissions as well as the individual emissions for natural gas, coal, and fuel oil.

<table>
<thead>
<tr>
<th>Emission Unit No.</th>
<th>South East Plant 2013 Total Emissions (Tons/Yr)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>NOx</td>
</tr>
<tr>
<td>EU 001</td>
<td>37.70</td>
</tr>
<tr>
<td>EU 002</td>
<td>14.80</td>
</tr>
<tr>
<td>EU 003</td>
<td>20.50</td>
</tr>
<tr>
<td>EU 004</td>
<td>Out of Service</td>
</tr>
<tr>
<td>EU 005</td>
<td>1.30</td>
</tr>
<tr>
<td>Total Facility Emissions</td>
<td>74.30</td>
</tr>
</tbody>
</table>

**Table 10: Total Facility Emissions**

<table>
<thead>
<tr>
<th>Emission Unit No.</th>
<th>South East Plant 2013 Natural Gas Emissions (Tons/Yr)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>NOx</td>
</tr>
<tr>
<td>EU 001</td>
<td>35.26</td>
</tr>
<tr>
<td>EU 002</td>
<td>14.72</td>
</tr>
<tr>
<td>EU 003</td>
<td>20.47</td>
</tr>
<tr>
<td>EU 004</td>
<td>Out of Service</td>
</tr>
<tr>
<td>EU 005</td>
<td>NA</td>
</tr>
<tr>
<td>Total Facility Emissions</td>
<td>70.45</td>
</tr>
</tbody>
</table>

**Table 11: Total Facility Natural Gas Emissions**

<table>
<thead>
<tr>
<th>Emission Unit No.</th>
<th>South East Plant 2013 Coal Emissions (Tons/Yr)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>NOx</td>
</tr>
<tr>
<td>EU 001</td>
<td>2.46</td>
</tr>
<tr>
<td>EU 002</td>
<td>NA</td>
</tr>
<tr>
<td>EU 003</td>
<td>NA</td>
</tr>
<tr>
<td>EU 004</td>
<td>Out of Service</td>
</tr>
<tr>
<td>EU 005</td>
<td>1.31</td>
</tr>
<tr>
<td>Total Facility Emissions</td>
<td>3.77</td>
</tr>
</tbody>
</table>

**Table 12: Total Facility Coal Emissions**
### Table 13: Total Facility #2 Fuel Oil Emissions

**Emissions Results**

The results of the pollutant testing for SO2 and NOx conducted in 2013 show that the boiler emissions are within the limits set by the facility permit.

As can be seen from the tables above, in 2013 the boiler emission levels were significantly lower than their limits. Table 14 below presents the times of operation for each boiler.

<table>
<thead>
<tr>
<th>Emission Unit No.</th>
<th>South East Plant 2013 #2 Oil Actual Emissions (Tons/Yr)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>NOx</td>
</tr>
<tr>
<td>EU 001</td>
<td>NA</td>
</tr>
<tr>
<td>EU 002</td>
<td>0.08</td>
</tr>
<tr>
<td>EU 003</td>
<td>NA</td>
</tr>
<tr>
<td>EU 004</td>
<td>Out of Service</td>
</tr>
<tr>
<td>EU 005</td>
<td>NA</td>
</tr>
<tr>
<td>Total Facility Emissions</td>
<td>0.08</td>
</tr>
</tbody>
</table>

### Table 14: 2013 South East Plant Boiler Operating Hours

<table>
<thead>
<tr>
<th>Boiler</th>
<th>Total Number of Days in Operation</th>
<th>Total Number of Hours of Operation</th>
<th>Average Days in Operation per Week</th>
</tr>
</thead>
<tbody>
<tr>
<td>EU 001</td>
<td>227.2</td>
<td>5,453</td>
<td>4.4</td>
</tr>
<tr>
<td>EU 002</td>
<td>175.8</td>
<td>4,219</td>
<td>3.4</td>
</tr>
<tr>
<td>EU 003</td>
<td>225.5</td>
<td>5,412</td>
<td>4.3</td>
</tr>
<tr>
<td>EU 004</td>
<td>0.0</td>
<td>0</td>
<td>0.0</td>
</tr>
<tr>
<td>EU 005</td>
<td>6.0</td>
<td>144</td>
<td>0.1</td>
</tr>
</tbody>
</table>
VI. PM/CN/SOP REVIEW AND RECOMMENDATIONS

The plant currently uses the MP2 software for maintenance.

Preventative Maintenance (PM) Program

The existing PM’s associated with the distribution system appears to consist of the following:
1. Visual inspection for leaks, failed traps, etc.
2. Conduct housekeeping in manhole and verify no water accumulation.
3. Verify condition of insulating blankets on valves.
4. Lubricate valves to ensure proper operation and that they do not freeze.

The following are PM’s carried out by the facility:

- Boiler MACT Tuning on all boilers
  ⇒ Conducted by Power Products in February of 2014 for Boiler EU-005
  ⇒ Measurements included: O2, CO, NO, NOx, stack temperatures, and boiler efficiency
  ⇒ Areas of inspection included: burner, flame pattern, and air-to-fuel ratio control system
  ⇒ Tuning included: optimizing emission for CO
- Annual Cleaning and Inspection of Boilers (EU-001, EU-002, EU-003, EU-005)
  ⇒ Furnace Arrowhead Nozzles
  ⇒ Primary Air Duct
  ⇒ Secondary Air Nozzles
  ⇒ ID Fan and Motor
  ⇒ FD Fan and Motor
  ⇒ Hanger Supports
  ⇒ PA Duct Expansion Joint
  ⇒ Economizer
  ⇒ Steam Coil Air Heater
  ⇒ Dust Collector Modules
  ⇒ Drain and Open Boiler
  ⇒ Service Boiler Drum and Tubes
  ⇒ Furnace Service
  ⇒ Burner Service
  ⇒ Soot Blower Outage Inspection
  ⇒ Superheater Inspection
  ⇒ Safety Valve Inspection
  ⇒ Flue Water / Steam Instrumentation
  ⇒ Damper Greasing and Inspection
- Steam Drum inspection and service
- Boiler FD and ID fan inspection and service
- Deaerator control valve inspection and service
- Air compressor cleaning and service
- Electrical equipment inspection (transformer and breakers)
- Opacity controller service
- Emission analyzer service
- Feedwater, raw water and miscellaneous pump inspection and maintenance
• Plant safety equipment inspection
• Valve inspections
• Air Handling Unit inspection and service – Performed by the South East Maintenance Team

SourceOne has several recommendations for regarding preventative maintenance:

• Pressure, temperature, and flow transmitters should be calibrated at least annually with many of the critical ones calibrated semi-annually.
• Natural gas, fuel oil, feedwater, steam, control valves, and atomizing steam valves should be calibrated annually.
• Motors should be lubricated (if required) and have an insulation resistance test performed on them routinely.
• Infrared Scan (IR) the critical electrical connections in the plant on an annual basis (i.e. HV and LV bus, circuit breaker, fused disconnect switch, and other terminations). This is a minimally invasive way of assessing the security of the electrical connections and ascertaining if a connection is loose, has excessive contact surface area pitting, or has an excessive amount of current flowing through it.
• Conduct electrical maintenance testing of critical transformers, circuit breakers, and switches once every three years. Utilize the most recent testing guidelines outlined by the International Electrical Testing Association (NETA) Maintenance Testing Standards (MTS) specifications.
• IR scanning could and should be carried out on the boilers themselves on an annual basis to ascertain if there are any hot spots which may indicate a breakdown in insulation/refractory.
• Quarterly inspection of steam traps. During the inspection the steam trap should either be infrared scanned or shot with a temperature/heat gun to ascertain if it has failed. Failed traps should have a corrective maintenance (CM) work order generated for them and they should be replaced as soon as possible. SourceOne recommends that a formal steam trap log be developed via a steam trap survey and those traps are included as separate equipment ID’s in a spreadsheet or maintenance program for tracking purposes.

Corrective Maintenance (CM) Issues

The major CM issues of the South East Plant are logged annually. All maintenance activities are reported in the MP2 program. Recent repairs to the site (Completed, In Progress, and Future) include the following, shown in Table 15.

<table>
<thead>
<tr>
<th>Item</th>
<th>Status</th>
<th>Completion Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>Steam Tunnel Repairs</td>
<td>Completed</td>
<td>Apr-13</td>
</tr>
<tr>
<td>UPS Battery Replacement</td>
<td>Completed</td>
<td>Sep-13</td>
</tr>
<tr>
<td>ICES Tunnel Insulation &amp; Repairs</td>
<td>Completed</td>
<td>Nov-13</td>
</tr>
<tr>
<td>ICES Tunnel Stanchion Repair</td>
<td>Completed</td>
<td>Nov-13</td>
</tr>
<tr>
<td>Replace Opacity Monitor on SG-201 (CFB)</td>
<td>Completed</td>
<td>Jan-14</td>
</tr>
<tr>
<td>Replace HP Steam Traps</td>
<td>In Progress</td>
<td>NA</td>
</tr>
<tr>
<td>Rebuild Turbine Driven HP FWP (P-103 C)</td>
<td>Future</td>
<td>NA</td>
</tr>
<tr>
<td>Replace Multiple Lines in Boiler</td>
<td>Future</td>
<td>NA</td>
</tr>
</tbody>
</table>

Table 15: Corrective Maintenance History / Plans
Standard Operating Procedures (SOP’s)

The following SOP’s were obtained from the plant’s historical records. Table 16 shows the facility’s standard operating procedures. SourceOne has no recommendations regarding the SOP list or the level of detail in each SOP.

<table>
<thead>
<tr>
<th>Item No.</th>
<th>South East Plant Standard Operation Procedure (SOP) Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Plant Cooling System</td>
</tr>
<tr>
<td>2</td>
<td>Plant Compressed Air System</td>
</tr>
<tr>
<td>3</td>
<td>Boiler Water Treatment System</td>
</tr>
<tr>
<td>4</td>
<td>Emission Control System</td>
</tr>
<tr>
<td>5</td>
<td>Control and Metering System</td>
</tr>
<tr>
<td>6</td>
<td>Feedwater System</td>
</tr>
<tr>
<td>7</td>
<td>Boilers</td>
</tr>
<tr>
<td>8</td>
<td>Turbine Generator and electrical distribution</td>
</tr>
<tr>
<td>9</td>
<td>Ash Handling System</td>
</tr>
<tr>
<td>10</td>
<td>Fire Protection System</td>
</tr>
<tr>
<td>11</td>
<td>Coal Handling System</td>
</tr>
<tr>
<td>12</td>
<td>Fuel Oil and Natural Gas System</td>
</tr>
<tr>
<td>13</td>
<td>Waste Water System</td>
</tr>
<tr>
<td>14</td>
<td>Ventilation System</td>
</tr>
</tbody>
</table>

Table 16: Standard Operating Procedures
VII. WALKTHROUGH ASSESSMENT

SourceOne conducted a facility walkthrough of all five boilers and their auxiliary systems with plant personnel. During the walkthrough a visual inspection of the boiler systems was conducted and the general equipment condition and any deficiencies identified were noted. The following systems were included as part of each boiler walkthrough:

- Distributed Control System
- Raw Water/City Water/Make-Up Water System
- Water Treatment
- Feedwater System
- Boiler Blowdown System
- Natural Gas System
- Coal Handling System
- #2 Fuel Oil System
- Combustion Air System
- Ash Handling System
- Exhaust/Flue Gas System
- Burner Front
- Condensate System
- Facility Lighting System

Overall, the boilers are in good condition. SourceOne did not notice any serious deficiencies associated with the equipment in the aforementioned systems for these five (5) boilers though there are several energy conservation measures (ECM’s) that could be enacted to help reduce costs and improve the overall efficiency of the equipment in the plant. These ECM’s are discussed in Section IX of this report.
VIII. RECENT CAPITAL PROJECTS AND LONG-TERM PLAN

Typical capital projects include major upgrades and expansions of the existing facility. There have been no major capital projects completed in the recent past and presently none planned for the near future.

