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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 26th of this year, SourceOne performed an on-site energy assessment of the Saint Paul Plant located at 952 Commonwealth Ave, Saint Paul, 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 Saint Paul plant has 12 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
Reviewed 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

Identified potential ECM’s for financial feasibility and attractiveness as measured by “simple payback”

- Identified twenty-six (26) 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-six (26) aforementioned SourceOne ECM’s should result in the following energy savings:

Compressed Air System

S1-CAS-ECM-1: Replacement of 40 HP Air Compressor Motors with High Efficiency Equivalents
- Energy Savings: 3,143 kWh
- Capital Cost: $4,300
- Payback: 13.7 years

S1-CAS-ECM-2: Replacement of 60 HP Air Compressor Motors with High Efficiency Equivalents
- Energy Savings: 8,292 kWh
- Capital Cost: $6,400
- Payback: 7.72 years
**Condensate System**

S1-CND-ECM-1: Replacement of 15 HP Condensate Pump Motors with High Efficiency Equivalents and Installation of VFDs
- Energy Savings: 25,453 kWh
- Capital Cost: $24,000
- Payback: 9.43 years

S1-CND-ECM-2: Replacement of 10 HP Condensate Pump Motor with High Efficiency Equivalent and Installation of VFD
- Energy Savings: 6,592 kWh
- Capital Cost: $7,500
- Payback: 11.4 years

S1-CND-ECM-3: Replacement of Boiler EU-006 Condensate Pump Motors with High Efficiency Equivalents
- Energy Savings: 737 kWh
- Capital Cost: $4,300
- Payback: 58.3 years *(Not Cost Justifiable Based Upon Energy Savings Alone)*

**Feedwater System**

S1-FWS-ECM-1: Replacement of Boilers EU-007 to EU-011 Feedwater Pump Motors with High Efficiency Equivalents and Installation of VFDs
- Energy Savings: 53,018 kWh
- Capital Cost: $45,900
- Payback: 8.66 years

**Coal Handling System**

S1-CHS-ECM-1: Replacement of Conveyor Drive Motor with High Efficiency Equivalent
- Energy Savings: 97 kWh
- Capital Cost: $1,150
- Payback: 119 years *(Not Cost Justifiable Based Upon Energy Savings Alone)*

S1-CHS-ECM-2: Replacement of Boiler EU-007 Pulverized Blower Motor with High Efficiency Equivalent
- Energy Savings: 189 kWh
- Capital Cost: $3,200
- Payback: 169 years *(Not Cost Justifiable Based Upon Energy Savings Alone)*

S1-CHS-ECM-3: Replacement of Boiler EU-008 Pulverized Blower Motor with High Efficiency Equivalent
- Energy Savings: 38 kWh
- Capital Cost: $3,200
- Payback: 845 years *(Not Cost Justifiable Based Upon Energy Savings Alone)*
**Combustion Air System**

S1-CA-ECM-1: Replacement of Boiler EU-006 Forced Draft Fan Motor with High Efficiency Equivalent and Installation of VFD
- Energy Savings: 428,422 kWh
- Capital Cost: $112,700
- Payback: 2.63 years

S1-CA-ECM-2: Replacement of Boiler EU-007 Forced Draft Fan Motor with High Efficiency Equivalent and Installation of VFD
- Energy Savings: 8,008 kWh
- Capital Cost: $13,000
- Payback: 16.2 years *(Not Cost Justifiable Based Upon Energy Savings Alone)*

S1-CA-ECM-3: Replacement of Boiler EU-007 Over-Fire Air Fan Motor with High Efficiency Equivalent
- Energy Savings: 705 kWh
- Capital Cost: $1,150
- Payback: 16.3 years *(Not Cost Justifiable Based Upon Energy Savings Alone)*

S1-CA-ECM-4: Replacement of Boiler EU-007 Induced Draft Fan Motor with High Efficiency Equivalent and Installation of VFD
- Energy Savings: 37,957 kWh
- Capital Cost: $41,300
- Payback: 10.9 years

S1-CA-ECM-5: Replacement of Boiler EU-008 Forced Draft Fan Motor with High Efficiency Equivalent and Installation of VFD
- Energy Savings: 2,099 kWh
- Capital Cost: $8,850
- Payback: 42.2 years *(Not Cost Justifiable Based Upon Energy Savings Alone)*

S1-CA-ECM-6: Replacement of Boiler EU-008 Induced Draft Fan Motor with High Efficiency Equivalent and Installation of VFD
- Energy Savings: 3,998 kWh
- Capital Cost: $13,000
- Payback: 32.5 years *(Not Cost Justifiable Based Upon Energy Savings Alone)*

S1-CA-ECM-7: Replacement of Boiler EU-008 Baghouse ID Fan Motor with High Efficiency Equivalent and Installation of VFD
- Energy Savings: 18,952 kWh
- Capital Cost: $41,300
- Payback: 21.8 years *(Not Cost Justifiable Based Upon Energy Savings Alone)*

S1-CA-ECM-8: Replacement of Boiler EU-009 Forced Draft Fan Motor with High Efficiency Equivalent and Installation of VFD
- Energy Savings: 5,593 kWh
- Capital Cost: $11,550
- Payback: 20.7 years *(Not Cost Justifiable Based Upon Energy Savings Alone)*

S1-CA-ECM-9: Replacement of Boiler EU-009 Induced Draft Fan Motor with High Efficiency Equivalent and Installation of VFD
- Energy Savings: 30,387 kWh
- Capital Cost: $22,100
- Payback: 7.27 years
S1-CA-ECM-10: Replacement of Boiler EU-009 Baghouse ID Fan Motor with High Efficiency Equivalent and Installation of VFD
⇒ Energy Savings: 23,589 kWh
⇒ Capital Cost: $26,700
⇒ Payback: 11.3 years

S1-CA-ECM-11: Replacement of Boiler EU-010 Forced Draft Fan Motor with High Efficiency Equivalent and Installation of VFD
⇒ Energy Savings: 9,693 kWh
⇒ Capital Cost: $17,200
⇒ Payback: 17.7 years (Not Cost Justifiable Based Upon Energy Savings Alone)

S1-CA-ECM-12: Replacement of Boiler EU-010 Induced Draft Fan Motor with High Efficiency Equivalent and Installation of VFD
⇒ Energy Savings: 19,859 kWh
⇒ Capital Cost: $26,700
⇒ Payback: 13.4 years

S1-CA-ECM-13: Replacement of Boiler EU-010 Baghouse ID Fan Motor with High Efficiency Equivalent and Installation of VFD
⇒ Energy Savings: 19,859 kWh
⇒ Capital Cost: $26,700
⇒ Payback: 13.4 years

S1-CA-ECM-14: Replacement of Boiler EU-011 Forced Draft Fan Motor with High Efficiency Equivalent and Installation of VFD
⇒ Energy Savings: 84,070 kWh
⇒ Capital Cost: $17,200
⇒ Payback: 2.05 years

**Fuel Oil System**

S1-FOS-ECM-1: Replacement of Fuel Oil Pump Motors with High Efficiency Equivalents and Installation of VFDs
⇒ Energy Savings: 1,378 kWh
⇒ Capital Cost: $19,700
⇒ Payback: 143 years (Not Cost Justifiable Based Upon Energy Savings Alone)

**Ash Handling System**

S1-AHS-ECM-1: Replacement of Boiler EU-010 Reverse Air Fan Motor with High Efficiency Equivalent
⇒ Energy Savings: 708 kWh
⇒ Capital Cost: $1,800
⇒ Payback: 25.4 years (Not Cost Justifiable Based Upon Energy Savings Alone)
Cooling Water

S1-CWS-ECM-1: Replacement of Cooling Water Pump Motors with High Efficiency Equivalents

⇒ Energy Savings: 4,989 kWh
⇒ Capital Cost: $1,600
⇒ Payback: 3.21 years

ENERGY CONSERVATION INITIATIVES (ECI’S)

The implementation of this one (1) aforementioned SourceOne ECI’s should result in the following energy savings:

Combustion Air System

ECI-1: Replacement of EU-011 Jackshaft with Independent Combustion Control Positioning Mechanisms

⇒ This ECI is an upgrade of the combustion air and fuel system on boiler EU-011. It includes the removal of an existing jackshaft (combustion control positioning mechanism) and the installation of automatic flow control valves.
⇒ Energy Savings: 4,000 MMBtu/yr

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 952 Commonwealth Ave, Saint Paul, MN. The plant was constructed in 1955 and is a dedicated steam supplier to the St. Paul 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 campus.

There are eight (8) boilers at the facility, six (6) of which are operational and produce steam, and two (2) of which have been officially decommissioned. Natural gas, coal, and oil 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 150 psig (saturated). Total steam generation capacity is approximately 660 MMBtu/hr, which equates to almost 550 Mlbs/hr at the steam distribution pressure. The present maximum steam requirements of the University could not be obtained from the documentation available. Table 1: Major Energy Consuming Boiler System Equipment, 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 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.”

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<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>40 HP; 460 V; 92.4% Efficient</td>
</tr>
<tr>
<td>2</td>
<td>Compressed Air System</td>
<td>Air Compressor</td>
<td>C-302, C-304</td>
<td>60 HP; 460 V; Variable Speed</td>
</tr>
<tr>
<td>3</td>
<td>Condensate System</td>
<td>Condensate Pump</td>
<td>CP-1, 2, 3</td>
<td>15 HP; 460 V; 91% Efficient</td>
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<tr>
<td>4</td>
<td>Condensate System</td>
<td>Condensate Pump</td>
<td>CP-4</td>
<td>10 HP; 460 V; Prem Efficient</td>
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<tr>
<td>5</td>
<td>Condensate System</td>
<td>Condensate Pump</td>
<td>(EU-006) CP-A, B</td>
<td>40 HP; 460 V; 91% Efficient</td>
</tr>
<tr>
<td>6</td>
<td>Feedwater System</td>
<td>Boiler Feedwater Pump</td>
<td>(EU-006) P-131A, 131B</td>
<td>300 HP; 460 V; 96.2% Efficient</td>
</tr>
<tr>
<td>7</td>
<td>Feedwater System</td>
<td>Boiler Feedwater Pump</td>
<td>(EU-006) P-131A, 131B</td>
<td>300 HP; 460 V; 96.2% Efficient</td>
</tr>
<tr>
<td>8</td>
<td>Coal System</td>
<td>Conveyer Drive Motor</td>
<td>#1</td>
<td>20 HP; 440 V</td>
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<tr>
<td>9</td>
<td>Coal System</td>
<td>Pulverized Blower Motor</td>
<td>(EU-007) B-311</td>
<td>60 HP; 440 V</td>
</tr>
<tr>
<td>10</td>
<td>Coal System</td>
<td>Pulverized Blower Motor</td>
<td>(EU-008) B-312</td>
<td>60 HP; 440 V</td>
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<tr>
<td>11</td>
<td>Coal System</td>
<td>Over-Fire Air Fan</td>
<td>(EU-010)</td>
<td>25 HP; 460 V; 89.5% Efficient</td>
</tr>
<tr>
<td>12</td>
<td>Combustion Air System</td>
<td>Forced Draft Fan</td>
<td>(EU-007)</td>
<td>20 HP; 460 V</td>
</tr>
<tr>
<td>13</td>
<td>Combustion Air System</td>
<td>Forced Draft Fan</td>
<td>(EU-008)</td>
<td>20 HP; 460 V</td>
</tr>
<tr>
<td>14</td>
<td>Combustion Air System</td>
<td>Forced Draft Fan</td>
<td>(EU-006) B-231</td>
<td>600 HP; 460 V; 95.4% Efficient</td>
</tr>
<tr>
<td>15</td>
<td>Combustion Air System</td>
<td>Forced Draft Fan</td>
<td>(EU-010) B-361</td>
<td>60 HP; 460 V; 91.7% Efficient</td>
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<td>16</td>
<td>Combustion Air System</td>
<td>Forced Draft Fan</td>
<td>(EU-011) B-371</td>
<td>60 HP; 460 V; 93.6% Efficient</td>
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<tr>
<td>17</td>
<td>Combustion Air System</td>
<td>Forced Draft Fan</td>
<td>(EU-007)</td>
<td>40 HP; 440 V</td>
</tr>
<tr>
<td>18</td>
<td>Combustion Air System</td>
<td>Forced Draft Fan</td>
<td>(EU-008)</td>
<td>40 HP; 440 V</td>
</tr>
<tr>
<td>19</td>
<td>Combustion Air System</td>
<td>Forced Draft Fan</td>
<td>(EU-009) B-352</td>
<td>100 HP; 440 V; 77% Efficient</td>
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<td>20</td>
<td>Combustion Air System</td>
<td>Induced Draft Fan</td>
<td>(EU-007) B-362</td>
<td>125 HP; 460 V</td>
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<tr>
<td>21</td>
<td>Combustion Air System</td>
<td>Baghouse ID Fan</td>
<td>(EU-007) B-314</td>
<td>200 HP; 480 V</td>
</tr>
<tr>
<td>22</td>
<td>Combustion Air System</td>
<td>Baghouse ID Fan</td>
<td>(EU-008) B-324</td>
<td>200 HP; 460 V</td>
</tr>
<tr>
<td>23</td>
<td>Combustion Air System</td>
<td>Baghouse ID Fan</td>
<td>(EU-009) B-354</td>
<td>125 HP; 460 V</td>
</tr>
<tr>
<td>24</td>
<td>Combustion Air System</td>
<td>Baghouse ID Fan</td>
<td>(EU-010) B-364</td>
<td>125 HP; 460 V</td>
</tr>
<tr>
<td>25</td>
<td>Fuel Oil System</td>
<td>Fuel Oil Pump</td>
<td>FOP-A, B</td>
<td>25 HP; 208 V</td>
</tr>
<tr>
<td>26</td>
<td>Ash Handling System</td>
<td>Reverse Air Fan</td>
<td>(EU-009)</td>
<td>30 HP; 460 V; 94.1% Efficient</td>
</tr>
<tr>
<td>27</td>
<td>Ash Handling System</td>
<td>Reverse Air Fan</td>
<td>(EU-010)</td>
<td>30 HP; 460 V</td>
</tr>
<tr>
<td>28</td>
<td>Cooling Water System</td>
<td>Cooling Water Pump</td>
<td>CWP-1, 2</td>
<td>10 HP; 480 V</td>
</tr>
<tr>
<td>29</td>
<td>Cooling Water System</td>
<td>Cooling Water Pump</td>
<td>CWP-1, 2</td>
<td>10 HP; 480 V</td>
</tr>
</tbody>
</table>
City Water/ Raw Water

Two (2) raw water feeds enter the plant and are split to supply the Fire Water, Cooling Water, and Make-Up Water Systems.