However, there was a recent installation of two (2) Atlas Copco air compressors which each produce 1500 ACFM at 132 psig. Although this was not a major installation, it will certainly improve the efficiency, dependability, and capacity of the Compressed Air System.
IX. RECOMMENDED ENERGY CONSERVATION MEASURES & INITIATIVES

SourceOne has identified twenty-eight (28) energy conservation measures (ECM’s) that can be enacted at the facility. They are as follows:

Compressed Air System

S1-CAS-ECM-1: Replacement of 60 HP Air Compressor Motors with High Efficiency Equivalents
S1-CAS-ECM-2: Replacement of 150 HP Air Compressor Motors with High Efficiency Equivalents

Feedwater System

S1-BFW-ECM-1: Replacement of 600 HP Feedwater Pump Motors with High Efficiency Equivalents and Installation of VFDs
S1-BFW-ECM-2: Replacement of 300 HP Feedwater Pump Motors with High Efficiency Equivalents and Installation of VFDs
S1-BFW-ECM-3: Replacement of Boiler EU-005 Feedwater Pump Motors with High Efficiency Equivalents

Water Treatment System

S1-WTS-ECM-1: Replacement of Raw Water Pump Motors with High Efficiency Equivalents
S1-WTS-ECM-2: Replacement of Demineralized Water Pump Motors with High Efficiency Equivalents and Installation of VFDs

Combustion Air System

S1-CA-ECM-1: Replacement of Boiler EU-005 Forced Draft Fan Motor with High Efficiency Equivalent
S1-CA-ECM-2: Replacement of Boiler EU-005 Over-Fire Air Fan Motor with High Efficiency Equivalent
S1-CA-ECM-3: Replacement of Boiler EU-005 Induced Draft Fan Motor with High Efficiency Equivalent and Installation of VFD
S1-CA-ECM-4: Replacement of Boiler EU-005 Baghouse Induced Draft Fan Motor with High Efficiency Equivalent
S1-CA-ECM-5: Replacement of Boiler EU-001 Forced Draft Fan Motor with High Efficiency Equivalent and Installation of VFD
S1-CA-ECM-6: Replacement of Boiler EU-001 Blower Motor with High Efficiency Equivalent
S1-CA-ECM-7: Replacement of Boiler EU-001 Induced Draft Fan Motor with High Efficiency Equivalent and Installation of VFD
S1-CA-ECM-8: Replacement of Boiler EU-002 Forced Draft Fan Motor with High Efficiency Equivalent and Installation of VFD
S1-CA-ECM-9: Replacement of Boiler EU-003 Forced Draft Fan Motor with High Efficiency Equivalent and Installation of VFD

Coal Handling System

S1-CHS-ECM-1: Replacement of Belt Drive Motor with High Efficiency Equivalent
S1-CHS-ECM-2: Replacement of 40 HP Crusher Drive Motor with High Efficiency Equivalent
S1-CHS-ECM-3: Replacement of Bucket Drive Motor with High Efficiency Equivalent
S1-CHS-ECM-4: Replacement of Conveyor Drive Motor with High Efficiency Equivalent

**Fuel Oil System**

S1-FOS-ECM-1: Replacement of Fuel Oil Pump Motors with High Efficiency Equivalents

**Lube Oil System**

S1-STG-ECM-1: Replacement of Lube Oil Pump Motors with High Efficiency Equivalents

**Condensate System**

S1-CND-ECM-1: Replacement of Condensate Pump (P-104A) Motor with High Efficiency Equivalent
S1-CND-ECM-2: Replacement of Condensate Pump (P-104B) Motor with High Efficiency Equivalent

**Cooling Water System**

S1-CW-ECM-1: Replacement of Cooling Tower Fan Motors with High Efficiency Equivalents and Installation of VFDs

**Limestone Handling System**

S1-LSH-ECM-1: Replacement of Limestone Blower Motor with High Efficiency Equivalent

**Ash Handling System**

S1-AHS-ECM-1: Replacement of Ash Blower Motor with High Efficiency Equivalent
S1-AHS-ECM-2: Replacement of Fly-Ash Re-Injection Pump Motor with High Efficiency Equivalent

SourceOne has identified one (1) energy conservation initiative (ECI) that can be enacted at the facility. This ECI is as follows:

**Blowdown System**

S1-BDS-ECI-1: Installation of Conductivity Meter and Auto-Dump Valves on Blowdown System

The appendix of this report contains the spreadsheet analysis evaluating each of these ECM’s. The estimated annual savings, material cost, labor cost, and simple payback is calculated for each ECM individually. It should be noted that the energy savings and simple payback calculations are based upon the reported electricity consumption, estimated electricity costs, reported fuel oil, coal, and natural gas consumption and cost figures from the site as well as the steam production numbers provided by the site. Total steam production includes cumulative fuel costs as well as the cost of electricity to keep the plant running. All of these values are detailed in following sections of this report. A summary of each is given in Tables 17 and 18.
Table 17: Electricity Cost and Consumption Summary 2013

<table>
<thead>
<tr>
<th>Electricity Cost</th>
<th>$946,918</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electricity Consumption (kWh)</td>
<td>11,637,697</td>
</tr>
<tr>
<td>Rate ($/kWh)</td>
<td>0.081</td>
</tr>
</tbody>
</table>

Table 18: Fuel Cost and Consumption Summary 2013

<table>
<thead>
<tr>
<th>Natural Gas Cost ($)</th>
<th>$4.57/MMBtu</th>
</tr>
</thead>
<tbody>
<tr>
<td>#2 Fuel Oil Cost ($)</td>
<td>$2.37/gal</td>
</tr>
<tr>
<td>Coal Cost ($)</td>
<td>$74.06/ton</td>
</tr>
<tr>
<td>Steam Production (Mlbs)</td>
<td>1,463,985</td>
</tr>
<tr>
<td>Steam Production Cost ($/Mlbs)</td>
<td>$6.88</td>
</tr>
</tbody>
</table>

Energy Conservation Measures (ECM’s)

Compressed Air System

S1-CA-ECM-1: Replacement of 60 HP Air Compressor Motors with High Efficiency Equivalents

Two (2) Air Compressors are currently used in the Compressed Air System. These pump motors are rated at 60 HP each and are fed 460 V power. An efficiency figure could not be obtained from the nameplate but, using industry standards, SourceOne estimates the efficiency of each motor to be approximately 91.7%.

It is recommended to upgrade each pump motor with a high efficiency equivalent with an expected rated efficiency of 95.4%. The upgrade analysis of the high efficiency motor is shown in the appendix. As can be seen there, the total annual savings is calculated to be 8,292 kWh, which corresponds to an annual cost savings of $663. The total material and labor cost associated with the retrofits is $6,400. The annual run-hours for the Air Compressors were estimated to be approximately 2190 hours per year based on industry average. This results in a simple payback of 9.65 years.

S1-CA-ECM-2: Replacement of 150 HP Air Compressor Motors with High Efficiency Equivalents

Two (2) Air Compressors are currently used in the Compressed Air System. These pump motors are rated at 150 HP each and are fed 460V power. An efficiency figure could not be obtained from the nameplate but, using industry standards, SourceOne estimates the efficiency of each motor to be approximately 92.4%.

It is recommended to upgrade each pump motor with a high efficiency equivalent with an expected rated efficiency of 95.8%. The upgrade analysis of the high efficiency motor is shown in the appendix. As can be seen there, the total annual savings is calculated to be 18,825 kWh, which corresponds to an annual cost savings of $1,506. The total material and labor cost associated with the retrofits is $14,700. The annual run-hours for the Air Compressors were estimated to be approximately 2190 hours per year. This results in a simple payback of 9.76 years.
Feedwater System

S1-BFW-ECM-1: Replacement of 600 HP Feedwater Pump Motors with High Efficiency Equivalents and Installation of VFDs

Two (2) Feedwater Pumps (BFP-103A&B) are currently used in the High Pressure Feedwater System. These pump motors are rated at 600 HP each and are fed 4000 V power. An efficiency figure could not be obtained from the nameplate but, using industry standards, SourceOne estimates the efficiency of each motor to be approximately 94%.

It is recommended to upgrade each pump motor with a high efficiency equivalent with an expected rated efficiency of 96%. Additionally, it is recommended to install a VFD to control the speed of each pump motor to maintain downstream header pressure.

According to the ‘pump laws’, for centrifugal pumps “flow is directly proportional to the speed, head is directly proportional to the square of the speed, and the pump motor power is directly proportional to the cube of the speed.” Figure 14 illustrates this relationship.

![Figure 14: Constant Speed Centrifugal Pump Curve](image)

Without a VFD, a constant speed centrifugal pump will ‘ride up’ its speed curve as the load (i.e. flow) reduces. As can be seen from Figure 14, the resulting reduction in power consumption is relatively low; a 25% reduction in flow results in a 10% reduction in the required power. With a VFD, however, a feedwater header pressure signal can be used by the drive to indicate a reduction in load due to a closing control/regulating valve downstream. The VFD can reduce the pump speed to precisely cater to the system flow requirement. This results in a considerable reduction in power consumption. This is illustrated in Figure 15.
Figure 15: Variable Speed Centrifugal Pump Curve

As can be seen from Figure 15, if the load (i.e. flow) is reduced by 25%, the VFD will reduce the pump speed such that the original speed curve (Speed Curve #1) is shifted down (Speed Curve #2). This shift results in a drastic reduction in the power consumption of the pump. In fact, with the VFD in use, a 25% reduction in flow results in a 50% reduction in the required power. This is significantly greater than the 10% reduction seen with a constant speed pump. Typical industry estimates yield average energy savings of 30% when a VFD is installed on a centrifugal pump. This is the estimate SourceOne used when analyzing the benefits of VFD installations on the Feedwater Pump.

Presently, the pumps are run at constant speed and a recirculation line returns water to Deaerator DH-102. The new VFD will be used to maintain feedwater header pressure based on a signal from a pressure transmitter.

The upgrade analysis of the high efficiency motor and VFD installation is shown in the appendix. As can be seen there, the total annual savings is calculated to be 1,084,817 kWh, which corresponds to an annual cost savings of $86,785. The total material and labor cost associated with the retrofit is $223,400. The annual run-hours for the Feedwater Pumps were estimated to be approximately 5,412 hours per year and were based on the run-hours of Boilers EU-001 and EU-003. This results in a simple payback of 2.57 years.

S1-BFW-ECM-2: Replacement of 300 HP Feedwater Pump Motors with High Efficiency Equivalents and Installation of VFDs

Two (2) Feedwater Pumps (BFP-105A&B) are currently used in the Medium Pressure Feedwater System which feeds Boiler EU-002. These pump motors are rated at 300 HP each and are fed 4000 V power. An efficiency figure could not be obtained from the nameplate but, using industry standards, SourceOne estimates the efficiency of each motor to be approximately 93.2%.

It is recommended to upgrade each pump motor with a high efficiency equivalent with an expected rated efficiency of 96%. Additionally, it is recommended to install a VFD to control the speed of each pump motor.
During normal operation, one (1) feedwater pump runs at 100% (one full sized spare) and uses a recirculation line to return pumped feedwater back to the deaerator (DH-102). A VFD will modulate the speed of the pump to maintain feedwater header pressure with the use of a pressure transmitter. The retrofits will also include closing the recirculation line to provide only the required flow to maintain header pressure and, consequently, drum level.

Similar to the Feedwater Pump analysis, SourceOne used the industry standard estimate of 30% energy savings via the use of a VFD on the Feedwater Pumps.

The upgrade analysis of the high efficiency motor and VFD installation is shown in the appendix. As can be seen there, the total annual savings is calculated to be 324,692 kWh, which corresponds to an annual cost savings of $25,975. The total material and labor cost associated with the retrofits is $114,800. The annual run-hours for the Feedwater Pumps were estimated to be approximately 4,219 hours per year based on the run time of Boiler EU-002. This results in a simple payback of 4.42 years.

**S1-BFW-ECM-3: Replacement of Boiler EU-005 Feedwater Pump Motors with High Efficiency Equivalents**

*Not Recommended*

Two (2) Feedwater Pumps are currently used in the Feedwater System for Boiler EU-005. These pump motors are rated at 250 HP each and are fed 460 V power. An efficiency figure could not be obtained from the nameplate but, using industry standards, SourceOne estimates the efficiency of each motor to be approximately 93%.

A high efficiency equivalent replacement for a motor of this size has an expected rated efficiency of 96.2%. The upgrade analysis of the high efficiency motor is shown in the appendix. As can be seen there, the total annual savings is calculated to be 961 kWh, which corresponds to an annual cost savings of $. The total material and labor cost associated with the retrofits is $27,000. The annual run-hours for the Feedwater Pumps for Boiler EU-005 were estimated to be approximately 72 hours per year and were based on the run-hours of the boiler. This results in a simple payback of 351 years. This ECM is not cost justifiable based upon energy savings alone.

**Water Treatment System**

**S1-WTS-ECM-1: Replacement of Raw Water Pump Motors with High Efficiency Equivalents**

*Not Recommended*

Two (2) Raw Water Pumps are currently used in the Water Treatment System. These pump motors are rated at 25 HP each and are fed 460V power. The efficiency of the motors was obtained from the nameplates and recorded as 86.5%.

A high efficiency equivalent replacement for a motor of this size has an expected rated efficiency of 93.6%. The upgrade analysis of the high efficiency motor is shown in the appendix. As can be seen there, the total annual savings is calculated to be 327 kWh, which corresponds to an annual cost savings of $26. The total material and labor cost associated with the retrofits is $2,800. The annual run-hours for the Raw Water Pumps were estimated to be approximately 100 hours per year and were based on the
necessity to use these pumps as mentioned by site personnel. Raw water (city water) pressure is typically high enough that these pumps are not needed. This results in a simple payback of 107 years. This ECM is not cost justifiable based upon energy savings alone.

S1-WTS-ECM-2: Replacement of Demineralized Water Pump Motors with High Efficiency Equivalents

Two (2) Demineralized Water Pumps are currently used in the Water Treatment System. These pump motors are rated at 60 HP each and are fed 460V power. The efficiency of the motors was obtained from the nameplates and recorded as 89.5%.

It is recommended to upgrade this motor with a high efficiency equivalent with an expected rated efficiency of 95.4%. The upgrade analysis of the high efficiency motor and VFD installation is shown in the appendix. As can be seen there, the total annual savings is calculated to be 6,804 kWh, which corresponds to an annual cost savings of $544. The total material and labor cost associated with the retrofits is $6,400. The annual run-hours for the Demineralized Water Pumps were estimated to be approximately 1100 hours per year and were calculated from the quantity of make-up water from lost condensate and the maximum flow rates of the pumps. This results in a simple payback of 11.7 years.

Combustion Air System

S1-CA-ECM-1: Replacement of EU-005 Forced Draft Fan Motor with High Efficiency Equivalent

A Forced Draft Fan on Boiler EU-005 is currently used in the Combustion Air System. This fan motor is rated at 100 HP and is fed 460V power. The efficiency of the motor was obtained from the nameplate and recorded as 93%.

A high efficiency equivalent replacement for a motor of this size has an expected rated efficiency of 95.4%. The upgrade analysis of the high efficiency motor is shown in the appendix. As can be seen there, the total annual savings is calculated to be 291 kWh, which corresponds to an annual cost savings of $23. The total material and labor cost associated with the retrofits is $4,100. The annual run-hours for the EU-005 Forced Draft Fan were estimated to be approximately 144 hours per year and were based on the run-hours of the boiler. This results in a simple payback of 176 years. This ECM is not cost justifiable based upon energy savings alone.

S1-CA-ECM-2: Replacement of Boiler EU-005 Over-Fire Air Fan Motor with High Efficiency Equivalent

[Not Recommended]

An Over-Fire Air Fan on Boiler EU-005 is currently used in the Combustion Air System. This fan motor is rated at 60 HP and is fed 460V power. The efficiency of the motor was obtained from the nameplate and recorded as 91.7%.

A high efficiency equivalent replacement for a motor of this size has an expected rated efficiency of 95.4%. The upgrade analysis of the high efficiency motor is shown in the appendix. As can be seen there, the total annual savings is calculated to be 273 kWh, which corresponds to an annual cost savings of $22. The total material and labor cost associated with the retrofits is $3,200. The annual run-hours for the Over-Fire Air Fan for Boiler EU-005 were estimated to be approximately 144 hours per year and
were based on the run-hours of the boiler. **This results in a simple payback of 147 years. This ECM is not cost justifiable based upon energy savings alone.**

**S1-CA-ECM-3: Replacement of EU-005 Induced Draft Fan Motor with High Efficiency Equivalent**

*[Not Recommended]*

An Induced Draft Fan for Boiler EU-005 is currently used in the Combustion Air System. This fan motor is rated at 250 HP and is fed 460V power. The efficiency of the motor was obtained from the nameplate and recorded as 93%.

A high efficiency equivalent replacement for a motor of this size has an expected rated efficiency of 96.2%. The upgrade analysis of the high efficiency motor is shown in the appendix. As can be seen there, the total annual savings is calculated to be 961 kWh, which corresponds to an annual cost savings of $77. The total material and labor cost associated with the retrofits is $13,500. The annual run-hours for the EU-005 Induced Draft Fan were estimated to be approximately 144 hours per year and were based on the run-hours of the boiler. **This results in a simple payback of 176 years. This ECM is not cost justifiable based upon energy savings alone.**

**S1-CA-ECM-4: Replacement of Boiler EU-005 Baghouse Induced Draft Fan Motor with High Efficiency Equivalent**

*[Not Recommended]*

The Baghouse Induced Draft Fan for Boiler EU-005 is currently used in the Combustion Air System. This fan motor is rated at 500 HP and is fed 460 V power. An efficiency figure could not be obtained from the nameplate but, using industry standards, SourceOne estimates the efficiency of this motor to be approximately 93.8%.

A high efficiency equivalent replacement for a motor of this size has an expected rated efficiency of 96%. The upgrade analysis of the high efficiency motor is shown in the appendix. As can be seen there, the total annual savings is calculated to be 1,312 kWh, which corresponds to an annual cost savings of $105. The total material and labor cost associated with the retrofits is $28,700. The annual run-hours for the Baghouse Induced Draft Fan for EU-005 were estimated to be approximately 144 hours per year and were based on the run-hours of the boiler. **This results in a simple payback of 273 years. This ECM is not cost justifiable based upon energy savings alone.**

**S1-CA-ECM-5: Replacement of Boiler EU-001 Forced Draft Fan Motor with High Efficiency Equivalent and Installation of VFD**

The Forced Draft Fan for Boiler EU-001 is currently used in the Combustion Air System. This fan motor is rated at 1000 HP and is fed 4160 V power. An efficiency figure could not be obtained from the nameplate but, using industry standards, SourceOne estimates the efficiency of this motor to be approximately 94.2%.

It is recommended to upgrade this motor with a high efficiency equivalent with an expected rated efficiency of 96%. Additionally, it is recommended to install a VFD to control the speed of the fan motor.
Without a VFD, a two-speed fan is limited to its Low and High speed settings. All air flow regulation between the two speed settings is controlled via damper positioning. However, with a VFD, the O2 trim system can be used to modulate the speed of the fan and therefore gain a significant reduction in power consumption. The dampers would be blocked open at 100% and can be used in the future for when the VFD is faulted and in bypass mode.

It is important to note that the horsepower requirement varies with the cube of the speed, so the slower the fan speed the less energy that is required. A fan running at 80% speed will consume only 50% of the power of a fan running at full speed. At 50% fan speed, power consumption is only 16%. This is illustrated in Figure 16.

![Figure 16: Relationship between Fan Speed and Motor HP Requirement](image)

To precisely calculate the energy savings associated with this ECM, SourceOne would need to know the exact amount of combustion air being discharged to the boiler relative to the full-load rating (cfm) of the FD Fan. This data is not currently available to us, but should be analyzed, if possible, as part of an investment grade study. Typical industry estimates yield average energy savings of 30% when a VFD is installed on a fan motor, where the fan loading varies significantly throughout the day/year. This is the estimate SourceOne used when analyzing the benefits of installing a VFD on the FD Fan Motor to control the flow of combustion air to the boiler.

The upgrade analysis of the high efficiency motor and VFD installation is shown in the appendix. As can be seen there, the total annual savings is calculated to be 1,352,201 kWh, which corresponds to an annual cost savings of $108,176. The total material and labor cost associated with the retrofits is $209,000. The annual run-hours for the Forced Draft Fan for EU-001 were estimated to be approximately 5453 hours per year based on the run-hours of the boiler. This results in a simple payback of 1.93 years.
S1-CA-ECM-6: Replacement of Boiler EU-001 Blower Motor with High Efficiency Equivalent

A blower is currently used in the Combustion Air System for Boiler EU-001. This blower motor is rated at 50 HP and is fed 460V power. The efficiency of the motor was obtained from the nameplate and recorded as 92.4%.

It is recommended to upgrade this motor with a high efficiency equivalent with an expected rated efficiency of 95%. The upgrade analysis of the high efficiency motor is shown in the appendix. As can be seen there, the total annual savings is calculated to be 6,025 kWh, which corresponds to an annual cost savings of $482. The total material and labor cost associated with the retrofits is $2,600. The annual run-hours for the Blower on Boiler EU-001 were estimated to be approximately 5453 hours per year and were based on the run-hours of the boiler. **This results in a simple payback of 5.39 years.**

S1-CA-ECM-7: Replacement of Boiler EU-001 Induced Draft Fan Motor with High Efficiency Equivalent and Installation of VFD

The Induced Draft Fan for Boiler EU-001 is currently used in the Combustion Air System. This fan motor is rated at 700 HP and is fed 4160 V power. An efficiency figure could not be obtained from the nameplate but, using industry standards, SourceOne estimates the efficiency of this motor to be approximately 94.2%.

It is recommended to upgrade this fan motor with a high efficiency equivalent with an expected rated efficiency of 96%. Additionally, it is recommended to install a VFD to control the speed of the fan motor. Presently, the induced draft fan is run at 100% and the exhaust damper is modulated to maintain furnace pressure while Boiler EU-002 is running. Following the installation, the Forced Draft Fan for the boiler will be modulated to maintain O2 levels and the Induced Draft Fan will modulate to maintain pressure in the furnace pressure.

Similar to the Forced Draft Fan analysis in S1-CA-ECM-5, SourceOne used the industry standard estimate of 30% energy savings via the use of a VFD on the EU-001 Induced Draft Fan.

The upgrade analysis of the high efficiency motor and VFD installation is shown in the appendix. As can be seen there, the total annual savings is calculated to be 946,541 kWh, which corresponds to an annual cost savings of $75,723. The total material and labor cost associated with the retrofits is $127,500. The annual run-hours for the EU-001 Induced Draft Fan were estimated to be approximately 5453 hours per year. **This results in a simple payback of 1.68 years.**

S1-CA-ECM-8: Replacement of Boiler EU-002 Forced Draft Fan Motor with High Efficiency Equivalent and Installation of VFD

One (1) EU-002 Forced Draft Fan is currently used in the Combustion Air System. This fan motor is rated at 600 HP and is fed 4160V power. The efficiency of the motor was obtained from the nameplate and recorded as 94.5%.

It is recommended to upgrade this fan motor with a high efficiency equivalent with an expected rated efficiency of 96%. Additionally, it is recommended to install a VFD to control the speed of the fan motor.
Similar to the Forced Draft Fan analysis in S1-CA-ECM-5, SourceOne used the industry standard estimate of 30% energy savings via the use of a VFD on the Forced Draft Fan for Boiler EU-002.

The upgrade analysis of the high efficiency motor and VFD installation is shown in the appendix. As can be seen there, the total annual savings is calculated to be 621,357 kWh, which corresponds to an annual cost savings of $49,709. The total material and labor cost associated with the retrofits is $112,700. The annual run-hours for the EU-002 Forced Draft Fan were estimated to be approximately 4219 hours per year. **This results in a simple payback of 2.27 years.**

**S1-CA-ECM-9: Replacement of Boiler EU-003 Forced Draft Fan Motor with High Efficiency Equivalent and Installation of VFD**

The Forced Draft Fan for Boiler EU-003 is currently used in the Combustion Air System. This fan motor is rated at 600 HP and is fed 4160V power. The efficiency of the motor was obtained from the nameplate and recorded as 94.5%.

It is recommended to upgrade this fan motor with a high efficiency equivalent with an expected rated efficiency of 96%. Additionally, it is recommended to install a VFD to control the speed of the fan motor.

Similar to the Forced Draft Fan analysis in S1-CA-ECM-5, SourceOne used the industry standard estimate of 30% energy savings via the use of a VFD on the EU-003 Forced Draft Fan.

The upgrade analysis of the high efficiency motor and VFD installation is shown in the appendix. As can be seen there, the total annual savings is calculated to be 797,057 kWh, which corresponds to an annual cost savings of $63,765. The total material and labor cost associated with the retrofits is $112,700. The annual run-hours for Forced Draft Fan of EU-003 were estimated to be approximately 5412 hours per year and were based on the run-time of the boiler. **This results in a simple payback of 1.77 years.**

**Coal Handling System**

**S1-CHS-ECM-1: Replacement of Belt Drive Motor with High Efficiency Equivalent**

One (1) Belt Drive is currently used in the Coal Handling System. This belt motor is rated at 15 HP and is fed 460 V power. An efficiency figure could not be obtained from the nameplate but, using industry standards, SourceOne estimates the efficiency of this motor to be approximately 86.8%.