Water Treatment System

The Water Treatment System (Figure 1) consists of two (2) trains of softeners and dealkalization tanks but only one train is in service at all times. From softening, the water is sent through a shell and tube heat exchanger (Figure 2) to the condensate tank via a regulating valve based on tank level. This heat exchanger uses heated cooling water return to preheat the softened water before the cooling water is returned to the cooling water tank (Figure 3).
Condensate

Condensate from the University and 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 (Figure 5). It is then pumped using a total of six (6) Condensate Pumps. Four (4) of the pumps (P-1,2,3&4) (Figure 7) are utilized for Boilers EU-007 to EU-011 while two (2) of the pumps (P-A&B) (Figure 8) are utilized for Boiler EU-006. The level in the condensate tank is maintained at a constant level by a local controller. A control valve on the discharge line of pumps P-1,2,3&4 controls the flow to deaerator (DH-101) which feeds Boilers EU-007 to EU-011. Surplus flow is returned to the Condensate Tank through a recirculation line. The Boiler No. 8 Moore Control system controls the flow to the Deaerator (DH-102) which is dedicated to Boiler EU-006. All condensate pumps are started and stopped manually.
Feedwater System

From Deaerator D-101, four (4) feedwater pumps (BFP-1,2,3&4) send feedwater to Boilers No. EU-007, EU-008, EU-009, EU-010, and EU-011. BFP-1 is a steam turbine driven pump (Figure 9) and the remaining are electric, constant-speed pumps (Figure 10). BFP-4 is VFD controlled and is typically in service for loads up to 65 Mlbs/hr. Over this load, as is the case with multiple boilers running, additional pumps come on-line. Surplus flow is recirculated back to the deaerator.

![Figure 9: Steam Turbine Driven Feedwater Pump (BFP-1)](image)

![Figure 10: Feedwater Pumps (BFP-1,2,3&4)](image)

![Figure 11: Deaerator DH-101 for EU-007 to EU-011](image)

![Figure 12: Deaerator DH-102 for EU-006](image)

Boilers

The plant has six (6) boilers that burn various fuel sources including natural gas, #2 fuel oil, coal, and wood. There are two high pressure boilers and two medium pressure boilers in the plant. All boilers produce steam that is either sent to the campus directly or desuperheated and then sent to the site. The steam is used for heating, steam-absorption chillers (air conditioning) and other process needs in the University. The boilers have several names each but are referred to by their emission unit numbers from the EPA and DEP documents (EU-006, EU-007, EU-008, EU-009, EU-010, and EU-011). These boiler names will be used throughout the report.
EU-006

Boiler EU-006 (Boiler No. 8, SG-231) is a package boiler and is capable of burning natural gas and No. 2 fuel oil. It has a steam discharge pressure of 256 psig and a temperature of 462 deg F which is attained through a superheater. This is the only boiler that produces superheated steam and two desuperheaters reduce the temperature and a pressure reducing control station reduces the pressure to allow the steam to be compatible with the existing system. The maximum steam flow is 250,000 lbs/hr when burning natural gas and 225,000 lbs/hr when burning No. 2 fuel oil. This boiler utilizes either air or steam to atomize oil. Air atomization is used for a cold startup on oil with no steam in the steam. A forced draft fan supplies combustion air to maintain positive furnace pressure in the boiler and an exhaust damper is used to control back pressure. This boiler is equipped with an oxygen analyzer which is used to regulate fuel and air ratios for optimally efficient combustion.

Figure 13: EU-006 Feedwater Pump (P-131A)

Figure 14: EU-006 Forced Draft Fan and Controls

EU-007

Boiler EU-007 (Boiler No. 1) is a water tube boiler and is capable of burning pulverized coal or natural gas and incorporates oil pilots. It is identical to EU-008. It has a maximum design pressure of 350 psig but is operated at 150 psig and 366 deg F. The maximum steam flow of the boiler is 35,000 lbs/hr. This boiler incorporates oil pilots for flame stabilization and carbon monoxide control during
coal light off. The flue gases pass through a common baghouse with Boiler EU-008 for particulate emission control. This boiler utilizes a forced draft fan (Figure 15) and an induced draft fan to control furnace pressure of (-0.1) in WC. The controls for this boiler function in manual mode only.

![Figure 15: EU-007 Forced Draft Fan](image)

**EU-008**

Boiler EU-008 (Boiler No. 2) is a water tube boiler and is capable of burning pulverized coal or natural gas and incorporates oil pilots. It is identical to EU-007. It has a maximum design pressure of 350 psig but is operated at 150 psig and 366 deg F. The maximum steam flow of the boiler is 35,000 lbs/hr. This boiler incorporates oil pilots for flame stabilization and carbon monoxide control during coal light off. The flue gases pass through a common baghouse with Boiler EU-007 for particulate emission control. This boiler utilizes a forced draft fan (Figure 16) and an induced draft fan to control furnace pressure of -0.1 in WC. The controls for this boiler function in manual mode only.

![Figure 16: EU-008 Forced Draft Fan](image)
EU-009 (Boiler No. 5) is a D-type stoker boiler (Figure 17) and is capable of burning coal, natural gas, and No. 2 fuel oil. It has a maximum design pressure of 350 psig but is operated at 150 psig and 366 deg F. The maximum steam flow of the boiler is 70,000 lbs/hr. The oil guns employ steam atomization for efficient combustion and natural gas pilots are provided for flame stabilization during light off. This boiler utilizes a forced draft fan (Figure 18) and an induced draft fan to control furnace pressure between -0.025 to -0.05 in WC. An over-fire air fan (Figure 19) is used to supplement the furnace with additional air to reduce NOx emissions. A dedicated baghouse for this boiler removes particulate from the flue gas.

Figure 17: EU-009 Boiler Front

Figure 18: EU-009 Forced Draft Fan

Figure 19: EU-009 Over-Fire Air Fan
EU-010

Boiler EU-010 (Boiler No. 6) is a D-type stoker boiler (Figure 20) and is capable of burning coal, natural gas, and No. 2 fuel oil. It has a maximum design pressure of 350 psig but is operated at 150 psig and 366 deg F. The maximum steam flow of the boiler is 70,000 lbs/hr. The oil guns employ steam atomization for efficient combustion and natural gas pilots are provided for flame stabilization during light off. This boiler utilizes a forced draft fan (Figure 21) and an induced draft fan to control furnace pressure between -0.025 to -0.05 in WC. A dedicated baghouse for this boiler removes particulate from the flue gas.

Figure 20: EU-010 Boiler Front

Figure 21: EU-010 Forced Draft Fan

Figure 22: EU-010 Over-Fire Air Fan
EU-011

Boiler EU-011 (Figure 23) is a package boiler and is capable of burning natural gas or No. 2 fuel oil. It has a maximum design pressure of 250 psig but is operated at 150 psig and 366 deg F. The maximum steam flow of the boiler is 82,000 lbs/hr. The natural gas burner is a high efficiency, low NOx type and the oil guns also employ steam atomization for efficient combustion. This boiler utilizes a forced draft fan (Figure 24), an exhaust damper (Figure 25), and an O2 trim system to control furnace pressure and combustion efficiency. Fuel to air ratio is governed by a jackshaft control. This boiler also has an electronic control system which is part of a programmable panel mounted operator control station.

Figure 23: EU-011 Boiler Front

Figure 24: EU-006 Forced Draft Fan

Figure 25: EU-006 Exhaust Damper Control
Boilers #3 and #4

These boilers have been officially decommissioned and retired in place.

Controls

Once running, all boilers are capable of operating automatically either at a fixed steam output or to follow the steam demand. There is no Distributed Control System (DCS) and the boiler controls are not interconnected. However, boiler master controls, which are local to each boiler, are connected to the main plant master. The local boiler master controls are shown in Figures 26, 27, and 28. Boiler EU-006 balance of plant control panel is shown in Figure 29 and boiler monitor screen shots are shown in Figures 30, 31, and 32.

Figure 26: Boilers EU-007 & EU-008 Control Panel

Figure 27: EU-009 Boiler Front
Figure 28: EU-010 Boiler Front

Figure 29: EU-006 Control Room Balance of Plant Panel

Figures 30, 31, and 32: EU-006 Monitoring System Screen Shots
Baghouse System

The plant uses three (3) baghouse systems to control particulate emission. Two (2) separate baghouses are used for Boilers EU-009 and EU-010 and a single baghouse is used for Boilers EU-007 and EU-008. Each baghouse utilizes a reverse air fan (Figure 33 and Figure 34) to remove flue gas particulate once it has been collected by the bag filters.

Blowdown

Blowdown lines from EU-007 to EU-011 are sent to a common header (Figure 35) before being sent to a blowdown tank. At the blowdown tank, it is quenched and then sent to the sewer. Continuous blowdown is manually set based on the water treatment results taken from the blowdown sampling area (Figure 36). Boiler EU-006 has its own blowdown system with a blowdown tank and quench water prior to sending it to sewer (Figure 37). Total dissolved solids are maintained on all boilers between 1500 and 2000 ppm in the boiler drum using both intermittent and continuous blowdown.
Desuperheaters

As mentioned above, to reduce the temperature of the superheated steam produced by EU-006, two desuperheaters are utilized: one at the boiler outlet and one after the pressure reducing control station prior to sendout to the University.

Steam Distribution

Steam is produced at two pressures (265 psig and 150 psig) but steam distributed to the University must remain at or below 150 psig and 366 deg F (saturated steam). The plant uses a pressure reducing station (Figure 40) to reduce the 265 psig high pressure steam down to 150 psig. As mentioned above, the steam feeds various processes including heating, steam-absorption chillers (air conditioning) and other process needs at the University. A primary steam tunnel connects the plant to the University and several other branch tunnels feed separate areas from there. Steam distributed to the University and condensate return rate are both controlled and monitored to track consumption and losses.
There are several steam drives within the plant that originally drove combustion air fans but most of these steam drive systems are now decoupled. The drives run on 150 psig steam and discharge steam at 20 psig. The site has very little use for 20 psig steam and, in order to increase steam cycle efficiency, has disconnected the drives.

**Figure 40: Pressure Reducing Station PV-9251**

**Fuel Systems**

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

**Coal System**

The coal system consists of an outdoor coal pile, conveyor, crusher unit, a track-mounted lorry (Figure 41), and coal bunkers for each of the coal fired boilers. The coal pile is located on the south side of the plant which typically contains sufficient fuel to supply the energy needs of the site for one (1) year. Heavy equipment operators use conventional bulldozers to push coal over a grating area while plant staff operates the conveyor system. The coal then follows the conveyor system to the bunkers and the boilers. Boilers EU-007, EU-008, EU-009, and EU-010 are capable of burning coal.