It is recommended to upgrade this belt drive motor with a high efficiency equivalent with an expected rated efficiency of 93%. The upgrade analysis of the high efficiency motor is shown in the appendix. As can be seen there, the total annual savings is calculated to be 1,255 kWh, which corresponds to an annual cost savings of $100. The total material and labor cost associated with the retrofits is $1,000. The annual run-hours for the Belt Drive were estimated to be approximately 1460 hours per year based on the run-hours of Boiler EU-005. **This results in a simple payback of 9.96 years.**
S1-CHS-ECM-2: Replacement of 40 HP Crusher Drive Motor with High Efficiency Equivalent

[Not Recommended]

A Crusher is currently used in the Coal Handling System to decrease the size of coal. This crusher motor is rated at 40 HP and is fed 460V power. The efficiency of the motor was obtained from the nameplate and recorded as 91.7%.

A high efficiency equivalent replacement for a motor of this size has an expected rated efficiency of 94.5%. The upgrade analysis of the high efficiency motor is shown in the appendix. As can be seen there, the total annual savings is calculated to be 1,408 kWh, which corresponds to an annual cost savings of $113. The total material and labor cost associated with the retrofits is $2,150. The annual run-hours for the Crusher Drive were estimated to be approximately 1460 hours per year. This results in a simple payback of 19.1 years. This ECM is not cost justifiable based upon energy savings alone.

S1-CHS-ECM-3: Replacement of Bucket Drive Motor with High Efficiency Equivalent

[Not Recommended]

A Bucket Drive is currently used in the Coal Handling System to move the bucket elevator. This drive motor is rated at 10 HP and is fed 460V power. The efficiency of the motor was obtained from the nameplate and recorded as 87.5%.

A high efficiency equivalent replacement for a motor of this size has an expected rated efficiency of 91.7%. The upgrade analysis of the high efficiency motor is shown in the appendix. As can be seen there, the total annual savings is calculated to be 570 kWh, which corresponds to an annual cost savings of $46. The total material and labor cost associated with the retrofits is $800. The annual run-hours for the Bucket Drive were estimated to be approximately 1460 hours per year. This results in a simple payback of 17.5 years. This ECM is not cost justifiable based upon energy savings alone.

S1-CHS-ECM-4: Replacement of Conveyor Drive Motor with High Efficiency Equivalent

[Not Recommended]

A Conveyor Drive motor is currently used as part of the Coal Handling System. This drive motor is rated at 7.5 HP and is fed 460 V power. An efficiency figure could not be obtained from the nameplate but, using industry standards, SourceOne estimates the efficiency of this motor to be approximately 85.2%.

A high efficiency equivalent replacement for a motor of this size has an expected rated efficiency of 91.7%. The upgrade analysis of the high efficiency motor is shown in the appendix. As can be seen there, the total annual savings is calculated to be 680 kWh, which corresponds to an annual cost savings of $54. The total material and labor cost associated with the retrofits is $670. The annual run-hours for the Conveyor Drive were estimated to be approximately 1460 hours per year. This results in a simple payback of 12.3 years. This ECM is not cost justifiable based upon energy savings alone.
Fuel Oil System

S1-FOS-ECM-1: Replacement of Fuel Oil Pump Motors with High Efficiency Equivalents

[Not Recommended]

Two (2) Fuel Oil Pumps are currently used in the Fuel Oil System. These pump motors are rated at 60 HP each and are fed 460V power. The efficiency of the motors was obtained from the nameplates and recorded as 93%.

A high efficiency equivalent replacement for a motor of this size has an expected rated efficiency of 95.4%. The upgrade analysis of the high efficiency motor is shown in the appendix. As can be seen there, the total annual savings is calculated to be 3,536 kWh, which corresponds to an annual cost savings of $283. The total material and labor cost associated with the retrofits is $6,400. The annual run-hours for the Fuel Oil Pumps were estimated to be approximately 1460 hours per year. This results in a simple payback of 22.6 years. This ECM is not cost justifiable based upon energy savings alone.

Lube Oil System

S1-STG-ECM-1: Replacement of Lube Oil Pump Motors with High Efficiency Equivalents

Two (2) Lube Oil Pumps (P-123, P-124) are currently used in the Lube Oil System for the steam turbine generator. These pump motors are rated at 50 HP each and are fed 460V power. The efficiency of the motors was obtained from the nameplates and recorded as 93%.

It is recommended to upgrade each pump motor with a high efficiency equivalent with an expected rated efficiency of 95%. The upgrade analysis of the high efficiency motor is shown in the appendix. As can be seen there, the total annual savings is calculated to be 7,397 kWh, which corresponds to an annual cost savings of $592. The total material and labor cost associated with the retrofits is $5,200. The annual run-hours for the Lube Oil Pumps were estimated to be approximately 8760 hours per year. This results in a simple payback of 8.79 years.

Condensate System

S1-CND-ECM-1: Replacement of Condensate Pump (P-104B) Motor with High Efficiency Equivalent

Two (2) Condensate Pumps (P-104A&B) are currently used in the Condensate System. However, P-104B has a higher efficiency motor than P-104A.

The pump motor for P-104B is rated at 200 HP and is fed 460V power. The efficiency of the motor was obtained from the nameplate and recorded as 86%.

It is recommended to upgrade this pump motor with a high efficiency equivalent with an expected rated efficiency of 96.2%. The upgrade analysis of the high efficiency motor is shown in the appendix. As can be seen there, the total annual savings is calculated to be 20,234 kWh, which corresponds to an annual cost savings of $1,619. The total material and labor cost associated with the retrofits is $10,800. The
annual run-hours for the Condensate Pump were estimated to be approximately 1100 hours per year. These run-hours were calculated based on the total condensate return per year and the maximum flow of the pump. This results in a simple payback of 6.67 years.

S1-CND-ECM-2: Replacement of Condensate Pump (P-104A) Motor with High Efficiency Equivalent

[Not Recommended]

Two (2) Condensate Pumps (P-104A&B) are currently used in the Condensate System. However, P-104B has a higher efficiency motor than P-104A.

The pump motor for P-104A is rated at 200 HP and is fed 460V power. The efficiency of the motor was obtained from the nameplate and recorded as 95.8%.

A high efficiency motor replacement of this size is expected to have a rated efficiency of 96.2% and is only marginally higher in efficiency than the existing motor. The upgrade analysis of the high efficiency motor is shown in the appendix. As can be seen there, the total annual savings is calculated to be 712 kWh, which corresponds to an annual cost savings of $57. The total material and labor cost associated with the retrofits is $10,800. The annual run-hours for the Condensate Pump were estimated to be approximately 1100 hours per year. These run-hours were calculated based on the total condensate return per year and the maximum flow of the pump. This results in a simple payback of 190 years. This ECM is not cost justifiable based upon energy savings alone.

Cooling Water System

S1-CW-ECM-1: Replacement of Cooling Tower Fan Motors with High Efficiency Equivalents and Installation of VFDs

Two (2) Cooling Tower Fans are currently used in the Cooling Water System. These pump motors are rated at 15 HP each and are fed 460 V power. An efficiency figure could not be obtained from the nameplate but, using industry standards, SourceOne estimates the efficiency of each motor to be approximately 86.8%.

It is recommended to upgrade each pump motor with a high efficiency equivalent with an expected rated efficiency of 93%. Additionally, it is recommended to install a VFD to control the speed of each pump motor. The VFD will be used to control basin water temperature. Presently, the cooling tower fans run at constant speed.

Similar to the Forced Draft Fan analysis in S1-CA-ECM-5, SourceOne used the industry standard estimate of 30% energy savings via the use of a VFD on the Cooling Tower Fan.

The upgrade analysis of the high efficiency motor and VFD installation is shown in the appendix. As can be seen there, the total annual savings is calculated to be 39,150 kWh, which corresponds to an annual cost savings of $3,132. The total material and labor cost associated with the retrofits is $16,000. The annual run-hours for the Cooling Tower Fans were estimated to be approximately 4380 hours per year. The estimate was based on running the towers for half of the year. This results in a simple payback of 5.11 years.
Limestone Handling System

S1-LSH-ECM-1: Replacement of Limestone Blower Motor with High Efficiency Equivalent

A Limestone Blower is currently used in the Limestone Handling System for the coal-fired boiler EU-005. This pump motor is rated at 30 HP and is fed 460 V power. An efficiency figure could not be obtained from the nameplate but, using industry standards, SourceOne estimates the efficiency of this motor to be approximately 89.7%.

A high efficiency equivalent replacement for a motor of this size has an expected rated efficiency of 94.1%. The upgrade analysis of the high efficiency motor is shown in the appendix. As can be seen there, the total annual savings is calculated to be 1,703 kWh, which corresponds to an annual cost savings of $136. The total material and labor cost associated with the retrofits is $1,800. The annual run-hours for the Limestone Blower were estimated to be approximately 1460 hours per year based on the run hours of Boiler EU-005. This results in a simple payback of 13.2 years. This ECM is not cost justifiable based upon energy savings alone.

Ash Handling System

S1-AHS-ECM-1: Replacement of Ash Blower Motor with High Efficiency Equivalent

[Not Recommended]

An Ash Blower is currently used in the Ash Handling System for the coal-fired boiler EU-005. This pump motor is rated at 150 HP and is fed 460V power. The efficiency of the motor was obtained from the nameplate and recorded as 95.4%.

A high efficiency motor replacement of this size is expected to have a rated efficiency of 95.8% and is only marginally higher in efficiency than the existing motor. The upgrade analysis of the high efficiency motor is shown in the appendix. As can be seen there, the total annual savings is calculated to be 715 kWh, which corresponds to an annual cost savings of $57. The total material and labor cost associated with the retrofits is $7,350. The annual run-hours for the Ash Blower were estimated to be approximately 1460 hours per year based on the run hours of Boiler EU-005. This results in a simple payback of 128 years. This ECM is not cost justifiable based upon energy savings alone.

S1-AHS-ECM-2: Replacement of Fly-Ash Re-Injection Pump Motor with High Efficiency Equivalent

A Fly-Ash Re-Injection Pump is currently used in the Ash Handling System for coal-fired boiler EU-005. This pump motor is rated at 30 HP and is fed 460 V power. An efficiency figure could not be obtained from the nameplate but, using industry standards, SourceOne estimates the efficiency of this motor to be approximately 89.7%.

A high efficiency equivalent replacement for a motor of this size has an expected rated efficiency of 94.1%. The upgrade analysis of the high efficiency motor is shown in the appendix. As can be seen there, the total annual savings is calculated to be 1,703 kWh, which corresponds to an annual cost savings of $136. The total material and labor cost associated with the retrofits is $1,800. The annual run-hours for the Fly-Ash Re-Injection Pump were estimated to be approximately 1460 hours per year based on the
run hours of Boiler EU-005. This results in a simple payback of 13.2 years. This ECM is not cost justifiable based upon energy savings alone.

**Energy Conservation Initiatives (ECI’s)**

**Blowdown System**

ECI-1: Installation of Conductivity Meter and Auto-Dump Valves on Blowdown System

Currently, the blowdown system is manually controlled by operations personnel based on boiler water chemistry. It is recommended that a conductivity meter be installed in the boiler drum of each boiler and an auto-dump valve be installed on each blowdown line.

The payback for this ECM is not easily calculated and for this reason it is an ECI. Cost savings will come by way of increased efficiency of operations personnel as well as improved boiler water chemistry. Improved boiler water chemistry will help to decrease the rate of scale build-up to increase the life of the boiler. Per boiler, the total material and labor cost associated with the Conductivity Meter and Auto-Dump Valves is $35,000.
X. APPENDIX

i. University of Minnesota – South East Plant – Process Flow Diagram

ii. SourceOne Recommended ECM Payback Summary Sheets
### S1-CA-ECM-1: Replacement of 60 HP Air Compressor Motors with High Efficiency Equivalents

<table>
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<th>Floor</th>
<th>Location</th>
<th>Field ID</th>
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<th>Existing Motor Electric Consumption (kWh)</th>
<th>Existing Motor Electric Costs ($)</th>
<th>New Motor Efficiency (%)</th>
<th>New Motor Electric Consumption (kWh)</th>
<th>New Motor Electric Costs ($)</th>
<th>Additional VFD Savings (kWh)</th>
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- **Total Yearly Savings ($):** $663
- **Total Material and Labor ($):** $8,000
- **Payback Factor (Years):** 9.65
### 150 HP AIR COMPRESSOR PAYBACK SUMMARY SHEET

**Project Name:** University of Minnesota  
**Date:** 4/18/2014  
**Cost of Electricity:** 0.0800 $/kWh

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**S1-CAG-ECM-2: Replacement of 150 HP Air Compressor Motors with High Efficiency Equivalents**

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<th>Existing Motor Electric Consumption (kWh)</th>
<th>Existing Motor Electric Costs ($)</th>
<th>New Motor Efficiency (%)</th>
<th>New Motor Electric Consumption (kWh)</th>
<th>New Motor Electric Costs ($)</th>
<th>Additional VFD Savings (kWh)</th>
<th>Yearly Savings ($)</th>
<th>Yearly Savings ($)</th>
<th>Material Cost ($)</th>
<th>Labor Cost ($)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Main Plant</td>
<td>First Floor</td>
<td>N/A</td>
<td>N/A</td>
<td>2190</td>
<td>150</td>
<td>92.40%</td>
<td>265,218</td>
<td>$21,217</td>
<td>90.80%</td>
<td>255,805</td>
<td>$20,464</td>
<td>0</td>
<td>9,413</td>
<td>$753</td>
<td>$6,000</td>
<td>$1,350</td>
</tr>
<tr>
<td>2</td>
<td>Main Plant</td>
<td>First Floor</td>
<td>N/A</td>
<td>N/A</td>
<td>2190</td>
<td>150</td>
<td>92.40%</td>
<td>265,218</td>
<td>$21,217</td>
<td>90.80%</td>
<td>255,805</td>
<td>$20,464</td>
<td>0</td>
<td>9,413</td>
<td>$753</td>
<td>$6,000</td>
<td>$1,350</td>
</tr>
</tbody>
</table>

**Total**  
18,825 | 1,506 | 12,000 | 2,700

---

**Total Yearly Savings ($)**: $1,506  
**Total Material and Labor ($)**: $14,700  
**Payback Factor (Years)**: 9.76
## S1:Replacement of 600 HP Feedwater Pump Motors with High Efficiency Equivalents and Installation of VFDs

<table>
<thead>
<tr>
<th>Line #</th>
<th>Building</th>
<th>Floor</th>
<th>Location</th>
<th>Field ID</th>
<th>Annual Hours</th>
<th>Motor Horsepower (HP)</th>
<th>Existing Motor Efficiency (%)</th>
<th>Existing Motor Electric Consumption (kWh)</th>
<th>Existing Motor Electric Costs ($)</th>
<th>New Motor Efficiency (%)</th>
<th>New Motor Electric Consumption (kWh)</th>
<th>New Motor Electric Costs ($)</th>
<th>Additional VFD Savings (kWh)</th>
<th>Yearly Savings (kWh)</th>
<th>Yearly Savings ($$)</th>
<th>Material Cost ($)</th>
<th>Labor Cost ($)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Main Plant</td>
<td>First Floor</td>
<td>N/A</td>
<td>BFP-103A</td>
<td>3621</td>
<td>600</td>
<td>94.00%</td>
<td>1,724.212</td>
<td>$137,937</td>
<td>96.00%</td>
<td>1,688.291</td>
<td>$135,063</td>
<td>506,487</td>
<td>542,408</td>
<td>$43,393</td>
<td>$102,000</td>
<td>$9,700</td>
</tr>
<tr>
<td>2</td>
<td>Main Plant</td>
<td>First Floor</td>
<td>N/A</td>
<td>BFP-103B</td>
<td>3621</td>
<td>600</td>
<td>94.00%</td>
<td>1,724.212</td>
<td>$137,937</td>
<td>96.00%</td>
<td>1,688.291</td>
<td>$135,063</td>
<td>506,487</td>
<td>542,408</td>
<td>$43,393</td>
<td>$102,000</td>
<td>$9,700</td>
</tr>
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<td></td>
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</tr>
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</table>

Total Yearly Savings ($): $86,785
Total Material and Labor ($): $223,400
Payback Factor (Years): 2.57
## 300 HP Feedwater Pump Payback Summary Sheet

**Project Name:** University of Minnesota  
**S1 Project Number:** S14-015  
**Date:** 4/18/2014  
**Cost of Electricity:** 0.0800 $/kWh

**S1.BFW-ECM-2: Replacement of 300 HP Feedwater Pump Motors with High Efficiency Equivalents and Installation of VFDs**

<table>
<thead>
<tr>
<th>Line #</th>
<th>Building</th>
<th>Floor</th>
<th>Location</th>
<th>Field ID</th>
<th>Annual Hours</th>
<th>Motor Horsepower (HP)</th>
<th>Existing Motor Efficiency (%)</th>
<th>Existing Motor Electric Consumption (kWh)</th>
<th>Existing Motor Electric Costs ($)</th>
<th>New Motor Efficiency (%)</th>
<th>New Motor Electric Consumption (kWh)</th>
<th>New Motor Electric Costs ($)</th>
<th>Additional VFD Savings (kWh)</th>
<th>Yearly Savings (kWh)</th>
<th>Yearly Savings ($)</th>
<th>Material Cost ($)</th>
<th>Labor Cost ($)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Main Plant</td>
<td>First Floor</td>
<td>N/A</td>
<td>BFP-105A</td>
<td>2110</td>
<td>300</td>
<td>93.20%</td>
<td>506,672</td>
<td>$40,534</td>
<td>96.00%</td>
<td>491,894</td>
<td>$39,352</td>
<td>147,568</td>
<td>162,346</td>
<td>$12,988</td>
<td>$51,000</td>
<td>$6,400</td>
</tr>
<tr>
<td>2</td>
<td>Main Plant</td>
<td>First Floor</td>
<td>N/A</td>
<td>BFP-105B</td>
<td>2110</td>
<td>300</td>
<td>93.20%</td>
<td>506,672</td>
<td>$40,534</td>
<td>96.00%</td>
<td>491,894</td>
<td>$39,352</td>
<td>147,568</td>
<td>162,346</td>
<td>$12,988</td>
<td>$51,000</td>
<td>$6,400</td>
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**Total**  
324,692  
$25,975  
$102,000  
$12,300

- **Total Yearly Savings ($):** $25,975  
- **Total Material and Labor ($):** $114,800  
- **Payback Factor (Years):** 4.42
EU-005 FEEDWATER PUMP PAYBACK SUMMARY SHEET

S1-BFW-ECM-3: Replacement of EU-005 Feedwater Pump Motors with High Efficiency Equivalents

<table>
<thead>
<tr>
<th>Line #</th>
<th>Building</th>
<th>Floor</th>
<th>Location</th>
<th>Field ID</th>
<th>Annual Hours</th>
<th>Motor Horsepower (HP)</th>
<th>Existing Motor Efficiency (%)</th>
<th>Existing Motor Electric Consumption (kWh)</th>
<th>Existing Motor Electric Costs ($)</th>
<th>New Motor Efficiency (%)</th>
<th>New Motor Electric Consumption (kWh)</th>
<th>New Motor Electric Costs ($)</th>
<th>Additional VFD Savings (kWh)</th>
<th>Yearly Savings (kWh)</th>
<th>Yearly Savings ($)</th>
<th>Material Cost ($)</th>
<th>Labor Cost ($)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Main Plant</td>
<td>First Floor</td>
<td>N/A</td>
<td>FWP-A</td>
<td>72</td>
<td>250</td>
<td>93.00%</td>
<td>14,439</td>
<td>$1,155</td>
<td>96.20%</td>
<td>13,958</td>
<td>$1,117</td>
<td>0</td>
<td>480</td>
<td>$38</td>
<td>$11,500</td>
<td>$2,000</td>
</tr>
<tr>
<td>2</td>
<td>Main Plant</td>
<td>First Floor</td>
<td>N/A</td>
<td>FWP-B</td>
<td>72</td>
<td>250</td>
<td>93.00%</td>
<td>14,439</td>
<td>$1,155</td>
<td>96.20%</td>
<td>13,958</td>
<td>$1,117</td>
<td>0</td>
<td>480</td>
<td>$38</td>
<td>$11,500</td>
<td>$2,000</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
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<td></td>
<td></td>
<td><strong>961</strong></td>
<td><strong>1300</strong></td>
<td><strong>96.00%</strong></td>
<td><strong>29,238</strong></td>
<td><strong>$3,315</strong></td>
<td><strong>96.20%</strong></td>
<td><strong>25,950</strong></td>
<td><strong>$2,317</strong></td>
<td><strong>0</strong></td>
<td><strong>5,760</strong></td>
<td><strong>$520</strong></td>
<td><strong>$13,000</strong></td>
<td><strong>$2,000</strong></td>
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Total Yearly Savings ($)：$77
Total Material and Labor ($)：$27,000
Payback Factor (Years)：351.35
### S1-WTS-ECM-1: Replacement of Raw Water Pump Motors with High Efficiency Equivalents

<table>
<thead>
<tr>
<th>Line #</th>
<th>Building</th>
<th>Floor</th>
<th>Location</th>
<th>Field ID</th>
<th>Annual Hours</th>
<th>Motor Horsepower (HP)</th>
<th>Existing Motor Efficiency (%)</th>
<th>Existing Motor Electric Consumption (kWh)</th>
<th>Existing Motor Electric Costs ($)</th>
<th>New Motor Efficiency (%)</th>
<th>New Motor Electric Consumption (kWh)</th>
<th>New Motor Electric Costs ($)</th>
<th>Additional VFD Savings (kWh)</th>
<th>Yearly Savings (kWh)</th>
<th>Yearly Savings ($)</th>
<th>Material Cost ($)</th>
<th>Labor Cost ($)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Main Plant</td>
<td>Second Floor</td>
<td>N/A</td>
<td>MP-101A</td>
<td>100</td>
<td>25</td>
<td>86.50%</td>
<td>2,156</td>
<td>$172</td>
<td>93.60%</td>
<td>1,993</td>
<td>$159</td>
<td>0</td>
<td>164</td>
<td>$13</td>
<td>$1,000</td>
<td>$400</td>
</tr>
<tr>
<td>2</td>
<td>Main Plant</td>
<td>Second Floor</td>
<td>N/A</td>
<td>MP-101B</td>
<td>100</td>
<td>25</td>
<td>86.50%</td>
<td>2,156</td>
<td>$172</td>
<td>93.60%</td>
<td>1,993</td>
<td>$159</td>
<td>0</td>
<td>164</td>
<td>$13</td>
<td>$1,000</td>
<td>$400</td>
</tr>
<tr>
<td>Total</td>
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</tr>
</tbody>
</table>

Total Yearly Savings ($) = $20

Total Material and Labor ($) = $2,800

Payback Factor (Years) = 107.00
### DEMINERALIZED WATER PUMP PAYBACK SUMMARY SHEET

**Project Name:** University of Minnesota  
**S1 Project Number:** S14-015  
**Date:** 4/18/2014  
**Cost of Electricity:** 0.0800 $/kWh

#### S1-WTS-ECM-2: Replacement of Demineralized Water Pump Motors with High Efficiency Equivalents

| Line # | Building | Floor | Location | Field ID | Annual Hours | Motor Horsepower (HP) | Existing Motor Efficiency (%) | Existing Motor Electric Consumption (kWh) | Existing Motor Electric Costs ($) | New Motor Efficiency (%) | New Motor Electric Consumption (kWh) | New Motor Electric Costs ($) | Additional VFD Savings (kWh) | Yearly Savings ($/kWh) | Yearly Savings ($) | Material Cost ($) | Labor Cost ($) |
|--------|----------|-------|----------|----------|--------------|-----------------------|-------------------------------|-------------------------------------|----------------------------------|----------------------------|---------------------------------|----------------------|----------------------|-----------------|----------------|----------------|
| 1      | Main Plant | Second Floor | N/A | P-102A | 1100 | 60 | 89.50% | 55,012 | $4,401 | 95.40% | 51,610 | $4,129 | 0 | 3,402 | $272 | $2,500 | $700 |
| 2      | Main Plant | Second Floor | N/A | P-102B | 1100 | 60 | 89.50% | 55,012 | $4,401 | 95.40% | 51,610 | $4,129 | 0 | 3,402 | $272 | $2,500 | $700 |