**Figure 41: Track Mounted Lorry**
Natural Gas System

Natural gas enters the site at a constant incoming supply pressure of 26 psig. It enters the site at the southwest corner and splits into four (4) lines to serve the boilers at different pressures. All boilers are capable of burning natural gas. Boiler EU-006 is supplied with 15 psig, Boilers EU-007 and EU-008 are supplied with 12 psig, Boilers EU-009 and EU-010 are supplied with 17 psig, and Boiler EU-011 is supplied with 11 psig. Each boiler has a local isolation valve which is kept closed except when the boiler is in service.

Fuel Oil System

The fuel oil system consists of two separate No. 2 fuel oil storage areas: the Day Tank fuel oil system and the Large Tank fuel oil system. These systems are connected to each other allowing oil to be pumped from one tank to another. Each system also has two (2) local pumps (Figure 42) that send fuel oil to any of the boilers in the plant (Figure 43). The Day Tank fuel oil system consists of two (2) 35,000 gallon storage tanks located in an earthen berm at the southwest corner of the plant. The Large Tank fuel oil system utilizes a 500,000 gallon storage tank located above ground just southeast of the plant. Boiler EU-006 has a fuel oil supply pressure of 175 psig. All other boilers have a supply pressure of 130 psig.
Compressed Air System

St. Paul utilizes four (4) water cooled screw compressors (Figure 45 and Figure 46) to deliver air at 105 psig. A dual chamber, heaterless desiccant type dryer runs automatic timed cycles between drying and reactivating periods. Following the air dryer (Figure 44), air is sent to a main receiver tank located next to the compressors in the heating plant. Air is then distributed to smaller receiver tanks to feed loads around the plant.

![Figure 44: Compressed Air System (40 HP Compressors and Desiccant Dryers)](image)

Figure 45: 40 HP Air Compressors  
Figure 46: 60 HP Air Compressors

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 Saint Paul plant is X-Cel Energy. The electric Bill of the Saint Paul plant includes coal processing. The plant consumption is metered and invoiced by the University of Minnesota. A rate around 10 cents per kWh is quite common. 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>Month</th>
<th>Import Consumption (kWh)</th>
<th>Electrical Import Cost ($)</th>
<th>Average Cost ($/kWh)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jan-12</td>
<td>313,237</td>
<td>$31,040</td>
<td>$0.099</td>
</tr>
<tr>
<td>Feb-12</td>
<td>305,203</td>
<td>$30,243</td>
<td>$0.099</td>
</tr>
<tr>
<td>Mar-12</td>
<td>222,875</td>
<td>$22,085</td>
<td>$0.099</td>
</tr>
<tr>
<td>Apr-12</td>
<td>88,912</td>
<td>$8,810</td>
<td>$0.099</td>
</tr>
<tr>
<td>May-12</td>
<td>142,015</td>
<td>$14,163</td>
<td>$0.100</td>
</tr>
<tr>
<td>Jun-12</td>
<td>178,887</td>
<td>$17,728</td>
<td>$0.099</td>
</tr>
<tr>
<td>Jul-12</td>
<td>145,514</td>
<td>$14,419</td>
<td>$0.099</td>
</tr>
<tr>
<td>Aug-12</td>
<td>144,761</td>
<td>$14,344</td>
<td>$0.099</td>
</tr>
<tr>
<td>Sep-12</td>
<td>170,980</td>
<td>$16,943</td>
<td>$0.099</td>
</tr>
<tr>
<td>Oct-12</td>
<td>160,000</td>
<td>$15,865</td>
<td>$0.099</td>
</tr>
<tr>
<td>Nov-12</td>
<td>267,500</td>
<td>$26,509</td>
<td>$0.099</td>
</tr>
<tr>
<td>Dec-12</td>
<td>398,164</td>
<td>$39,458</td>
<td>$0.099</td>
</tr>
<tr>
<td>Total</td>
<td>2,538,048</td>
<td>$251,608</td>
<td>$0.099</td>
</tr>
</tbody>
</table>

Table 2: Saint Paul Plant 2012 Electricity Cost and Rates

<table>
<thead>
<tr>
<th>Month</th>
<th>Import Consumption (kWh)</th>
<th>Electrical Import Cost ($)</th>
<th>Average Cost ($/kWh)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jan-13</td>
<td>405,221</td>
<td>$40,157</td>
<td>$0.099</td>
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<tr>
<td>Feb-13</td>
<td>423,170</td>
<td>$41,936</td>
<td>$0.099</td>
</tr>
<tr>
<td>Mar-13</td>
<td>374,318</td>
<td>$37,095</td>
<td>$0.099</td>
</tr>
<tr>
<td>Apr-13</td>
<td>209,501</td>
<td>$20,762</td>
<td>$0.099</td>
</tr>
<tr>
<td>May-13</td>
<td>156,962</td>
<td>$15,555</td>
<td>$0.099</td>
</tr>
<tr>
<td>Jun-13</td>
<td>171,672</td>
<td>$17,013</td>
<td>$0.099</td>
</tr>
<tr>
<td>Jul-13</td>
<td>165,705</td>
<td>$14,899</td>
<td>$0.090</td>
</tr>
<tr>
<td>Aug-13</td>
<td>170,582</td>
<td>$16,905</td>
<td>$0.099</td>
</tr>
<tr>
<td>Sep-13</td>
<td>140,143</td>
<td>$13,888</td>
<td>$0.099</td>
</tr>
<tr>
<td>Oct-13</td>
<td>169,792</td>
<td>$16,826</td>
<td>$0.099</td>
</tr>
<tr>
<td>Nov-13</td>
<td>266,060</td>
<td>$26,367</td>
<td>$0.099</td>
</tr>
<tr>
<td>Dec-13</td>
<td>373,741</td>
<td>$43,103</td>
<td>$0.115</td>
</tr>
<tr>
<td>Total</td>
<td>3,026,867</td>
<td>$304,505</td>
<td>$0.101</td>
</tr>
</tbody>
</table>

Table 3: Saint Paul Plant 2013 Electricity Cost and Rates
X-Cel Energy provides natural gas for the Saint Paul plant. The consumption and cost for 2013 can be seen in Table 4 below.

<table>
<thead>
<tr>
<th>Month</th>
<th>Consumption (MMBTU)</th>
<th>Total Cost ($)</th>
<th>Average Cost ($/MMBTU)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jan-13</td>
<td>84,025</td>
<td>$437,659</td>
<td>$5.21</td>
</tr>
<tr>
<td>Feb-13</td>
<td>70,534</td>
<td>$370,336</td>
<td>$5.25</td>
</tr>
<tr>
<td>Mar-13</td>
<td>68,080</td>
<td>$357,467</td>
<td>$5.25</td>
</tr>
<tr>
<td>Apr-13</td>
<td>53,881</td>
<td>$274,930</td>
<td>$5.10</td>
</tr>
<tr>
<td>May-13</td>
<td>31,716</td>
<td>$162,027</td>
<td>$5.11</td>
</tr>
<tr>
<td>Jun-13</td>
<td>21,702</td>
<td>$111,019</td>
<td>$5.12</td>
</tr>
<tr>
<td>Jul-13</td>
<td>18,955</td>
<td>$99,718</td>
<td>$5.26</td>
</tr>
<tr>
<td>Aug-13</td>
<td>17,262</td>
<td>$90,854</td>
<td>$5.26</td>
</tr>
<tr>
<td>Sep-13</td>
<td>19,351</td>
<td>$101,792</td>
<td>$5.26</td>
</tr>
<tr>
<td>Oct-13</td>
<td>38,112</td>
<td>$200,019</td>
<td>$5.25</td>
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<tr>
<td>Nov-13</td>
<td>58,412</td>
<td>$315,066</td>
<td>$5.39</td>
</tr>
<tr>
<td>Dec-13</td>
<td>81,665</td>
<td>$440,973</td>
<td>$5.40</td>
</tr>
<tr>
<td>Total</td>
<td>563,695</td>
<td>$2,961,860</td>
<td>$5.25</td>
</tr>
</tbody>
</table>

Table 4: Saint Paul Plant Natural Gas Usage and Rates

River Trading Company is the coal supplier for the Saint Paul Plant and the average cost of coal per ton is $75.83. The consumption data can be seen for 2013 in Table 5 below.

<table>
<thead>
<tr>
<th>Month</th>
<th>Consumption (Tons)</th>
<th>Total Cost ($)</th>
<th>Average Cost ($/Ton)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jan-13</td>
<td>NA</td>
<td>NA</td>
<td>NA</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>196.3</td>
<td>$14,886</td>
<td>$75.83</td>
</tr>
<tr>
<td>Total</td>
<td>196</td>
<td>$14,886</td>
<td>$75.83</td>
</tr>
</tbody>
</table>

Table 5: Saint Paul Plant Coal Usage and Rates
Yocum Oil is the #2 Fuel Oil supplier for the Saint Paul plant. The Saint Paul Plant has one (1) 500,000 gallon storage tank and two (2) 35,000 gallon day-tanks. On average, the cost of #2 Fuel Oil is $2.00 per gallon. Fuel oil is used as a pilot fuel prior to burning coal. 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>NA</td>
<td>NA</td>
<td>NA</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>4,085</td>
<td>$8,186</td>
<td>$2.00</td>
</tr>
<tr>
<td>Total</td>
<td>4,085</td>
<td>$8,186</td>
<td>$2.00</td>
</tr>
</tbody>
</table>

Table 6: Saint Paul Plant #2 Fuel Oil Usage and Rates

As can be seen from the data above and Figure 47, the consumption of #2 Fuel Oil and Coal is only a small portion of the total fuel consumed by the plant.
IV. STEAM SENDOUT PRODUCTION

Table 7 below presents the 2013 steam production values for the St. Paul 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. 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-006 (Mlbs)</th>
<th>EU-007 (Mlbs)</th>
<th>EU-008 (Mlbs)</th>
<th>EU-009 (Mlbs)</th>
<th>EU-010 (Mlbs)</th>
<th>EU 011 (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>63,787</td>
<td>0</td>
<td>295</td>
<td>2,578</td>
<td>352</td>
<td>2,581</td>
<td>(6,731)</td>
<td>69,593</td>
<td>62,862</td>
<td>62,933</td>
</tr>
<tr>
<td>Feb-13</td>
<td>57,772</td>
<td>42</td>
<td>0</td>
<td>1,238</td>
<td>269</td>
<td>62</td>
<td>(6,019)</td>
<td>59,383</td>
<td>53,364</td>
<td>53,294</td>
</tr>
<tr>
<td>Mar-13</td>
<td>55,617</td>
<td>0</td>
<td>0</td>
<td>8</td>
<td>1,088</td>
<td>0</td>
<td>(5,785)</td>
<td>56,713</td>
<td>50,928</td>
<td>51,160</td>
</tr>
<tr>
<td>Apr-13</td>
<td>783</td>
<td>0</td>
<td>3,207</td>
<td>11,241</td>
<td>9,697</td>
<td>21,289</td>
<td>(8,527)</td>
<td>46,217</td>
<td>37,691</td>
<td>37,883</td>
</tr>
<tr>
<td>May-13</td>
<td>0</td>
<td>0</td>
<td>2,510</td>
<td>0</td>
<td>130</td>
<td>23,438</td>
<td>(3,207)</td>
<td>26,078</td>
<td>22,871</td>
<td>21,134</td>
</tr>
<tr>
<td>Jun-13</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>6,171</td>
<td>11,429</td>
<td>17,600</td>
<td>(2,385)</td>
<td>17,600</td>
<td>15,215</td>
<td>13,892</td>
</tr>
<tr>
<td>Jul-13</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>15,399</td>
<td>(1,985)</td>
<td>15,399</td>
<td>13,414</td>
<td>12,602</td>
<td></td>
</tr>
<tr>
<td>Aug-13</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>13,925</td>
<td>(1,685)</td>
<td>13,925</td>
<td>12,241</td>
<td>12,098</td>
<td></td>
</tr>
<tr>
<td>Sep-13</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>15,413</td>
<td>(1,287)</td>
<td>15,413</td>
<td>14,294</td>
<td>13,497</td>
<td></td>
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<tr>
<td>Oct-13</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>26,593</td>
<td>(3,564)</td>
<td>26,593</td>
<td>30,906</td>
<td>27,342</td>
<td>25,597</td>
</tr>
<tr>
<td>Nov-13</td>
<td>7,016</td>
<td>7,964</td>
<td>1,711</td>
<td>3,887</td>
<td>0</td>
<td>26,751</td>
<td>(5,113)</td>
<td>47,329</td>
<td>42,216</td>
<td>38,762</td>
</tr>
<tr>
<td>Dec-13</td>
<td>67,550</td>
<td>0</td>
<td>1,004</td>
<td>1,247</td>
<td>1,017</td>
<td>897</td>
<td>(6,031)</td>
<td>71,715</td>
<td>65,684</td>
<td>60,450</td>
</tr>
<tr>
<td>Total</td>
<td>252,525</td>
<td>12,319</td>
<td>8,727</td>
<td>20,367</td>
<td>18,724</td>
<td>157,777</td>
<td>(52,318)</td>
<td>470,439</td>
<td>418,121</td>
<td>403,304</td>
</tr>
<tr>
<td>Total %</td>
<td>53.7%</td>
<td>2.62%</td>
<td>1.86%</td>
<td>4.33%</td>
<td>3.98%</td>
<td>33.5%</td>
<td>-11.1%</td>
<td>100%</td>
<td>88.9%</td>
<td>85.7%</td>
</tr>
</tbody>
</table>