**Total** | | | | | | | | | | | | | | | | | | | | | 6,804 | $544 | $5,000 | $1,400 |

**Total Yearly Savings ($)**: $544  
**Total Material and Labor ($)**: $6,400  
**Payback Factor (Years)**: 11.76
BOILER EU-005 FORCED DRAFT FAN PAYBACK SUMMARY SHEET

Date: 4/18/2014
Cost of Electricity: 0.0800 $/kWh

S1:CA-ECM-1: Replacement of Boiler EU-005 Forced Draft Fan Motor with High Efficiency Equivalent

<table>
<thead>
<tr>
<th>Line #</th>
<th>Building</th>
<th>Floor</th>
<th>Location</th>
<th>Field ID</th>
<th>Annual Hours</th>
<th>Motor Horsepower (HP)</th>
<th>Existing Motor Efficiency (%)</th>
<th>Existing Motor Electric Consumption (kWh)</th>
<th>Existing Motor Electric Costs ($)</th>
<th>New Motor Efficiency (%)</th>
<th>New Motor Electric Consumption (kWh)</th>
<th>New Motor Electric Costs ($)</th>
<th>Additional VFD Savings (kWh)</th>
<th>Yearly Savings ($)</th>
<th>Yearly Savings ($CF)</th>
<th>Material Cost ($)</th>
<th>Labor Cost ($)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Main Plant</td>
<td>Local to Boiler</td>
<td>N/A</td>
<td>N/A</td>
<td>144</td>
<td>100</td>
<td>93.00%</td>
<td>11,351</td>
<td>$924</td>
<td>90.40%</td>
<td>11,260</td>
<td>$901</td>
<td>0</td>
<td>291</td>
<td>$23</td>
<td>$4,000</td>
<td>$100</td>
</tr>
</tbody>
</table>

Total 291 $23 $4,000 $100

Total Yearly Savings ($) = $23
Total Material and Labor ($) = $4,100
Payback Factor (Years) = 176.37
# BOILER EU-005 OVER-FIRE AIR FAN PAYBACK SUMMARY SHEET

**Project Name:** University of Minnesota  
**S1 Project Number:** S14-015  
**Date:** 4/18/2014  
**Cost of Electricity:** 0.0800 $/kWh

## S1-CA-ECM-2: Replacement of Boiler EU-005 Over-Fire Air Fan Motor with High Efficiency Equivalent

| Line # | Building | Floor | Location | Field ID | Annual Hours | Motor Horsepower (HP) | Existing Motor Efficiency (%) | Existing Motor Electric Consumption (kWh) | Existing Motor Electric Costs ($) | New Motor Efficiency (%) | New Motor Electric Consumption (kWh) | New Motor Electric Costs ($) | Additional VFD Savings (kWh) | Yearly Savings ($) | Material Cost ($) | Labor Cost ($) |
|--------|----------|-------|----------|----------|---------------|------------------------|----------------------------------|---------------------------------------|----------------------------------|----------------------------|-------------------------------|-----------------------------|---------------------------|-----------------|---------------|
| 1      | Main Plant | Local to Boiler | N/A | N/A | 144 | 60 | 91.70% | 7,029 | $562 | 90.40% | 6,758 | $540 | 0 | 273 | $22 | $2,500 | $700 |
| **Total** | | | | | | | | | | | | | | | | | | |

Total Yearly Savings ($): $22  
Total Material and Labor ($): $3,200  
Payback Factor (Years): 146.73
### S1-CA-ECM-3: Replacement of Boiler EU-005 Induced Draft Fan Motor with High Efficiency Equivalent

<table>
<thead>
<tr>
<th>Line #</th>
<th>Building</th>
<th>Floor</th>
<th>Location</th>
<th>Field ID</th>
<th>Annual Hours</th>
<th>Existing Motor Horsepower (HP)</th>
<th>Existing Motor Efficiency (%)</th>
<th>Existing Motor Electric Consumption (kWh)</th>
<th>Existing Motor Electric Costs ($)</th>
<th>New Motor Efficiency (%)</th>
<th>New Motor Electric Consumption (kWh)</th>
<th>New Motor Electric Costs ($)</th>
<th>Additional VFD Savings (kWh)</th>
<th>Yearly Savings (kWh)</th>
<th>Yearly Savings ($)</th>
<th>Material Cost ($)</th>
<th>Labor Cost ($)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Main Plant Local to Boiler</td>
<td>N/A</td>
<td>N/A</td>
<td>144</td>
<td>250</td>
<td>93.00%</td>
<td>28,977</td>
<td>$2,310</td>
<td>96.20%</td>
<td>27,917</td>
<td>$2,233</td>
<td>0</td>
<td>961</td>
<td>$77</td>
<td>$11,500</td>
<td>$2,000</td>
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</tbody>
</table>

**Total**  
961 | $77 | $11,500 | $2,000

**Total Yearly Savings ($)**: $77  
**Total Material and Labor ($)**: $11,500  
**Payback Factor (Years)**: 175.05
**BOILER EU-005 BAGHOUSE INDUCED DRAFT FAN PAYBACK SUMMARY SHEET**

**Project Name:** University of Minnesota  
**S1 Project Number:** S14-015  
**Date:** 4/18/2014  
**Cost of Electricity:** 0.0800 $/kWh

**S1-CA-ECM-4: Replacement of Boiler EU-005 Baghouse Induced Draft Fan Motor with High Efficiency Equivalent**

<table>
<thead>
<tr>
<th>Line #</th>
<th>Building</th>
<th>Floor</th>
<th>Location</th>
<th>Field ID</th>
<th>Annual Hours</th>
<th>Motor Horsepower (HP)</th>
<th>Existing Motor Efficiency (%)</th>
<th>Existing Motor Electric Consumption (kWh)</th>
<th>New Motor Efficiency (%)</th>
<th>New Motor Electric Consumption (kWh)</th>
<th>Additional VFD Savings (kWh)</th>
<th>Yearly Savings (kWh)</th>
<th>Yearly Savings ($)</th>
<th>Material Cost ($)</th>
<th>Labor Cost ($)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Main Plant</td>
<td>Baghouse</td>
<td>N/A</td>
<td>N/A</td>
<td>144</td>
<td>500</td>
<td>93.80%</td>
<td>57,262</td>
<td>96.00%</td>
<td>55,950</td>
<td>0</td>
<td>1,312</td>
<td>$105</td>
<td>$25,000</td>
<td>$3,700</td>
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</tbody>
</table>

**Total**  
1,312  
$105  
$25,000  
$3,700

**Total Yearly Savings ($)**: $105  
**Total Material and Labor ($)**: $28,700  
**Payback Factor (Years)**: 273.38
**Boiler EU-001 Forced Draft Fan Payback Summary Sheet**

**Project Name:** University of Minnesota  
**S1 Project Number:** S14-015  
**Date:** 4/18/2014  
**Cost of Electricity:** $0.0800/kWh

**S1-CA-ECM-5: Replacement of Boiler EU-001 Forced Draft Fan Motor with High Efficiency Equivalent and Installation of VFD**

<table>
<thead>
<tr>
<th>Line #</th>
<th>Building</th>
<th>Floor</th>
<th>Location</th>
<th>Field ID</th>
<th>Annual Hours</th>
<th>Motor Horsepower (HP)</th>
<th>Motor Efficiency (%)</th>
<th>Existing Motor Electric Consumption (kWh)</th>
<th>Existing Motor Electric Costs ($)</th>
<th>New Motor Efficiency (%)</th>
<th>New Motor Electric Consumption (kWh)</th>
<th>New Motor Electric Costs ($)</th>
<th>Additional VFD Savings (kWh)</th>
<th>Yearly Savings (kWh)</th>
<th>Yearly Savings ($)</th>
<th>Material Cost ($)</th>
<th>Labor Cost ($)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Main Plant</td>
<td>Local to Boiler</td>
<td>N/A</td>
<td>B-201</td>
<td>5453</td>
<td>1000</td>
<td>94.20%</td>
<td>4,318,456</td>
<td>$3,454,722</td>
<td>96.00%</td>
<td>4,237,435</td>
<td>$3,389,995</td>
<td>1,271,231</td>
<td>1,352,201</td>
<td>$108,176</td>
<td>$192,000</td>
<td>$17,000</td>
</tr>
</tbody>
</table>

**Total**  
1,352,201 | $108,176 | $192,000 | $17,000

**Total Yearly Savings ($):** $108,176  
**Total Material and Labor ($):** $398,000  
**Payback Factor (Years):** 1.9
**BOILER EU-001 BLOWER PAYBACK SUMMARY SHEET**

**Project Name:** University of Minnesota  
**Date:** 4/18/2014  
**Cost of Electricity:** 0.0800 $/kWh  

**S1-CA-ECM-6: Replacement of Boiler EU-001 Blower Motor with High Efficiency Equivalent**

<table>
<thead>
<tr>
<th>Line #</th>
<th>Building</th>
<th>Floor</th>
<th>Location</th>
<th>Field ID</th>
<th>Annual Hours</th>
<th>Motor Horsepower (HP)</th>
<th>Existing Motor Efficiency (%)</th>
<th>Existing Motor Electric Consumption (kWh)</th>
<th>Existing Motor Electric Costs ($)</th>
<th>New Motor Efficiency (%)</th>
<th>New Motor Electric Consumption (kWh)</th>
<th>New Motor Electric Costs ($)</th>
<th>Additional VFD Savings (kWh)</th>
<th>Yearly Savings ($)</th>
<th>Yearly Savings ($)</th>
<th>Material Cost ($)</th>
<th>Labor Cost ($)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Main Plant</td>
<td>Local to Boiler</td>
<td>N/A</td>
<td>B-204</td>
<td>543</td>
<td>60</td>
<td>92.40%</td>
<td>220,127</td>
<td>$17,510</td>
<td>95.00%</td>
<td>214,102</td>
<td>$17,128</td>
<td>0</td>
<td>5.025</td>
<td>482</td>
<td>2,000</td>
<td>600</td>
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<tr>
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</tbody>
</table>

**Total Yearly Savings ($):** $482  
**Total Material and Labor ($):** $2,600  
**Payback Factor (Years):** 5.39
### BOILER EU-001 INDUCED DRAFT FAN PAYBACK SUMMARY SHEET

**Project Name:** University of Minnesota  
**S1 Project Number:** S14-015  
**Date:** 4/18/2014  
**Cost of Electricity:** 0.0800 $/kWh

**S1-CA-ECM-7: Replacement of Boiler EU-001 Induced Draft Fan Motor with High Efficiency Equivalent and Installation of VFD**

<table>
<thead>
<tr>
<th>Line #</th>
<th>Building</th>
<th>Floor</th>
<th>Location</th>
<th>Field ID</th>
<th>Annual Hours</th>
<th>Motor Horsepower (HP)</th>
<th>Existing Motor Efficiency (%)</th>
<th>Existing Motor Electric Consumption (kWh)</th>
<th>Existing Motor Electric Costs ($)</th>
<th>New Motor Efficiency (%)</th>
<th>New Motor Electric Consumption (kWh)</th>
<th>New Motor Electric Costs ($)</th>
<th>Additional VFD Savings (kWh)</th>
<th>Yearly Savings (kWh)</th>
<th>Yearly Savings ($)</th>
<th>Material Cost ($)</th>
<th>Labor Cost ($)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Main Plant</td>
<td>Local to Boiler</td>
<td>N/A</td>
<td>B-203</td>
<td>5453</td>
<td>700</td>
<td>94.20%</td>
<td>3,022,884</td>
<td>$241,831</td>
<td>96.00%</td>
<td>2,966,205</td>
<td>$237,296</td>
<td>889,861</td>
<td>946,541</td>
<td>$75,723</td>
<td>$117,000</td>
<td>$10,500</td>
</tr>
</tbody>
</table>

**Total**  
946,541 $75,723 $117,000 $10,500

Total Yearly Savings ($) = $75,723  
Total Material and Labor ($) = $137,500  
Payback Factor (Years) = 1.56
### BOILER EU-002 FORCED DRAFT FAN PAYBACK SUMMARY SHEET

**Project Name:** University of Minnesota  
**S1 Project Number:** S14-015  
**Date:** 4/18/2014  
**Cost of Electricity:** 0.0800 $/kWh

**S1-CA-ECM-8: Replacement of Boiler EU-002 Forced Draft Fan Motor with High Efficiency Equivalent and Installation of VFD**

<table>
<thead>
<tr>
<th>Line #</th>
<th>Building</th>
<th>Floor</th>
<th>Location</th>
<th>Field ID</th>
<th>Annual Hours</th>
<th>Motor Horsepower (HP)</th>
<th>Existing Motor Efficiency (%)</th>
<th>Existing Motor Electric Consumption (kWh)</th>
<th>Existing Motor Electric Costs ($)</th>
<th>New Motor Efficiency (%)</th>
<th>New Motor Electric Consumption (kWh)</th>
<th>New Motor Electric Costs ($)</th>
<th>Additional VFD Savings (kWh)</th>
<th>Yearly Savings ($KWh)</th>
<th>Yearly Savings ($)</th>
<th>Material Cost ($)</th>
<th>Labor Cost ($)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Main Plant</td>
<td>Local to Boiler</td>
<td>N/A</td>
<td>B-210</td>
<td>4219</td>
<td>600</td>
<td>84.50%</td>
<td>1,988,333</td>
<td>966,867</td>
<td>96.00%</td>
<td>1,987,109</td>
<td>961,369</td>
<td>590,133</td>
<td>621,357</td>
<td>49,709</td>
<td>102,000</td>
<td>10,700</td>
</tr>
</tbody>
</table>

**Total**  
621,357 $  
49,709 $  
102,000 $  
10,700 $

Total Yearly Savings ($) = $49,709  
Total Material and Labor ($) = $112,700  
Payback Factor (Years) = 2.27
**BOILER EU-003 FORCED DRAFT FAN PAYBACK SUMMARY SHEET**

**Project Name:** University of Minnesota  
**S1 Project Number:** S14-015  
**Date:** 4/18/2014  
**Cost of Electricity:** 0.0800 $/kWh

**S1-CA-ECM-9: Replacement of Boiler EU-003 Forced Draft Fan Motor with High Efficiency Equivalent and Installation of VFD**

<table>
<thead>
<tr>
<th>Line #</th>
<th>Building</th>
<th>Floor</th>
<th>Location</th>
<th>Field ID</th>
<th>Annual Hours</th>
<th>Motor Horsepower (HP)</th>
<th>Existing Motor Efficiency (%)</th>
<th>Existing Motor Electric Consumption (kWh)</th>
<th>Existing Motor Electric Costs ($)</th>
<th>New Motor Efficiency (%)</th>
<th>New Motor Electric Consumption (kWh)</th>
<th>New Motor Electric Costs ($)</th>
<th>Additional VFD Savings (kWh)</th>
<th>Yearly Savings (kWh)</th>
<th>Yearly Savings ($)</th>
<th>Material Cost ($)</th>
<th>Labor Cost ($)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Main Plant Local to Boiler</td>
<td>N/A</td>
<td>B-220</td>
<td>5412</td>
<td>600</td>
<td>94.50%</td>
<td>2,563,398</td>
<td>$205,072</td>
<td>96.00%</td>
<td>2,523,345</td>
<td>$201,868</td>
<td>757,004</td>
<td>797,057</td>
<td>$63,765</td>
<td>$102,000</td>
<td>$10,700</td>
<td></td>
</tr>
</tbody>
</table>

Total: 797,057  
$63,765  
$102,000  
$10,700

**Total Yearly Savings ($)**: $63,765  
**Total Material and Labor ($)**: $112,700  
**Payback Factor (Years)**: 1.77
**BELT DRIVE PAYBACK SUMMARY SHEET**

**Project Name:** University of Minnesota  
**S1 Project Number:** S14-015  
**Date:** 4/18/2014  
**Cost of Electricity:** 0.0800 $/kWh

---

**S1-CHS-ECM-1: Replacement of Belt Drive Motor with High Efficiency Equivalent**

<table>
<thead>
<tr>
<th>Line #</th>
<th>Building</th>
<th>Floor</th>
<th>Location</th>
<th>Field ID</th>
<th>Annual Hours</th>
<th>Motor Horsepower (HP)</th>
<th>Existing Motor Electric Consumption (kWh)</th>
<th>Existing Motor Electric Costs ($)</th>
<th>New Motor Efficiency (%)</th>
<th>New Motor Electric Consumption (kWh)</th>
<th>New Motor Electric Costs ($)</th>
<th>Additional VFD Savings (kWh)</th>
<th>Yearly Savings ($)</th>
<th>Yearly Savings ($)</th>
<th>Material Cost ($)</th>
<th>Labor Cost ($)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Main Plant</td>
<td>Coal Tunnel</td>
<td>N/A</td>
<td>N/A</td>
<td>1460</td>
<td>15</td>
<td>86.80%</td>
<td>15.922</td>
<td>$1,506</td>
<td>93.00%</td>
<td>17.567</td>
<td>0</td>
<td>1,255</td>
<td>$100</td>
<td>$100</td>
<td>$300</td>
</tr>
</tbody>
</table>

**Total**  

<table>
<thead>
<tr>
<th>Material Cost ($)</th>
<th>Labor Cost ($)</th>
</tr>
</thead>
<tbody>
<tr>
<td>$100</td>
<td>$300</td>
</tr>
</tbody>
</table>

---

**Total Yearly Savings ($)**: $100  
**Total Material and Labor ($)**: $1,405  
**Payback Factor (Years)**: 9.96
### 40 HP CRUSHER DRIVE PAYBACK SUMMARY SHEET

**Project Name:** University of Minnesota  
**S1 Project Number:** S14-015  
**Date:** 4/18/2014  
**Cost of Electricity:** 0.0800 $/kWh

**S1-CHS-ECM-2: Replacement of 40 HP Crusher Drive Motor with High Efficiency Equivalent**

<table>
<thead>
<tr>
<th>Line #</th>
<th>Building</th>
<th>Floor</th>
<th>Location</th>
<th>Field ID</th>
<th>Annual Hours</th>
<th>Motor Horsepower (HP)</th>
<th>Existing Motor Efficiency (%)</th>
<th>Existing Motor Electric Consumption (kWh)</th>
<th>Existing Motor Electric Costs ($)</th>
<th>New Motor Efficiency (%)</th>
<th>New Motor Electric Consumption (kWh)</th>
<th>New Motor Electric Costs ($)</th>
<th>Additional VFD Savings (kWh)</th>
<th>Yearly Savings (kWh)</th>
<th>Yearly Savings ($)</th>
<th>Material Cost ($)</th>
<th>Labor Cost ($)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Main Plant</td>
<td>Coal Tunnel</td>
<td>N/A</td>
<td>N/A</td>
<td>1460</td>
<td>40</td>
<td>91.70%</td>
<td>47,510</td>
<td>$3,801</td>
<td>94.50%</td>
<td>46,102</td>
<td>$3,688</td>
<td>0</td>
<td>1,408</td>
<td>$113</td>
<td>$1,600</td>
<td>$550</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td>1,408</td>
<td>$113</td>
<td>$1,600</td>
<td>$550</td>
<td></td>
<td></td>
<td></td>
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<td></td>
</tr>
</tbody>
</table>

- **Total Yearly Savings ($):** $113
- **Total Material and Labor ($):** $2,150
- **Payback Factor (Years):** 19.09

University of Minnesota - South East Plant
**S1-CHS-ECM-3: Replacement of Bucket Drive Motor with High Efficiency Equivalent**

<table>
<thead>
<tr>
<th>Line #</th>
<th>Building</th>
<th>Floor</th>
<th>Location</th>
<th>Field ID</th>
<th>Annual Hours</th>
<th>Motor Horsepower (HP)</th>
<th>Existing Motor Efficiency (%)</th>
<th>Existing Motor Electric Consumption (kWh)</th>
<th>Existing Motor Electric Costs ($)</th>
<th>New Motor Efficiency (%)</th>
<th>New Motor Electric Consumption (kWh)</th>
<th>New Motor Electric Costs ($)</th>
<th>Additional VFD Savings (kWh)</th>
<th>Yearly Savings (kWh)</th>
<th>Yearly Savings ($)</th>
<th>Material Cost ($)</th>
<th>Labor Cost ($)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Main Plant</td>
<td>Coal Tunnel</td>
<td>N/A</td>
<td>N/A</td>
<td>1460</td>
<td>10</td>
<td>87.50%</td>
<td>12,448</td>
<td>$996</td>
<td>91.70%</td>
<td>11,877</td>
<td>$950</td>
<td>0</td>
<td>570</td>
<td>$46</td>
<td>$550</td>
<td>$250</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Total**

- Yearly Savings (kWh): 570
- Yearly Savings ($): 46
- Material Cost ($): 550
- Labor Cost ($): 250

**Total Yearly Savings ($):** $46
**Total Material and Labor ($):** $550

**Payback Factor (Years):** 17.54
**S1-CHS-ECM-4: Replacement of Conveyor Drive Motor with High Efficiency Equivalent**

| Line # | Building | Floor | Location | Field ID | Annual Hours | Existing Motor Horsepower (HP) | Motor Effort Efficiency (%) | Existing Motor Electric Consumption (kWh) | Existing Motor Electric Costs ($) | New Motor Horsepower (HP) | New Motor Efficiency (%) | New Motor Electric Consumption (kWh) | New Motor Electric Costs ($) | Additional VFD Savings (kWh) | Yearly Savings (kWh) | Yearly Savings ($) | Material Cost ($) | Labor Cost ($) |
|-------|----------|-------|----------|----------|--------------|-------------------------------|----------------------------|-----------------------------------------|-------------------------------|----------------------------|----------------------------|--------------------------------|-------------------------|-------------------|-------------------|---------------|---------------|
| 1     | Main Plant | Coal Tunnel | N/A     | N/A     | 1460        | 7.5                            | 85.20%                     | 9,588                                    | $767                          | 91.70%                     | 8,908                                    | $713                        | 0                        | 680               | $54             | $450          | $220          |

**Total**  
680   $54   $450   $220

- **Total Yearly Savings ($):** $54  
- **Total Material and Labor ($):** $670  
- **Payback Factor (Years):** 12.32
## FUEL OIL PUMP PAYBACK SUMMARY SHEET

### S1-FOB-ECM-1: Replacement of Fuel Oil Pump Motors with High Efficiency Equivalents

<table>
<thead>
<tr>
<th>Line #</th>
<th>Building</th>
<th>Floor</th>
<th>Location</th>
<th>Field ID</th>
<th>Annual Hours</th>
<th>Motor Horsepower (HP)</th>
<th>Existing Motor Efficiency (%)</th>
<th>Existing Motor Electric Consumption (kWh)</th>
<th>Existing Motor Electric Costs ($)</th>
<th>New Motor Efficiency (%)</th>
<th>New Motor Electric Consumption (kWh)</th>
<th>New Motor Electric Costs ($)</th>
<th>Additional VFD Savings (kWh)</th>
<th>Yearly Savings ($)</th>
<th>Yearly Savings ($)</th>
<th>Material Cost ($)</th>
<th>Labor Cost ($)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Main Plant</td>
<td>Second Floor</td>
<td>N/A</td>
<td>P-115A</td>
<td>1460</td>
<td>60</td>
<td>93.00%</td>
<td>70,268</td>
<td>$5,621</td>
<td>95.40%</td>
<td>68,501</td>
<td>$5,480</td>
<td>0</td>
<td>1,768</td>
<td>$141</td>
<td>$2,500</td>
<td>$700</td>
</tr>
<tr>
<td>2</td>
<td>Main Plant</td>
<td>Second Floor</td>
<td>N/A</td>
<td>P-115B</td>
<td>1460</td>
<td>60</td>
<td>93.00%</td>
<td>70,268</td>
<td>$5,621</td>
<td>95.40%</td>
<td>68,501</td>
<td>$5,480</td>
<td>0</td>
<td>1,768</td>
<td>$141</td>
<td>$2,500</td>
<td>$700</td>
</tr>
</tbody>
</table>

Total

- Yearly Savings ($) = 3,536
- Total Material and Labor ($) = 6,400
- Payback Factor (Years) = 22.63

Total Yearly Savings ($) = 283
Total Material and Labor ($) = 6,400
### LUBE OIL PUMP PAYBACK SUMMARY SHEET