Table 7: 2013 Saint Paul 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>EU006/SV005</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>St. Paul Boiler 8 SG231</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>EU007/SV006</td>
<td>Less than or equal to 20% except (1) six minute period per hour up to 60%</td>
<td>Less than or equal to 1.15 lb/MMBtu based on fuel sampling</td>
<td>Not Applicable</td>
</tr>
<tr>
<td>St. Paul Boiler 1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>EU008/SV006</td>
<td>Less than or equal to 20% except (1) six minute period per hour up to 60%</td>
<td>Less than or equal to 1.15 lb/MMBtu based on fuel sampling</td>
<td>Not Applicable</td>
</tr>
<tr>
<td>St. Paul Boiler 2</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>EU009/SV006</td>
<td>Less than or equal to 20% except (1) six minute period per hour up to 60%</td>
<td>Less than or equal to 1.15 lb/MMBtu based on fuel sampling</td>
<td>Not Applicable</td>
</tr>
<tr>
<td>St. Paul Boiler 5</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>EU010/SV006</td>
<td>Less than or equal to 20% except (1) six minute period per hour up to 60%</td>
<td>Less than or equal to 1.15 lb/MMBtu based on fuel sampling</td>
<td>Not Applicable</td>
</tr>
<tr>
<td>St. Paul Boiler 6</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>EU011/SV/007</td>
<td>Less than or equal to 20% except (1) six minute period per hour up to 27%</td>
<td>Not Applicable</td>
<td>Not Applicable</td>
</tr>
<tr>
<td>St. Paul Boiler 7</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>EU006/SV005</td>
<td>No Data Available</td>
<td>Not Applicable</td>
<td>(Total) 303,030 MMBtu/yr Limit: 21.2 tons/yr</td>
</tr>
<tr>
<td>St. Paul Boiler 8 SG231</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>EU007/SV006</td>
<td>No Data Available</td>
<td>(Total) 14,782 MMBtu/yr Limit: 8.5 tons/yr</td>
<td>Not Applicable</td>
</tr>
<tr>
<td>St. Paul Boiler 1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>EU008/SV006</td>
<td>No Data Available</td>
<td>(Total) 10,472 MMBtu/yr Limit: 6.02 tons/yr</td>
<td>Not Applicable</td>
</tr>
<tr>
<td>St. Paul Boiler 2</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>EU009/SV006</td>
<td>No Data Available</td>
<td>(Total) 24,440 MMBtu/yr Limit: 14.1 tons/yr</td>
<td>Not Applicable</td>
</tr>
<tr>
<td>St. Paul Boiler 5</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>EU010/SV006</td>
<td>No Data Available</td>
<td>(Total) 22,460 MMBtu/yr Limit: 12.9 tons/yr</td>
<td>Not Applicable</td>
</tr>
<tr>
<td>St. Paul Boiler 6</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>EU011/SV/007</td>
<td>No Data Available</td>
<td>Not Applicable</td>
<td>Not Applicable</td>
</tr>
<tr>
<td>St. Paul Boiler 7</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>Saint Paul Plant 2013 Total Emissions (Tons/Yr)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>NOx</td>
</tr>
<tr>
<td>EU 006</td>
<td>14.60</td>
</tr>
<tr>
<td>EU 007</td>
<td>0.70</td>
</tr>
<tr>
<td>EU 008</td>
<td>0.60</td>
</tr>
<tr>
<td>EU 009</td>
<td>1.50</td>
</tr>
<tr>
<td>EU 010</td>
<td>1.40</td>
</tr>
<tr>
<td>EU 011</td>
<td>9.70</td>
</tr>
<tr>
<td><strong>Total Facility Emissions</strong></td>
<td><strong>28.50</strong></td>
</tr>
</tbody>
</table>

Table 10: Total Facility Emissions

<table>
<thead>
<tr>
<th>Emission Unit No.</th>
<th>Saint Paul Plant 2013 Natural Gas Emissions (Tons/Yr)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>NOx</td>
</tr>
<tr>
<td>EU 006</td>
<td>14.56</td>
</tr>
<tr>
<td>EU 007</td>
<td>0.74</td>
</tr>
<tr>
<td>EU 008</td>
<td>0.35</td>
</tr>
<tr>
<td>EU 009</td>
<td>1.21</td>
</tr>
<tr>
<td>EU 010</td>
<td>1.15</td>
</tr>
<tr>
<td>EU 011</td>
<td>9.66</td>
</tr>
<tr>
<td><strong>Total Facility Emissions</strong></td>
<td><strong>27.67</strong></td>
</tr>
</tbody>
</table>

Table 11: Total Facility Natural Gas Emissions

<table>
<thead>
<tr>
<th>Emission Unit No.</th>
<th>Saint Paul Plant 2013 Subbituminous Coal Emissions (Tons/Yr)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>NOx</td>
</tr>
<tr>
<td>EU 006</td>
<td>NA</td>
</tr>
<tr>
<td>EU 007</td>
<td>NA</td>
</tr>
<tr>
<td>EU 008</td>
<td>0.26</td>
</tr>
<tr>
<td>EU 009</td>
<td>0.27</td>
</tr>
<tr>
<td>EU 010</td>
<td>0.27</td>
</tr>
<tr>
<td>EU 011</td>
<td>NA</td>
</tr>
<tr>
<td><strong>Total Facility Emissions</strong></td>
<td><strong>0.80</strong></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 14: 2013 Saint Paul Plant Boiler Operating Hours
VI. PM/CM/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:

- Annual Cleaning and Inspection of Boilers (EU-006, EU-007, EU-008, EU-009, EU-010, EU-011)
  - 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 Saint Paul 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 Saint Paul Plant are logged annually on a budget. All maintenance activities are reported in the MP2 program. Recent repairs to the site (Completed, Ongoing, and Quoted) include the following:

<table>
<thead>
<tr>
<th>Item</th>
<th>Status</th>
<th>Completion Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>Replace UPS on EU-006 (SG-231, Boiler #8)</td>
<td>Completed</td>
<td>Oct-13</td>
</tr>
<tr>
<td>Roof Repl. and Repairs Above EU-007/EU-008, EU-009, EU-010 Baghouses</td>
<td>Postponed</td>
<td>NA</td>
</tr>
<tr>
<td>Upgrade Electric Breaker Panel</td>
<td>Future</td>
<td>NA</td>
</tr>
<tr>
<td>Replace Gaitranics Intercom System</td>
<td>Future</td>
<td>NA</td>
</tr>
</tbody>
</table>

Table 15: Corrective Maintenance Issues
Standard Operating Procedures (SOP’s)

The following SOP’s were obtained from the plant’s historical record. 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>Saint Paul Plant Standard Operation Procedure (SOP) Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Cooling System</td>
</tr>
<tr>
<td>2</td>
<td>Compressed Air System</td>
</tr>
<tr>
<td>3</td>
<td>Boiler Water Treatment System</td>
</tr>
<tr>
<td>4</td>
<td>Baghouse System</td>
</tr>
<tr>
<td>5</td>
<td>Control, Monitoring &amp; 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>Electrical System</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>Oil, Gas Handling System</td>
</tr>
<tr>
<td>13</td>
<td>Plumbing System</td>
</tr>
<tr>
<td>14</td>
<td>Outside Air Heating Systems</td>
</tr>
</tbody>
</table>

Table 16: Standard Operating Procedures
VII. WALKTHROUGH ASSESSMENT

SourceOne conducted a facility walkthrough of all six 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 six (6) 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

Capital projects include major upgrades and expansions on the existing facility. There have been no capital projects completed and there are presently none planned for the St. Paul facility.
IX. RECOMMENDED ENERGY CONSERVATION MEASURES & INITIATIVES

SourceOne has identified twenty-six (26) 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 40 HP Air Compressor Motors with High Efficiency Equivalents
S1-CAS-ECM-2: Replacement of 60 HP Air Compressor Motors with High Efficiency Equivalents

**Condensate System**

S1-CND-ECM-1: Replacement of 15 HP Condensate Pump Motors with High Efficiency Equivalents and Installation of VFDs
S1-CND-ECM-2: Replacement of 10 HP Condensate Pump Motor with High Efficiency Equivalent and Installation of VFD
S1-CND-ECM-3: Replacement of Boiler EU-006 Condensate Pump Motors with High Efficiency Equivalents

**Feedwater System**

S1-FWS-ECM-1: Replacement of Boilers EU-007 to EU-011 Feedwater Pump Motors with High Efficiency Equivalents and Installation of VFDs

**Coal Handling System**

S1-CHS-ECM-1: Replacement of Conveyor Drive Motor with High Efficiency Equivalent
S1-CHS-ECM-2: Replacement of Boiler EU-007 Pulverized Blower Motor with High Efficiency Equivalent
S1-CHS-ECM-3: Replacement of Boiler EU-008 Pulverized Blower Motor with High Efficiency Equivalent

**Combustion Air System**

S1-CA-ECM-1: Replacement of Boiler EU-006 Forced Draft Fan Motor with High Efficiency Equivalent and Installation of VFD
S1-CA-ECM-2: Replacement of Boiler EU-007 Forced Draft Fan Motor with High Efficiency Equivalent and Installation of VFD
S1-CA-ECM-3: Replacement of Boiler EU-007 Over-Fire Air Fan Motor with High Efficiency Equivalent
S1-CA-ECM-4: Replacement of Boiler EU-007 Induced Draft Fan Motor with High Efficiency Equivalent and Installation of VFD
S1-CA-ECM-5: Replacement of Boiler EU-008 Forced Draft Fan Motor with High Efficiency Equivalent and Installation of VFD
S1-CA-ECM-6: Replacement of Boiler EU-008 Induced Draft Fan Motor with High Efficiency Equivalent and Installation of VFD
S1-CA-ECM-7: Replacement of Boiler EU-008 Baghouse ID Fan Motor with High Efficiency Equivalent and Installation of VFD
S1-CA-ECM-8: Replacement of Boiler EU-009 Forced Draft Fan Motor with High Efficiency Equivalent and Installation of VFD
S1-CA-ECM-9: Replacement of Boiler EU-009 Induced Draft Fan Motor with High Efficiency Equivalent and Installation of VFD
S1-CA-ECM-10: Replacement of Boiler EU-009 Baghouse ID Fan Motor with High Efficiency Equivalent and Installation of VFD
S1-CA-ECM-11: Replacement of Boiler EU-010 Forced Draft Fan Motor with High Efficiency Equivalent and Installation of VFD
S1-CA-ECM-12: Replacement of Boiler EU-010 Induced Draft Fan Motor with High Efficiency Equivalent and Installation of VFD
S1-CA-ECM-13: Replacement of Boiler EU-010 Baghouse ID Fan Motor with High Efficiency Equivalent and Installation of VFD
S1-CA-ECM-14: Replacement of Boiler EU-011 Forced Draft Fan Motor with High Efficiency Equivalent and Installation of VFD

**Fuel Oil System**

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

**Ash Handling System**

S1-AHS-ECM-1: Replacement of Boiler EU-010 Reverse Air Fan Motor with High Efficiency Equivalent

**Cooling Water**

S1-CWS-ECM-1: Replacement of Cooling Water Pump Motors with High Efficiency Equivalents

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

**Combustion Air System**

S1-CA-ECI-1: Replacement of EU-011 Jackshaft with Independent Combustion Control Positioning Mechanisms

**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, fuel oil, and natural gas consumption and cost figures from the site as well as the steam production numbers provided by the site. All of these values are detailed in following sections of this report. A summary of them are given in Tables 17 and 18.
Compressed Air System

**S1-CAS-ECM-1: Replacement of 40 HP Air Compressor Motors with High Efficiency Equivalents**

Two (2) 40 HP Air Compressors are currently used in the Compressed Air System. These air compressor motors are rated at 40 HP each and are fed 460V power. The efficiency of the motors was obtained from the nameplates and recorded as 92.4%.

It is recommended to upgrade each air compressor motor with a high efficiency equivalent with 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 3,143 kWh, which corresponds to an annual cost savings of $314. The total material and labor cost associated with the retrofits is $4,300. The annual run-hours for the 40 HP Air Compressors were estimated to be approximately 2190 hours per year. **This results in a simple payback of 13.7 years.**

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

Two (2) 60 HP Air Compressors are currently used in the Compressed Air System. These air compressor 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 air compressor 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 $829. The total material and labor cost associated with the retrofits is $6,400. The annual run-hours for the 60 HP Air Compressors were estimated to be approximately 2190 hours per year. **This results in a simple payback of 7.72 years.**
**Condensate System**

S1-CND-ECM-1: Replacement of 15 HP Condensate Pump Motors with High Efficiency Equivalents and Installation of VFDs

Three (3) 15 HP Condensate Pumps are currently used in the Condensate System for Boilers EU-007 to EU-011. These pumps are part of a set of four (4) condensate pumps used to feed the deaerator used for Boilers EU-007 to EU-011. The fourth pump is discussed in S1-CND-ECM-2. These pump motors are rated at 15 HP each and are fed 460V power. The efficiency of the motors was obtained from the nameplates and recorded as 91%.

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. Presently, the condensate pumps are manually started and run at constant speed. A level control valve at the deaerator is throttled to control flow and a recirculation line returns excess condensate flow to the condensate tank.

According to the ‘pump laws’, for centrifugals 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 48 illustrates this relationship.

![Figure 48: 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 48, 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, the 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 49.
Figure 49: Variable Speed Centrifugal Pump Curve

As can be seen from Figure 49 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 15 HP Condensate Pump motor.

It is recommended to install a VFD on each of the pumps and to remove the level control valve at the deaerator. The VFD’s will be controlled by the level transmitters on the deaerator.

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 25,453 kWh, which corresponds to an annual cost savings of $2,545. The total material and labor cost associated with the retrofits is $24,000. The annual run-hours for the 15 HP Condensate Pumps were estimated to be approximately 2190 hours per year. This results in a simple payback of 9.43 years.

S1-CND-ECM-2: Replacement of 10 HP Condensate Pump Motor with High Efficiency Equivalent and Installation of VFD

A 10 HP Condensate Pump is currently used in the Condensate System for Boilers EU-007 to EU-011. This pump motor is rated at 10 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 85.7%.
As mentioned in S1-CND-ECM-1, this pump is one (1) of four (4) condensate pumps used to feed Boilers EU-007 to EU-011. It is recommended to upgrade this pump motor with a high efficiency equivalent with an expected rated efficiency of 91.7%. Additionally, it is recommended to install a VFD to control the speed of each pump motor. Presently, the condensate pumps are manually started and run at constant speed. A level control valve at the deaerator is throttled to control flow and a recirculation line returns excess condensate flow to the condensate tank.

Similar to the S1-CND-ECM-1 analysis, SourceOne used the industry standard estimate of 30% energy savings via the use of a VFD on the 10 HP Condensate Pump.

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 6,592 kWh, which corresponds to an annual cost savings of $659. The total material and labor cost associated with the retrofits is $7500. The annual run-hours for the 10 HP Condensate Pump were estimated to be approximately 2190 hours per year. This results in a simple payback of 11.4 years.

S1-CND-ECM-3: Replacement of Boiler EU-006 Condensate Pump Motors with High Efficiency Equivalents

[Not Recommended]

Two (2) Condensate Pumps are currently used in the Condensate System for Boiler EU-006. These pump motors are rated at 40 HP each and are fed 460V power. The efficiency of the motors was obtained from the nameplates and recorded as 91%.

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 737 kWh, which corresponds to an annual cost savings of $74. The total material and labor cost associated with the retrofits is $4,300. The annual run-hours for the Condensate Pumps were estimated to be approximately 303.5 hours per year. This results in a simple payback of 58.3 years. This ECM is not cost justifiable based upon energy savings alone.

Feedwater System

S1-FWS-ECM-1: Replacement of Boilers EU-007 to EU-011 Feedwater Pump Motors with High Efficiency Equivalents and Installation of VFDs

Three (3) electric Feedwater Pumps are currently used in the Feedwater System for Boilers EU-007 to EU-011. 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%. In total, there are four (4) pumps that feed these boilers. The remaining pump (BFP-1) is steam driven.

It is recommended to upgrade each pump motor with a high efficiency equivalent with an expected rated efficiency of 95%. Additionally, it is recommended to install a VFD to control the speed of each pump motor. One (1) of the feedwater pumps (BFP-4) has a VFD which is used to control header pressure. Presently, as additional flow is needed, a second pump is brought online to maintain boiler drum level. Following the installation, the VFD’s will be used to maintain feedwater header pressure.
Similar to the S1-CND-ECM-1 analysis, SourceOne used the industry standard estimate of 30% energy savings via the use of a VFD on the Feedwater Pump.

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 53,018 kWh, which corresponds to an annual cost savings of $3,653. The total material and labor cost associated with the retrofits is $33,200. The annual run-hours for the Feedwater Pumps were estimated to be approximately 1400 hours per year. This results in a simple payback of 9.09 years.

**Coal Handling System**

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

[Not Recommended]

A Conveyor Drive is currently used in the Coal Handling System. This drive motor is rated at 20 HP and is fed 440 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 87.7%.

A high efficiency equivalent replacement for a motor of this size has 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 97 kWh, which corresponds to an annual cost savings of $10. The total material and labor cost associated with the retrofits is $1,150. The annual run-hours for the Conveyor Drive were estimated to be approximately 100 hours per year. This results in a simple payback of 119 years. This ECM is not cost justifiable based upon energy savings alone.

**S1-CHS-ECM-2: Replacement of Boiler EU-007 Pulverized Blower Motor with High Efficiency Equivalent**

[Not Recommended]

A Pulverized Blower is currently used in the Coal Handling System for Boiler EU-007. This blower motor is rated at 60 HP and is fed 440 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 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 189 kWh, which corresponds to an annual cost savings of $19. The total material and labor cost associated with the retrofits is $3,200. The annual run-hours for the Pulverized Blower were estimated to be approximately 100 hours per year. This results in a simple payback of 169 years. This ECM is not cost justifiable based upon energy savings alone.

**S1-CHS-ECM-3: Replacement of Boiler EU-008 Pulverized Blower Motor with High Efficiency Equivalent**

[Not Recommended]

A Pulverized Blower is currently used in the Coal Handling System for Boiler EU-008. This blower motor
is rated at 60 HP and is fed 440 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 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 38 kWh, which corresponds to an annual cost savings of $4. The total material and labor cost associated with the retrofits is $3,200. The annual run-hours for the Pulverized Blower were estimated to be approximately 20 hours per year. This results in a simple payback of 845 years. This ECM is not cost justifiable based upon energy savings alone.

**Combustion Air System**

**S1-CA-ECM-1: Replacement of Boiler EU-006 Forced Draft Fan Motor with High Efficiency Equivalent and Installation of VFD**

A Forced Draft Fan is currently used in the Combustion Air System for Boiler EU-006. This fan motor is rated at 600 HP and is fed 460V power. The efficiency of the motor was obtained from the nameplate and recorded as 95.4%.

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 fan is constant speed and is used to maintain O2 levels with combustion air dampers. Following the installation, the VFD will modulate the fan motor speed to maintain O2 levels.

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 50.
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 428,422 kWh, which corresponds to an annual cost savings of $42,842. The total material and labor cost associated with the retrofits is $112,700. The annual run-hours for the Forced Draft Fan were estimated to be approximately 3000 hours per year. **This results in a simple payback of 2.63 years.**

**S1-CA-ECM-2: Replacement of Boiler EU-007 Forced Draft Fan Motor with High Efficiency Equivalent and Installation of VFD**

*Not Recommended*

A Forced Draft Fan is currently used in the Combustion Air System for Boiler EU-007. This fan motor is rated at 40 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 90.1%.

A high efficiency equivalent replacement for a motor of this size has an expected rated efficiency of 94.5%. Additionally, efficiency can be increased through the use of a VFD to control the speed of the fan motor. Presently, the fan is constant speed and is used to maintain O2 levels with combustion air dampers. Following the installation, the VFD will modulate the fan motor speed to maintain O2 levels.
Similar to the S1-CA-ECM-1 analysis, SourceOne used the industry standard estimate of 30% energy savings via the use of a VFD on the 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 8,008 kWh, which corresponds to an annual cost savings of $801. The total material and labor cost associated with the retrofits is $13,000. The annual run-hours for the Forced Draft Fan were estimated to be approximately 727 hours per year. This results in a simple payback of 16.2 years. This ECM is not cost justifiable based upon energy savings alone.

S1-CA-ECM-3: Replacement of Boiler EU-007 Over-Fire Air Fan Motor with High Efficiency Equivalent

[Not Recommended]

An Over-Fire Air Fan is currently used in the Combustion Air System for Boiler EU-007. This fan motor is rated at 20 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 87.7%.

A high efficiency equivalent replacement for a motor of this size has 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 705 kWh, which corresponds to an annual cost savings of $70. The total material and labor cost associated with the retrofits is $1,150. The annual run-hours for the Over-Fire Air Fan were estimated to be approximately 727 hours per year. This results in a simple payback of 16.3 years. This ECM is not cost justifiable based upon energy savings alone.

S1-CA-ECM-4: Replacement of Boiler EU-007 Induced Draft Fan Motor with High Efficiency Equivalent and Installation of VFD

An Induced Draft Fan is currently used in the Combustion Air System for Boiler EU-007. This fan motor is rated at 200 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 92.8%.

It is recommended to upgrade this fan motor with a high efficiency equivalent with an expected rated efficiency of 96.2%. Additionally, it is recommended to install a VFD to control the speed of the fan motor. Presently, the fan is constant speed and is used to control furnace pressure with exhaust dampers. Following the installation, the VFD will modulate the fan motor speed to maintain furnace pressure.

Similar to the S1-CA-ECM-1 analysis, SourceOne used the industry standard estimate of 30% energy savings via the use of a VFD on the 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 37,957 kWh, which corresponds to an annual cost savings of $3,796. The total material and labor cost associated with the retrofits is $41,300. The annual run-hours for the Induced Draft Fan were estimated to be approximately 727 hours per year. This results in a simple payback of 10.9 years.
S1-CA-ECM-5: Replacement of EU-008 Forced Draft Fan Motor with High Efficiency Equivalent and Installation of VFD

[Not Recommended]

A Forced Draft Fan is currently used in the Combustion Air System for Boiler EU-008. This fan motor is rated at 20 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 87.7%.

A high efficiency equivalent replacement for a motor of this size has an expected rated efficiency of 93%. Additionally, efficiency can be increased through the use of a VFD to control the speed of the fan motor. Presently, the fan is constant speed and is used to maintain O2 levels with combustion air dampers. Following the installation, the VFD will modulate the fan motor speed to maintain O2 levels.

Similar to the S1-CA-ECM-1 analysis, SourceOne used the industry standard estimate of 30% energy savings via the use of a VFD on the 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 2,099 kWh, which corresponds to an annual cost savings of $210. The total material and labor cost associated with the retrofits is $8,850. The annual run-hours for the Forced Draft Fan were estimated to be approximately 363 hours per year. This results in a simple payback of 42.2 years. This ECM is not cost justifiable based upon energy savings alone.

S1-CA-ECM-6: Replacement of Boiler EU-008 Induced Draft Fan Motor with High Efficiency Equivalent and Installation of VFD

[Not Recommended]

An Induced Draft Fan is currently used in the Combustion Air System for Boiler EU-008. This fan motor is rated at 40 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 90.1%.

A high efficiency equivalent replacement for a motor of this size has an expected rated efficiency of 94.5%. Additionally, efficiency can be increased through the use of a VFD to control the speed of the fan motor. Presently, the fan is constant speed and is used to control furnace pressure with exhaust dampers. Following the installation, the VFD will modulate the fan motor speed to maintain furnace pressure.

Similar to the S1-CA-ECM-1 analysis, SourceOne used the industry standard estimate of 30% energy savings via the use of a VFD on the 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 3,998 kWh, which corresponds to an annual cost savings of $400. The total material and labor cost associated with the retrofits is $13,000. The annual run-hours for the Induced Draft Fan were estimated to be approximately 363 hours per year.
This results in a simple payback of 32.5 years. This ECM is not cost justifiable based upon energy savings alone.

S1-CA-ECM-7: Replacement of Boiler EU-008 Baghouse ID Fan Motor with High Efficiency Equivalent and Installation of VFD

[Not Recommended]

A Baghouse ID Fan is currently used in the Combustion Air System for Boiler EU-008. This fan motor is rated at 200 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 92.8%.

A high efficiency equivalent replacement for a motor of this size has an expected rated efficiency of 96.2%. Additionally, efficiency can be increased through the use of a VFD to control the speed of the fan motor. Presently, the fan is constant speed and is used to control baghouse differential pressure with exhaust dampers. Following the installation, the VFD will modulate the fan motor speed to maintain differential pressure across the baghouse.

Similar to the S1-CA-ECM-1 analysis, SourceOne used the industry standard estimate of 30% energy savings via the use of a VFD on the 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 18,952 kwh, which corresponds to an annual cost savings of $1,895. The total material and labor cost associated with the retrofits is $41,300. The annual run-hours for the Baghouse ID Fan were estimated to be approximately 363 hours per year. This results in a simple payback of 21.8 years. This ECM is not cost justifiable based upon energy savings alone.