**Project Name:** University of Minnesota  
**Date:** 4/18/2014  
**Cost of Electricity:** 0.0800 $/kWh

**Project Number:** S14-015  
**S1-ECM-1:** Replacement of Lube Oil Pump Motors with High Efficiency Equivalents

<table>
<thead>
<tr>
<th>Line #</th>
<th>Building</th>
<th>Floor</th>
<th>Location</th>
<th>Field ID</th>
<th>Annual Hours</th>
<th>Motor Horsepower (HP)</th>
<th>Existing Motor Efficiency (%)</th>
<th>Existing Motor Electric Consumption (kWh)</th>
<th>Existing Motor Electric Costs ($)</th>
<th>New Motor Efficiency (%)</th>
<th>New Motor Electric Consumption (kWh)</th>
<th>New Motor Electric Costs ($)</th>
<th>Additional VFD Savings (kWh)</th>
<th>Yearly Savings ($</th>
<th>Yearly Savings ($)</th>
<th>Material Cost ($)</th>
<th>Labor Cost ($)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Main Plant</td>
<td>Second Floor</td>
<td>N/A</td>
<td>P-123</td>
<td>4380</td>
<td>50</td>
<td>93.00%</td>
<td>175,671</td>
<td>$14,054</td>
<td>95.00%</td>
<td>171,973</td>
<td>$13,758</td>
<td>0</td>
<td>3,698</td>
<td>$296</td>
<td>$2,000</td>
<td>$600</td>
</tr>
<tr>
<td>2</td>
<td>Main Plant</td>
<td>Second Floor</td>
<td>N/A</td>
<td>P-124</td>
<td>4380</td>
<td>50</td>
<td>93.00%</td>
<td>175,671</td>
<td>$14,054</td>
<td>95.00%</td>
<td>171,973</td>
<td>$13,758</td>
<td>0</td>
<td>3,698</td>
<td>$296</td>
<td>$2,000</td>
<td>$600</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>4880</td>
<td>50</td>
<td>93.00%</td>
<td>175,671</td>
<td>$14,054</td>
<td>95.00%</td>
<td>171,973</td>
<td>$13,758</td>
<td>0</td>
<td>3,698</td>
<td>$296</td>
<td>$2,000</td>
</tr>
</tbody>
</table>

Total Yearly Savings ($): $592  
Total Material and Labor ($): $4,000  
Payback Factor (Years): 8.79
**CONDENSATE PUMP (P-104A) PAYBACK SUMMARY SHEET**

<table>
<thead>
<tr>
<th>Line #</th>
<th>Building</th>
<th>Floor</th>
<th>Location</th>
<th>Field ID</th>
<th>Annual Hours</th>
<th>Motor Horsepower (HP)</th>
<th>Existing Motor Efficiency (%)</th>
<th>Existing Motor Electric Consumption (kWh)</th>
<th>Existing Motor Electric Costs ($)</th>
<th>New Motor Efficiency (%)</th>
<th>New Motor Electric Consumption (kWh)</th>
<th>New Motor Electric Costs ($)</th>
<th>Additional VFD Savings (kWh)</th>
<th>Yearly Savings (kWh)</th>
<th>Yearly Savings ($)</th>
<th>Material Cost ($)</th>
<th>Labor Cost ($)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Main Plant</td>
<td>Below</td>
<td>Deaerator</td>
<td>P-104A</td>
<td>1100</td>
<td>200</td>
<td>86.00%</td>
<td>190,837</td>
<td>$15,267</td>
<td>96.20%</td>
<td>170,603</td>
<td>$13,648</td>
<td>0</td>
<td>20,234</td>
<td>$1,619</td>
<td>$9,000</td>
<td>$1,800</td>
</tr>
</tbody>
</table>

Total

- Yearly Savings (kWh): 20,234
- Yearly Savings ($): $1,619
- Total Material and Labor ($): $10,800
- Payback Factor (Years): 6.67

---

S1-CND-ECM-1: Replacement of Condensate Pump (P-104A) Motor with High Efficiency Equivalent

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University of Minnesota - South East Plant
## CONDENSATE PUMP (P-105A) PAYBACK SUMMARY SHEET

**Project Name:** University of Minnesota  
**S1 Project Number:** S14-015  
**Date:** 4/18/2014  
**Cost of Electricity:** 0.0800 $/kWh

**S1-CND-ECM-2:** Replacement of Condensate Pump (P-105A) Motor with High Efficiency Equivalent

<table>
<thead>
<tr>
<th>Line #</th>
<th>Building</th>
<th>Floor Location</th>
<th>Field ID</th>
<th>Annual Hours</th>
<th>Motor Horsepower (HP)</th>
<th>Existing Motor Efficiency (%)</th>
<th>Existing Motor Electric Consumption (kWh)</th>
<th>Existing Motor Electric Costs ($)</th>
<th>New Motor Efficiency (%)</th>
<th>New Motor Electric Consumption (kWh)</th>
<th>New Motor Electric Costs ($)</th>
<th>Additional VFD Savings (kWh)</th>
<th>Yearly Savings (kWh)</th>
<th>Yearly Savings ($)</th>
<th>Material Cost ($)</th>
<th>Labor Cost ($)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Main Plant</td>
<td>Below Deaerator</td>
<td>N/A</td>
<td>1100</td>
<td>200</td>
<td>95.8%</td>
<td>171,315</td>
<td>13,705</td>
<td>96.20%</td>
<td>170,603</td>
<td>13,648</td>
<td>0</td>
<td>712</td>
<td>$57</td>
<td>$9,000</td>
<td>$1,800</td>
</tr>
</tbody>
</table>

**Total**                                                                                                               
712                                                                                                     
57                                                                                                       
9,000                                                                                                      
1,800

**Total Yearly Savings ($):** $57  
**Total Material and Labor ($):** $10,800  
**Payback Factor (Years):** 189.52
### S1-CW-ECM-1: Replacement of Cooling Tower Fan Motors with High Efficiency Equivalents and Installation of VFDs

<table>
<thead>
<tr>
<th>Line #</th>
<th>Building</th>
<th>Floor</th>
<th>Location</th>
<th>Field ID</th>
<th>Annual Hours</th>
<th>Motor Horsepower (HP)</th>
<th>Existing Motor Efficiency (%)</th>
<th>Existing Motor Electric Consumption (kWh)</th>
<th>New Motor Efficiency (%)</th>
<th>New Motor Electric Consumption (kWh)</th>
<th>Annual Hours</th>
<th>New Motor Electric Costs ($)</th>
<th>New Motor Electric Costs ($)</th>
<th>VFD Savings (kWh)</th>
<th>Yearly Savings (kWh)</th>
<th>Yearly Savings ($)</th>
<th>Material Cost ($)</th>
<th>Labor Cost ($)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Main Plant</td>
<td>Rooftop</td>
<td>N/A</td>
<td>P-106A</td>
<td>15</td>
<td>86.80%</td>
<td>56,466</td>
<td>$4,517</td>
<td>93.00%</td>
<td>52,701</td>
<td>$4,216</td>
<td>15,810</td>
<td>19,575</td>
<td>$1,566</td>
<td>$6,200</td>
<td>$1,800</td>
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<td></td>
</tr>
<tr>
<td>2</td>
<td>Main Plant</td>
<td>Rooftop</td>
<td>N/A</td>
<td>P-106B</td>
<td>15</td>
<td>86.80%</td>
<td>56,466</td>
<td>$4,517</td>
<td>93.00%</td>
<td>52,701</td>
<td>$4,216</td>
<td>15,810</td>
<td>19,575</td>
<td>$1,566</td>
<td>$6,200</td>
<td>$1,800</td>
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Total

<table>
<thead>
<tr>
<th>Line #</th>
<th>Building</th>
<th>Floor</th>
<th>Location</th>
<th>Field ID</th>
<th>Annual Hours</th>
<th>Motor Horsepower (HP)</th>
<th>Existing Motor Efficiency (%)</th>
<th>Existing Motor Electric Consumption (kWh)</th>
<th>New Motor Efficiency (%)</th>
<th>New Motor Electric Consumption (kWh)</th>
<th>Annual Hours</th>
<th>New Motor Electric Costs ($)</th>
<th>New Motor Electric Costs ($)</th>
<th>VFD Savings (kWh)</th>
<th>Yearly Savings (kWh)</th>
<th>Yearly Savings ($)</th>
<th>Material Cost ($)</th>
<th>Labor Cost ($)</th>
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Total

- Total Yearly Savings ($) = $3,132
- Total Material and Labor ($) = $16,000
- Payback Factor (Years) = 5.11
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<th>Line #</th>
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<th>Annual Hours</th>
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<th>Existing Motor Efficiency (%)</th>
<th>Existing Motor Electric Consumption (kWh)</th>
<th>Existing Motor Electric Costs ($)</th>
<th>New Motor Efficiency (%)</th>
<th>New Motor Electric Consumption (kWh)</th>
<th>New Motor Electric Costs ($)</th>
<th>Additional VFD Savings (kWh)</th>
<th>Yearly Savings (kWh)</th>
<th>Yearly Savings ($)</th>
<th>Material Cost ($)</th>
<th>Labor Cost ($)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Main Plant</td>
<td>Local to Boiler</td>
<td>N/A</td>
<td>N/A</td>
<td>1460</td>
<td>30</td>
<td>89.70%</td>
<td>36,427</td>
<td>$2,914</td>
<td>94.10%</td>
<td>34,723</td>
<td>$2,778</td>
<td>0</td>
<td>1,703</td>
<td>$136</td>
<td>$1,300</td>
<td>$500</td>
</tr>
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</tbody>
</table>

Total Yearly Savings ($) : $130
Total Material and Labor ($) : $1,800
Payback Factor (Years) : 13.21
### PAYBACK SUMMARY SHEET

**Project Name:** University of Minnesota  
**S1 Project Number:** S14-015  
**Date:** 4/18/2014  
**Cost of Electricity:** 0.0800 $/kWh

**S1.HS-ECM-1: Replacement of Ash Blower Motor with High Efficiency Equivalent**

<table>
<thead>
<tr>
<th>Line #</th>
<th>Building</th>
<th>Floor</th>
<th>Location</th>
<th>Field ID</th>
<th>Annual Hours</th>
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<th>New Motor Electric Consumption (kWh)</th>
<th>New Motor Electric Costs ($)</th>
<th>Additional VFD Savings (kWh)</th>
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<th>Yearly Savings ($)</th>
<th>Material Cost ($)</th>
<th>Labor Cost ($)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Main Plant</td>
<td>Local to Boiler</td>
<td>N/A</td>
<td>N/A</td>
<td>1460</td>
<td>150</td>
<td>95.40%</td>
<td>171.252</td>
<td>$13,700</td>
<td>95.80%</td>
<td>170.537</td>
<td>$13,643</td>
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<td>715</td>
<td>$57</td>
<td>$6,000</td>
<td>$1,350</td>
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**Total**  
715 $57 $6,000 $1,350

**Total Yearly Savings ($):** $57  
**Total Material and Labor ($):** $7,350  
**Payback Factor (Years):** 128.49
**FLY-ASH RE-INJECTION PUMP PAYBACK SUMMARY SHEET**

**Project Name:** University of Minnesota  
**S1 Project Number:** S14-015  
**Date:** 4/18/2014  
**Cost of Electricity:** 0.0800 $/kWh

**S1-AHS-ECM-2: Replacement of Fly-Ash Re-Injection Pump Motor with High Efficiency Equivalent**

<table>
<thead>
<tr>
<th>Line #</th>
<th>Building</th>
<th>Floor</th>
<th>Location</th>
<th>Field ID</th>
<th>Annual Hours</th>
<th>Motor Horsepower (HP)</th>
<th>Existing Motor Efficiency (%)</th>
<th>Existing Motor Electric Consumption (kWh)</th>
<th>Existing Motor Electric Costs ($)</th>
<th>New Motor Efficiency (%)</th>
<th>New Motor Electric Consumption (kWh)</th>
<th>New Motor Electric Costs ($)</th>
<th>Additional VFD Savings (kWh)</th>
<th>Yearly Savings (kWh)</th>
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<tbody>
<tr>
<td>1</td>
<td>Main Plant</td>
<td>Local to Boiler</td>
<td>N/A</td>
<td>N/A</td>
<td>1460</td>
<td>30</td>
<td>89.70%</td>
<td>36,427</td>
<td>$2,914</td>
<td>94.10%</td>
<td>34,723</td>
<td>$2,778</td>
<td>0</td>
<td>1,703</td>
<td>$136</td>
<td>$1,300</td>
<td>$500</td>
</tr>
</tbody>
</table>

**Total**

1,703 $136 $1,300 $500

**Total Yearly Savings ($) :** $136  
**Total Material and Labor ($) :** $1,800  
**Payback Factor (Years):** 13.21