S1-CA-ECM-8: Replacement of Boiler EU-009 Forced Draft Fan Motor with High Efficiency Equivalent and Installation of VFD

[Not Recommended]

A Forced Draft Fan is currently used in the Combustion Air System for Boiler EU-009. This fan motor is rated at 30 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 94.1%. Additionally, efficiency can be increased through the use of a VFD to control the speed of the fan motor. Presently, the fan is constant speed and is used to maintain O2 levels with combustion air dampers. Following the installation, the VFD will modulate the fan motor speed to maintain O2 levels.

Similar to the S1-CA-ECM-1 analysis, SourceOne used the industry standard estimate of 30% energy savings via the use of a VFD on the 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 5,593 kWh, which corresponds to an annual cost savings of $559. The total material and labor cost associated with the retrofits is $11,550. The annual run-hours for the Forced Draft Fan were estimated to be approximately 721 hours per year. **This results in a simple payback of 20.7 years. This ECM is not cost justifiable based upon energy savings alone.**

**S1-CA-ECM-9: Replacement of Boiler EU-009 Induced Draft Fan Motor with High Efficiency Equivalent and Installation of VFD**

An Induced Draft Fan is currently used in the Combustion Air System for Boiler EU-009. 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 77%.

It is recommended to upgrade this fan motor with a high efficiency equivalent with an expected rated efficiency of 95.4%. Additionally, it is recommended to install a VFD to control the speed of the fan motor. Presently, the fan is constant speed and is used to control furnace pressure with exhaust dampers. Following the installation, the VFD will modulate the fan motor speed to maintain furnace pressure.

Similar to the S1-CA-ECM-1 analysis, SourceOne used the industry standard estimate of 30% energy savings via the use of a VFD on the 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 30,387 kWh, which corresponds to an annual cost savings of $3,039. The total material and labor cost associated with the retrofits is $22,100. The annual run-hours for the Induced Draft Fan were estimated to be approximately 721 hours per year. **This results in a simple payback of 7.27 years.**

**S1-CA-ECM-10: Replacement of Boiler EU-009 Baghouse ID Fan Motor with High Efficiency Equivalent and Installation of VFD**

A Baghouse ID Fan is currently used in the Combustion Air System for Boiler EU-009. This fan motor is rated at 125 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 92.2%.

It is recommended to upgrade this fan motor with a high efficiency equivalent with an expected rated efficiency of 95.4%. Additionally, it is recommended to install a VFD to control the speed of the fan motor. Presently, the fan is constant speed and is used to control furnace pressure with exhaust dampers. Following the installation, the VFD will modulate the fan motor speed to maintain differential pressure across the baghouse.

Similar to the S1-CA-ECM-1 analysis, SourceOne used the industry standard estimate of 30% energy savings via the use of a VFD on the 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 23,589 kWh, which corresponds to an annual cost savings of $2,359. The total material and labor cost associated with the retrofits is $26,700. The annual run-hours for the Baghouse ID Fan were estimated to be approximately 721 hours per year. This results in a simple payback of 11.3 years.

S1-CA-ECM-11: Replacement of Boiler EU-010 Forced Draft Fan Motor with High Efficiency Equivalent and Installation of VFD

[Not Recommended]

A Forced Draft Fan is currently used in the Combustion Air System for Boiler EU-010. 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%. Additionally, efficiency can be increased through the use of a VFD to control the speed of the fan motor. Presently, the fan is constant speed and is used to maintain O2 levels with combustion air dampers. Following the installation, the VFD will modulate the fan motor speed to maintain O2 levels.

Similar to the S1-CA-ECM-1 analysis, SourceOne used the industry standard estimate of 30% energy savings via the use of a VFD on the 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 9,693 kWh, which corresponds to an annual cost savings of $969. The total material and labor cost associated with the retrofits is $17,200. The annual run-hours for the Forced Draft Fan were estimated to be approximately 607 hours per year. This results in a simple payback of 17.7 years. This ECM is not cost justifiable based upon energy savings alone.

S1-CA-ECM-12: Replacement of Boiler EU-010 Induced Draft Fan Motor with High Efficiency Equivalent and Installation of VFD

An Induced Draft Fan is currently used in the Combustion Air System for Boiler EU-010. This fan motor is rated at 125 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 92.2%.

It is recommended to upgrade this fan motor with a high efficiency equivalent with an expected rated efficiency of 95.4%. Additionally, it is recommended to install a VFD to control the speed of the fan motor. Presently, the fan is constant speed and is used to control furnace pressure with exhaust dampers. Following the installation, the VFD will modulate the fan motor speed to maintain furnace pressure.

Similar to the S1-CA-ECM-1 analysis, SourceOne used the industry standard estimate of 30% energy savings via the use of a VFD on the 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 19,859 kWh, which corresponds to an annual cost savings of $1,986. The total material and labor cost associated with the retrofits is $26,700. The annual run-hours for the Induced Draft Fan were estimated to be approximately 607 hours per year. This results in a simple payback of 13.4 years.

**S1-CA-ECM-13: Replacement of EU-010 Baghouse ID Fan Motor with High Efficiency Equivalent and Installation of VFD**

A Baghouse ID Fan is currently used in the Combustion Air System for Boiler EU-010. This fan motor is rated at 125 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 92.2%.

It is recommended to upgrade this fan motor with a high efficiency equivalent with an expected rated efficiency of 95.4%. Additionally, it is recommended to install a VFD to control the speed of the fan motor. Presently, the fan is constant speed and is used to control furnace pressure with exhaust dampers. Following the installation, the VFD will modulate the fan motor speed to maintain differential pressure across the baghouse.

Similar to the S1-CA-ECM-1 analysis, SourceOne used the industry standard estimate of 30% energy savings via the use of a VFD on the 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 19,859 kWh, which corresponds to an annual cost savings of $1,986. The total material and labor cost associated with the retrofits is $26,700. The annual run-hours for the Baghouse ID Fan were estimated to be approximately 607 hours per year. This results in a simple payback of 13.4 years.

**S1-CA-ECM-14: Replacement of Boiler EU-011 Forced Draft Fan Motor with High Efficiency Equivalent and Installation of VFD**

A Forced Draft Fan is currently used in the Combustion Air System for Boiler EU-011. 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 93.6%.

It is recommended to upgrade this fan motor with a high efficiency equivalent with an expected rated efficiency of 95.4%. Additionally, it is recommended to install a VFD to control the speed of the fan motor. Presently, the fan is constant speed and is used to maintain O2 levels with combustion air dampers. Following the installation, the VFD will modulate the fan motor speed to maintain O2 levels.

Similar to the S1-CA-ECM-1 analysis, SourceOne used the industry standard estimate of 30% energy savings via the use of a VFD on the 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 84,070 kWh, which corresponds to an annual cost savings of $8,407. The total material and labor cost associated with the retrofits is $17,200. The annual run-hours for the Forced Draft Fan were estimated to be approximately 5613 hours per year. **This results in a simple payback of 2.05 years.**

**Fuel Oil System**

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

[Not Recommended]

Two (2) Fuel Oil Pumps are currently used in the Fuel Oil System. These pump motors are rated at 25 HP each and are fed 208 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 89.5%.

A high efficiency equivalent replacement for a motor of this size has an expected rated efficiency of 93.6%. Additionally, efficiency can be increased through the use of a VFD to control the speed of each pump motor. Presently, the fuel pumps run at constant speed and utilize a recirculation line to return the oil to the day tank. Following the installation, the VFD would be used to control header pressure and the recirculation line will not be utilized.

Similar to the S1-CND-ECM-1 analysis, SourceOne used the industry standard estimate of 30% energy savings via the use of a VFD on the Fuel Oil Pump.

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 1,378 kWh, which corresponds to an annual cost savings of $138. The total material and labor cost associated with the retrofits is $19,700. The annual run-hours for the Fuel Oil Pumps were estimated to be approximately 100 hours per year. **This results in a simple payback of 143 years. This ECM is not cost justifiable based upon energy savings alone.**

**Ash Handling System**

S1-AHS-ECM-1: Replacement of Reverse Air Fan Motor with High Efficiency Equivalent

[Not Recommended]

A Reverse Air Fan is currently used in the Ash Handling System for Boiler EU-010. This fan 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 708 kWh, which corresponds to an annual cost savings of $71. The total material and labor cost associated with the retrofits is $1,800. The annual run-hours for the Reverse Air Fan were estimated to be approximately 607 hours per year. **This results in a simple payback of 25.4 years. This ECM is not cost justifiable based upon energy savings alone.**

**Cooling Water**

**S1-CWS-ECM-1: Replacement of Cooling Water Pump Motors with High Efficiency Equivalents**

Two (2) Cooling Water Pumps are currently used in the Cooling Water. These pump motors are rated at 10 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 85.7%.

It is recommended to upgrade each pump motor with a high efficiency equivalent with 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 4,989 kWh, which corresponds to an annual cost savings of $499. The total material and labor cost associated with the retrofits is $1,600. The annual run-hours for the Cooling Water Pumps were estimated to be approximately 4380 hours per year. **This results in a simple payback of 3.21 years.**

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

**Combustion Air**

**ECI-1: Replacement of EU-011 Jackshaft with Independent Combustion Control Positioning Mechanisms**

Currently, Boiler EU-011 is using a jackshaft to control the air-fuel ratio. Jackshafts are mechanical linkages and cams that work by opening both the fuel oil valve, the natural gas valve, and combustion air damper together to provide the boiler with a varying air-fuel ratio as the boiler is modulated. Jackshafts are an antiquated technology and, over time, can become loose and less effective. Furthermore, as boilers age, the optimum ratio of air to fuel can vary from its original design causing either an insufficient air or insufficient fuel mixture. Insufficient air causes an increase in CO and insufficient fuel causes an increase in NOx. Both of these pollutants contain oxygen and indicate inefficient combustion. A controls package can be used to optimize these levels. The jackshaft on Boiler EU-011 is shown Figure 51.
It is recommended to remove the jackshaft and upgrade the boiler with a new controls package in order to increase efficiency over the entire operating range of the boiler. Over time, the efficiency of the boiler will undoubtedly decrease. However, some of the efficiency can be recovered through combustion controls tuning (air-to-fuel ratio adjustments) as well as damper and fuel valve calibrations. The use of a jackshaft for determining the air-to-fuel ratio limits one’s ability to tune a boiler’s combustion controls; fine adjustments are not possible. This is why SourceOne is recommending the elimination of the jackshaft for combustion control.

Figure 51: Jackshaft on Boiler EU-011
The installation will include the elimination of the jackshaft, the installation of pneumatic or motorized control valve actuators for the natural gas and fuel oil flow control valves, the installation and programming of a new microprocessor and the follow-up tuning. The new control valves can be controlled with the existing O2 trim system and will provide energy efficient combustion controls.

We are only looking at the benefits associated with fuel savings (typically 2.5% to 5%) from having fine and independent control over the control valves and eliminating the “slop” associated with the linkages becoming loose over time (as is typically the case). With a 2.5% fuel savings, the total annual energy savings is calculated to be 4,000 MMBTU of natural gas (fuel oil savings was ignored since it is rarely burned), which corresponds to a cost savings of $21,000.

**Blowdown System**

S1-BDS-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 and a significant decrease in make-up water. 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 – Saint Paul Plant – Process Flow Diagram

ii. SourceOne Recommended ECM Payback Summary Sheets
Attachment A: Saint Paul Plant Layout
## 40 HP AIR COMPRESSOR PAYBACK SUMMARY SHEET

**Project Name:** University of Minnesota

**S1 Project Number:** S14-015

**Date:** 4/18/2014

**Cost of Electricity:** 0.1000 $/kWh

### S1-CAS-ECM-1: Replacement of 40 HP Air Compressor Motors with High Efficiency Equivalents

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<th>Field ID</th>
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<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>
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<td>$7,072</td>
<td>94.50%</td>
<td>69,153</td>
<td>$6,915</td>
<td>0</td>
<td>1,572</td>
<td>$197</td>
<td>$1,600</td>
<td>$550</td>
</tr>
<tr>
<td>2</td>
<td>Main Plant</td>
<td>First Floor</td>
<td>N/A</td>
<td>#2</td>
<td>2190</td>
<td>40</td>
<td>92.40%</td>
<td>70,725</td>
<td>$7,072</td>
<td>94.50%</td>
<td>69,153</td>
<td>$6,915</td>
<td>0</td>
<td>1,572</td>
<td>$197</td>
<td>$1,600</td>
<td>$550</td>
</tr>
</tbody>
</table>

**Total** | 3,143 | $314 | $3,200 | $1,100 |

**Total Yearly Savings ($) :** $314

**Total Material and Labor ($) :** $4,300

**Payback Factor (Years) :** 13.68
# 60 HP Air Compressor Payback Summary Sheet

**Project Name:** University of Minnesota

**S1 Project Number:** S14-015

**Date:** 4/18/2014

**Cost of Electricity:** $0.1000/kWh

## S1-CAS-ECM-2: Replacement of 60 HP Air Compressor 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 | First Floor | N/A | C-302 | 2190 | 60 | 91.70% | 106,897 | $10,690 | 95.40% | 102,761 | $10,275 | 0 | 4,146 | $415 | $2,500 | $700 |
| 2      | Main Plant | First Floor | N/A | C-304 | 2190 | 60 | 91.70% | 106,897 | $10,690 | 95.40% | 102,761 | $10,275 | 0 | 4,146 | $415 | $2,500 | $700 |

**Total**

$829  
$6,400  
7.72

**Total Yearly Savings ($)**: $829  
**Total Material and Labor ($)**: $6,400  
**Payback Factor (Years)**: 7.72
### 15 HP CONDENSATE PUMP PAYBACK SUMMARY SHEET

**Project Name:** University of Minnesota  
**Date:** 4/18/2014  
**S1 Project Number:** S14-015

**S1-CND-ECM-1: Replacement of 15 HP Condensate Pump Motors with High Efficiency Equivalents and Installation of VFDs**

<table>
<thead>
<tr>
<th>Line #</th>
<th>Building</th>
<th>Floor</th>
<th>Location Field ID</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>Local to Condensate Tank</td>
<td>N/A CP-1</td>
<td>2190</td>
<td>15</td>
<td>91.00%</td>
<td>26,930</td>
<td>$2,693</td>
<td>93.00%</td>
<td>26,351</td>
<td>$2,635</td>
<td>7,905</td>
<td>$848</td>
</tr>
<tr>
<td>2</td>
<td>Main Plant</td>
<td>Local to Condensate Tank</td>
<td>N/A CP-2</td>
<td>2190</td>
<td>15</td>
<td>91.00%</td>
<td>26,930</td>
<td>$2,693</td>
<td>93.00%</td>
<td>26,351</td>
<td>$2,635</td>
<td>7,905</td>
<td>$848</td>
</tr>
<tr>
<td>3</td>
<td>Main Plant</td>
<td>Local to Condensate Tank</td>
<td>N/A CP-3</td>
<td>2190</td>
<td>15</td>
<td>91.00%</td>
<td>26,930</td>
<td>$2,693</td>
<td>93.00%</td>
<td>26,351</td>
<td>$2,635</td>
<td>7,905</td>
<td>$848</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Total Yearly Savings ($)**: $2,545  
**Total Material and Labor ($)**: $24,000  
**Payback Factor (Years)**: 9.43

---

University of Minnesota - St Paul Plant
## 10 HP CONDENSATE PUMP PAYBACK SUMMARY SHEET

**Project Name:** University of Minnesota  
**S1 Project Number:** S14-015  
**Date:** 4/18/2014  
**Cost of Electricity:** 0.1000 $/kWh

### S1-CND-ECM-2: Replacement of 10 HP Condensate Pump 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</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 Condensate Tank</td>
<td>N/A</td>
<td>CP-4</td>
<td>2190</td>
<td>10</td>
<td>85.70%</td>
<td>19,063</td>
<td>$1,906</td>
<td>91.70%</td>
<td>17,816</td>
<td>$1,782</td>
<td>5,345</td>
<td>6,592</td>
<td>$659</td>
<td>$5,750</td>
<td>$1,750</td>
</tr>
</tbody>
</table>

**Total**  
6,592 669 5,750 1,750

**Total Yearly Savings ($)**: $659  
**Total Material and Labor ($)**: $7,500  
**Payback Factor (Years)**: 11.38
### BOILER EU-006 CONDENSATE PUMP PAYBACK SUMMARY SHEET

**Project Name:** University of Minnesota  
**S1 Project Number:** S14-015  
**Date:** 4/18/2014  
**Cost of Electricity:** 0.1000 $/kWh

**S1-CND-ECM-3: Replacement of Boiler EU-006 Condensate 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>Local to Condensate Tank</td>
<td>N/A</td>
<td>CP-A</td>
<td>303.5</td>
<td>40</td>
<td>91.00%</td>
<td>9,952</td>
<td>$995</td>
<td>94.50%</td>
<td>9,584</td>
<td>$958</td>
<td>0</td>
<td>369</td>
<td>$37</td>
<td>$1,600</td>
<td>$550</td>
</tr>
<tr>
<td>2</td>
<td>Main Plant</td>
<td>Local to Condensate Tank</td>
<td>N/A</td>
<td>CP-B</td>
<td>303.5</td>
<td>40</td>
<td>91.00%</td>
<td>9,952</td>
<td>$995</td>
<td>94.50%</td>
<td>9,584</td>
<td>$958</td>
<td>0</td>
<td>369</td>
<td>$37</td>
<td>$1,600</td>
<td>$550</td>
</tr>
</tbody>
</table>

**Total**  
737 kWh | $74 | $3,200 | $1,100

- **Total Yearly Savings ($)**: $74  
- **Total Material and Labor ($)**: $4,300  
- **Payback Factor (Years)**: 58.33
## S1.FWS-ECM-1: Replacement of Boilers EU-007 to EU-011 Feedwater Pump Motors with High Efficiency Equivalents and Installation of VFDs

| 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 | First Floor | N/A | BFP-2 | 1400 | 50 | 93.00% | 56.151 | $5,615 | 95.00% | 54.968 | $5,497 | 16.491 | 17.873 | $1,767 | $12,200 | $3,100 |
| 2      | Main Plant | First Floor | N/A | BFP-3 | 1400 | 50 | 93.00% | 56.151 | $5,615 | 95.00% | 54.968 | $5,497 | 16.491 | 17.873 | $1,767 | $12,200 | $3,100 |
| 3      | Main Plant | First Floor | N/A | BFP-4 | 1400 | 50 | 93.00% | 56.151 | $5,615 | 95.00% | 54.968 | $5,497 | 0 | 1,182 | $118 | $2,000 | $600 |

**Total**

- Total Yearly Savings ($) = $3,653
- Total Material and Labor ($) = $33,200
- Payback Factor (Years) = 9.09
### CONVEYOR DRIVE PAYBACK SUMMARY SHEET

**Project Name:** University of Minnesota  
**Date:** 4/18/2014  
**Cost of Electricity:** 0.1000 $/kWh

#### S1-CHS-ECM-1: Replacement of Conveyor 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>Coal Tunnel</td>
<td>Plant Side</td>
<td>N/A</td>
<td>#1</td>
<td>100</td>
<td>20</td>
<td>87.70%</td>
<td>1,701</td>
<td>$170</td>
<td>93.00%</td>
<td>1,604</td>
<td>$160</td>
<td>0</td>
<td>97</td>
<td>$10</td>
<td>$800</td>
<td>$350</td>
</tr>
</tbody>
</table>

**Total**  
97 | $10 | $800 | $350

**Total Yearly Savings ($)**: $10  
**Total Material and Labor ($)**: $1,150  
**Payback Factor (Years)**: 118.61
### S1-CHS-ECM-2: Replacement of Boiler EU-007 Pulverized 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 (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-311</td>
<td>100</td>
<td>60</td>
<td>91.70%</td>
<td>4.881</td>
<td>$488</td>
<td>90.40%</td>
<td>4.692</td>
<td>$469</td>
<td>0</td>
<td>189</td>
<td>$19</td>
<td>$2,500</td>
<td>$700</td>
</tr>
</tbody>
</table>

**Total**

|                     |                     |                     |                     |                     |                     |                     |                     |                     |                     |                     |                     |                     |                     |                     |                     |                     |                     |
|---------------------|---------------------|---------------------|---------------------|---------------------|---------------------|---------------------|---------------------|---------------------|---------------------|---------------------|---------------------|---------------------|---------------------|---------------------|---------------------|---------------------|
|                     |                     |                    |                     |                     |                     |                     |                     |                     |                     |                     |                     |                     |                     |                     |                     |                     |                     |
|                     |                     | 189                 |                     |                     |                     |                     |                     |                     |                     |                     |                     |                     |                     |                     |                     |                     |                     |

**Total Yearly Savings ($):** $19

**Total Material and Labor ($):** $3,200

**Payback Factor (Years):** 169.03
**Table: BOILER EU-008 PULVERIZED BLOWER 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>Local to Boiler</td>
<td>N/A</td>
<td>B-312</td>
<td>20</td>
<td>60</td>
<td>91.70%</td>
<td>976</td>
<td>968</td>
<td>940</td>
<td>954</td>
<td>94</td>
<td>0</td>
<td>38</td>
<td>4</td>
<td>2,500</td>
<td>700</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
</tbody>
</table>

- **Total Yearly Savings ($):** $4
- **Total Material and Labor ($):** $3,200
- **Payback Factor (Years):** 845.17
## BOILER EU-006 FORCED DRAFT FAN PAYBACK SUMMARY SHEET

**S1 Project Number:** S14-015

**Project Name:** University of Minnesota

**Date:** 4/18/2014

**Cost of Electricity:** 0.1000 $/kWh

*S1-CA-ECM-1: Replacement of Boiler EU-006 Forced Draft Fan Motor with High Efficiency Equivalent and Installation of VFD*

| 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 | Local to Boiler | N/A | B-231 | 3000 | 600 | 95.40% | 1,407,547 | 140,755 | 96.00% | 1,398,750 | 139,875 | 419,625 | 428,422 | 428,422 | $102,000 | $10,700 |

| Total | | | | | | | | | | | | $428,422 | $428,422 | $102,000 | $10,700 |

**Total Yearly Savings ($)**: $428,422

**Total Material and Labor ($)**: $112,700

**Payback Factor (Years)**: 2.63
**BOILER EU-007 FORCED DRAFT FAN PAYBACK SUMMARY SHEET**

**S1-CA-ECM-2: Replacement of Boiler EU-007 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>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>Local to Boiler</td>
<td>N/A</td>
<td>N/A</td>
<td>727</td>
<td>40</td>
<td>90.10%</td>
<td>24,377</td>
<td>94.50%</td>
<td>22,956</td>
<td>6.887</td>
<td>8,008</td>
<td>$801</td>
<td>$10,600</td>
<td>$2,400</td>
</tr>
<tr>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>$801</td>
<td>$10,600</td>
</tr>
</tbody>
</table>

**Total Yearly Savings ($)**: $801

**Total Material and Labor ($)**: $11,000

**Payback Factor (Years)**: 16.24
### S1-CA-ECM-3: Replacement of Boiler EU-007 Overfire Air 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 (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>727</td>
<td>20</td>
<td>87.70%</td>
<td>12,368</td>
<td>$1,237</td>
<td>93.00%</td>
<td>11,663</td>
<td>$1,166</td>
<td>0</td>
<td>705</td>
<td>$70</td>
<td>$800</td>
<td>$350</td>
</tr>
</tbody>
</table>

**Total**

|                | 705 | 70 | $800 | $350 |

**Total Yearly Savings ($)**: $705  
**Total Material and Labor ($)**: $1,150  
**Payback Factor (Years)**: 16.32
### BOILER EU-007 INDUCED DRAFT FAN PAYBACK SUMMARY SHEET

**Project Name:** University of Minnesota  
**S1 Project Number:** S14-015  
**Date:** 4/18/2014  
**Cost of Electricity:** 0.1000 $/kWh

#### S1-CA-ECM-4: Replacement of Boiler EU-007 Induced Draft Fan Motor with High Efficiency Equivalent and Installation of VFD

<table>
<thead>
<tr>
<th>Line #</th>
<th>Building</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 Baghouse</td>
<td>N/A</td>
<td>727</td>
<td>200</td>
<td>92.80%</td>
<td>116,884</td>
<td>$11,688</td>
<td>96.20%</td>
<td>112,753</td>
<td>$11,275</td>
<td>33,826</td>
<td>37,957</td>
<td>$3,796</td>
<td>$36,000</td>
<td>$5,300</td>
</tr>
</tbody>
</table>

**Total**

$3,796  
$41,300  
$5,300

**Payback Factor (Years):** 10.88

**Total Yearly Savings ($):** $3,796  
**Total Material and Labor ($):** $36,000  
**Total Material and Labor ($):** $41,300
**BOILER EU-008 FORCED DRAFT FAN PAYBACK SUMMARY SHEET**

**Project Name:** University of Minnesota  
**S1 Project Number:** S14-015  
**Date:** 4/18/2014  
**Cost of Electricity:** 0.1000 $/kWh

---

### S1-CA-ECM-5: Replacement of Boiler EU-008 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>N/A</td>
<td>362</td>
<td>20</td>
<td>87.70%</td>
<td>6.176</td>
<td>$618</td>
<td>93.00%</td>
<td>5.824</td>
<td>$582</td>
<td>1.747</td>
<td>2,099</td>
<td>$210</td>
<td>$7,000</td>
<td>$1,850</td>
</tr>
</tbody>
</table>

**Total** | $210 | $7,000 | $1,850

---

**Total Yearly Savings ($)**: $210  
**Total Material and Labor ($)**: $8,850  
**Payback Factor (Years)**: 42.16
**S1-CA-ECM-6: Replacement of Boiler EU-008 Induced Draft Fan Motor with High Efficiency Equivalent and Installation of VFD**

<table>
<thead>
<tr>
<th>Line #</th>
<th>Building</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 Baghouse</td>
<td>N/A</td>
<td>363</td>
<td>40</td>
<td>90.10%</td>
<td>12,022</td>
<td>$1,202</td>
<td>94.50%</td>
<td>11,462</td>
<td>$1,146</td>
<td>3,439</td>
<td>3,998</td>
<td>$400</td>
<td>$10,600</td>
<td>$2,400</td>
</tr>
</tbody>
</table>

Total  

- Yearly Savings: 3,998 kWh  
- Yearly Savings Cost: $400  
- Total Material Cost: $10,600  
- Total Labor Cost: $2,400

Total Yearly Savings ($): $400  
Total Material and Labor ($): $13,000  
Payback Factor (Years): 32.51
S1-CA-ECM-7: Replacement of Boiler EU-008 Baghouse ID 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>Baghouse</td>
<td>Local to Baghouse</td>
<td>N/A</td>
<td>N/A</td>
<td>363</td>
<td>200</td>
<td>92.80%</td>
<td>58,362</td>
<td>$5,836</td>
<td>96.20%</td>
<td>56,299</td>
<td>$5,630</td>
<td>16,890</td>
<td>18,952</td>
<td>$1,895</td>
<td>$36,000</td>
<td>$5,300</td>
</tr>
</tbody>
</table>

Total | 18,952 | $1,895 | $36,000 | $5,300 |

Total Yearly Savings ($) = $1,895
Total Material and Labor ($) = $41,300
Payback Factor (Years) = 21.79
## BOILER EU-009 FORCED DRAFT FAN PAYBACK SUMMARY SHEET

**Project Name:** University of Minnesota  
**Date:** 4/18/2014  
**S1 Project Number:** S14-015  
**Cost of Electricity:** 0.1000 $/kWh

### S1-CA-ECM-8: Replacement of Boiler EU-009 Forced Draft Fan Motor with High Efficiency Equivalent and Installation of VFD

<table>
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<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>N/A</td>
<td>721</td>
<td>30</td>
<td>91.70%</td>
<td>17,596</td>
<td>$1,760</td>
<td>94.10%</td>
<td>17,148</td>
<td>$1,715</td>
<td>5,144</td>
<td>$559</td>
<td>$9,300</td>
<td>$2,250</td>
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</tbody>
</table>

**Total**  
- Yearly Savings ($) : $559  
- Total Material and Labor ($) : $11,550  
- Payback Factor (Years) : 20.65
<table>
<thead>
<tr>
<th>Line #</th>
<th>Building</th>
<th>Floor Location</th>
<th>Field ID</th>
<th>Annual Hours</th>
<th>Motor Horsepower (HP)</th>
<th>Existing Motor Efficiency (%)</th>
<th>Existing Motor Electric Consumption (kWh)</th>
<th>Existing Motor Electric Costs ($)</th>
<th>Motor Efficiency (%)</th>
<th>New Motor Electric Consumption (kWh)</th>
<th>New Motor Electric Costs ($)</th>
<th>Additional VFD Savings (kWh)</th>
<th>Yearly Savings (kWh)</th>
<th>Material Cost ($)</th>
<th>Labor Cost ($)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Main Plant</td>
<td>Local to Baghouse</td>
<td>N/A</td>
<td>721</td>
<td>100</td>
<td>77.00%</td>
<td>69,853</td>
<td>$6,985</td>
<td>95.40%</td>
<td>56,380</td>
<td>$5,638</td>
<td>16,914</td>
<td>30,387</td>
<td>$3,039</td>
<td>$19,000</td>
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<tr>
<td>Total</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td>30,387</td>
<td>$3,039</td>
</tr>
</tbody>
</table>

Total Yearly Savings ($) : $3,039
Total Material and Labor ($) : $22,100
Payback Factor (Years): 7.27

University of Minnesota - St Paul Plant
### Project Name: University of Minnesota

### S1 Project Number: S14-015

**Date:** 4/18/2014

**Cost of Electricity:** 0.1000 $/kWh

---

**S1-CA-ECM-10: Replacement of Boiler EU-009 Baghouse ID 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>Baghouse</td>
<td>Local to Baghouse</td>
<td>N/A</td>
<td>B-354</td>
<td>721</td>
<td>125</td>
<td>92.20%</td>
<td>72,921</td>
<td>$7,292</td>
<td>95.40%</td>
<td>70,475</td>
<td>$7,048</td>
<td>21,143</td>
<td>23,589</td>
<td>$2,359</td>
<td>$22,000</td>
<td>$4,700</td>
</tr>
</tbody>
</table>

**Total**

- Yearly Savings (kWh): 23,589
- Total Material and Labor ($) : $26,700
- Payback Factor (Years): 11.32

---

<table>
<thead>
<tr>
<th>Total Yearly Savings ($)</th>
<th>$2,359</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Material and Labor ($)</td>
<td>$26,700</td>
</tr>
<tr>
<td>Payback Factor (Years)</td>
<td>11.32</td>
</tr>
</tbody>
</table>
**BOILER EU-010 FORCED DRAFT FAN PAYBACK SUMMARY SHEET**

**Project Name:** University of Minnesota  
**Date:** 4/18/2014  
**S1 Project Number:** S14-015  
**Cost of Electricity:** 0.1000 $/kWh

---

**S1-CA-ECM-11: Replacement of Boiler EU-010 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-361</td>
<td>607</td>
<td>60</td>
<td>91.70%</td>
<td>29,628</td>
<td>$2,963</td>
<td>95.40%</td>
<td>28,479</td>
<td>$2,848</td>
<td>8,544</td>
<td>9,693</td>
<td>$969</td>
<td>$14,000</td>
<td>$3,200</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td></td>
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<td></td>
</tr>
</tbody>
</table>

**Total Yearly Savings ($)**: $969  
**Total Material and Labor ($)**: $17,200  
**Payback Factor (Years)**: 17.74
**BOILER EU-010 INDUCED DRAFT FAN PAYBACK SUMMARY SHEET**

**Project Name:** University of Minnesota  
**S1 Project Number:** S14-015  
**Date:** 4/18/2014  
**Cost of Electricity:** 0.1000 $/kWh

**S1-CA-ECM-12: Replacement of Boiler EU-010 Induced Draft Fan Motor with High Efficiency Equivalent and Installation of VFD**

<table>
<thead>
<tr>
<th>Line #</th>
<th>Building</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 Baghouse</td>
<td>N/A</td>
<td>607</td>
<td>125</td>
<td>92.20%</td>
<td>61,391</td>
<td>95.40%</td>
<td>59,332</td>
<td>17,800</td>
<td>19,859</td>
<td>19,859</td>
<td>19,859</td>
<td>19,859</td>
<td>19,859</td>
<td>19,859</td>
</tr>
</tbody>
</table>

**Total**

<table>
<thead>
<tr>
<th>Material Cost ($)</th>
<th>Labor Cost ($)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1,986</td>
<td>22,000</td>
</tr>
</tbody>
</table>

**Total Yearly Savings ($):** 19,859  
**Total Material and Labor ($):** 23,986  
**Payback Factor (Years):** 13.44
**BOILER EU-010 BAGHOUSE ID FAN PAYBACK SUMMARY SHEET**

**Project Name:** University of Minnesota  
**S1 Project Number:** S1-015  
**Date:** 4/18/2014  
**Cost of Electricity:** 0.1000 $/kWh

**S1-CA-ECM-13: Replacement of Boiler EU-010 Baghouse ID 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>Baghouse</td>
<td>Local to Baghouse</td>
<td>N/A</td>
<td>B-364</td>
<td>607</td>
<td>125</td>
<td>92.20%</td>
<td>61,391</td>
<td>$6,139</td>
<td>95.40%</td>
<td>59,332</td>
<td>$5,933</td>
<td>17,800</td>
<td>19,859</td>
<td>$1,986</td>
<td>$22,000</td>
<td>$4,700</td>
</tr>
</tbody>
</table>

**Total**  
19,859 $1,986 $22,000 $4,700

**Total Yearly Savings ($)**: $1,986  
**Total Material and Labor ($)**: $22,000  
**Payback Factor (Years)**: 13.44
**BOILER EU-011 FORCED DRAFT FAN PAYBACK SUMMARY SHEET**

**Project Name:** University of Minnesota  
**S1 Project Number:** S14-015  
**Date:** 4/18/2014  
**Cost of Electricity:** 0.1000 $/kWh

**S1-CA-ECM-14: Replacement of Boiler EU-011 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-371</td>
<td>5613</td>
<td>60</td>
<td>93.60%</td>
<td>268,417</td>
<td>$26,842</td>
<td>95.40%</td>
<td>263,352</td>
<td>$26,335</td>
<td>79,006</td>
<td>$4,070</td>
<td>$8,407</td>
<td>$14,000</td>
<td>$3,200</td>
</tr>
</tbody>
</table>

**Total** | | | | | | | | | | | | | | | $4,070 | $8,407 | $14,000 | $3,200 |

- **Total Yearly Savings ($):** $8,407  
- **Total Material and Labor ($):** $17,200  
- **Payback Factor (Years):** 2.05
FUEL OIL PUMP 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>
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</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Main Plant</td>
<td>First Floor</td>
<td>N/A</td>
<td>FOP-A</td>
<td>100</td>
<td>25</td>
<td>89.50%</td>
<td>2.084</td>
<td>$208</td>
<td>99.60%</td>
<td>1.693</td>
<td>$199</td>
<td>588</td>
<td>689</td>
<td>$69</td>
<td>$7,700</td>
<td>$2,150</td>
</tr>
<tr>
<td>2</td>
<td>Main Plant</td>
<td>First Floor</td>
<td>N/A</td>
<td>FOP-B</td>
<td>100</td>
<td>25</td>
<td>89.50%</td>
<td>2.084</td>
<td>$208</td>
<td>99.60%</td>
<td>1.693</td>
<td>$199</td>
<td>588</td>
<td>689</td>
<td>$69</td>
<td>$7,700</td>
<td>$2,150</td>
</tr>
<tr>
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</tr>
</tbody>
</table>

Total Yearly Savings ($) : $138
Total Material and Labor ($) : $18,700
Payback Factor (Years) : 142.95
## S1.AHS-ECM-1: Replacement of Boiler EU-010 Reverse Air Fan Motor with High Efficiency Equivalent

<table>
<thead>
<tr>
<th>Line #</th>
<th>Building</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 Baghouse</td>
<td>N/A</td>
<td>607</td>
<td>30</td>
<td>89.70%</td>
<td>15,145</td>
<td>$1,514</td>
<td>94.10%</td>
<td>14,436</td>
<td>$1,444</td>
<td>0</td>
<td>708</td>
<td>$71</td>
<td>$1,300</td>
<td>$500</td>
</tr>
</tbody>
</table>

Total: 708 $71 $1,300 $500

Total Yearly Savings ($) : $71
Total Material and Labor ($) : $1,800
Payback Factor (Years): 25.42
<table>
<thead>
<tr>
<th>Line #</th>
<th>Building</th>
<th>Floor</th>
<th>Location</th>
<th>Field ID</th>
<th>Annual Hours</th>
<th>Motor Horsepower (HP)</th>
<th>Existing Motor Efficiency (%)</th>
<th>Existing Motor Electric Consumption (kWh)</th>
<th>Existing Motor Electric Costs ($)</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>CWP-1</td>
<td>4380</td>
<td>10</td>
<td>85.70%</td>
<td>38127</td>
<td>$3,813</td>
<td>91.70%</td>
<td>35632</td>
<td>$3,563</td>
<td>0</td>
<td>2,495</td>
<td>$249</td>
<td>$550</td>
<td>$250</td>
</tr>
<tr>
<td>2</td>
<td>Main Plant</td>
<td>First Floor</td>
<td>N/A</td>
<td>CWP-2</td>
<td>4380</td>
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<td>85.70%</td>
<td>38127</td>
<td>$3,813</td>
<td>91.70%</td>
<td>35632</td>
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<td>0</td>
<td>2,495</td>
<td>$249</td>
<td>$550</td>
<td>$250</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
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<td>4,380</td>
<td>$499</td>
<td>$1,100</td>
<td>$500</td>
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</tbody>
</table>

Total Yearly Savings ($) : $499
Total Material and Labor ($) : $1,600
Payback Factor (Years) : 3.21