Pepco C&I Energy Savings Program

Custom Incentives

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1.0 INTRODUCTION

This Custom Incentives Program Manual is intended to provide guidance to the calculation of energy savings associated with the installation of energy efficiency measures (EEMs) and is intended to support the Technical Analysis Study Report. A template for the Technical Analysis Report can be found in Appendix B (as an embedded file).

The Program provides financial incentives at a fixed rate to customers who undertake electricity-saving projects that involve installing energy-efficiency measures that are not covered by the prescriptive or HVAC Programs. Measures are grouped in terms of the following categories:

- Packaged Air-Conditioners and Heat Pumps (includes RTUs, ASHPs, WSHPs, GSHPs)
- Chillers
- Large Motors
- Controls and Energy Management Systems
- Compressed Air Systems
- VFDs on Pumps
- VFDs on Fans
- Domestic Water Heating
- Generic Process Upgrades

Some measures involve replacing an item of equipment with a similar, more-efficient model, while others entail enhancing the performance of existing equipment. For example, a measure may consist of modifying the programming of a control system and perhaps also adding one or more sensors and/or circuit-control devices, or it may involve modifying an existing pump or changing a piping system to reduce pressure drop, such that the motor driving the pump draws less power.

Whenever an incentive exists under the Prescriptive Incentives Program, those incentives must be used instead of incentives under the Custom Incentives Program.

Savings are calculated individually for each energy-efficiency measure (EEM) and then summed to obtain the total savings for the project, with an adjustment made for interactions among measures that would increase or decrease savings. The standardized algorithms provided in Sections 2 through 10 of this manual should be used to calculate measure savings. In addition, a Technical Analysis Study (TAS) report, structured per the template provided in Appendix B, should be prepared for each project. The TAS report will contain complete documentation for the proposed project, and forms a vital element for the formal Impact Evaluation that will be performed at a later time by an evaluation contractor.
The purposes of the TAS report are:

- Identify the customer (organization), key customer representatives and their contact information, and the location of the facility that will host the proposed project.
- Describe the host facility (typically with a photograph and/or sketch showing site layout or floor plan).
- Document monthly electricity use, and identify Pepco account number and meter number.
- Describe the baseline equipment and provide its electricity-use (with estimated load shape\(^1\)) and estimated annual O&M costs.
- Describe the new equipment to be added, together with key performance specifications and expected lifetime, or otherwise complete the description of the measure (i.e., EMS reprogramming and new control functions).
- Provide estimated electricity-use (and estimated load shape) for the retrofit condition.
- Provide the energy and demand savings calculations,\(^2\) together with (1) the source of input parameter numbers, and (2) justification for each assumption made.
- Provide the cost to implement the project, together with a cost breakdown and, when possible, written quotations for major equipment item(s) and estimates of ongoing annual O&M costs.
- Provide the estimated financial incentive and estimated annual cost savings, together with the financial metric(s) requested by the customer (i.e., simple payback, IRR, ROI).

The TAS report is also often used by the customer to get funding approval of the project from upper management.

As noted above, some measures may involve modifying existing controls or energy management systems so they perform more functions and act more effectively to minimize electricity use while still producing the desired or needed service outputs as a function of time. Examples include the installation of VAV fans and sensors and the installation of a multistage efficient chiller, with each of these new systems controlled by an existing energy management system. This type of project will involve reprogramming of the EMS for the new control functions. It is most important that the TAS report fully describe the new equipment recommended, the new ventilation and chiller controls strategies to be implemented, and the specific EMS control functions that require reprogramming.

The TAS report may be prepared by employees of the customer, but most frequently it is prepared by an engineering firm, contractor, or equipment vendor (collectively referred to as “Trade Allies”).

After the TAS report is submitted, together with an application signed by the customer that references the TAS report, an engineer on the Program staff will formally review it and independently check the savings calculations. (The Engineering Manager or a designated Senior Engineer will confirm that the checking was performed correctly.) The TAS report will either be approved or returned to the customer with a written explanation of what modifications are needed. When modifications are required, the revision number and date are noted on the cover, new signatures are affixed, and the TAS report is resubmitted.

After final approval by the Program Office, the customer is authorized to proceed with implementing the project. Program staff will monitor progress and offer advice if this is needed and it is feasible for program staff to provide this assistance.

When the project is completed and operational, a program staff member will visit the facility to verify that the installed project conforms to the proposed project as it was described in the TAS report. All deviations

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\(^1\) Load shape expressed as monthly kWh and kW.
\(^2\) Reductions in Greenhouse Gas emissions or other environmental data should be included when available.
are noted on the Inspection Report, and a record is made of nameplate data and performance data. Photographs are taken if these are permitted by the customer. Copies of documents that show actual project costs are compiled. A Project Completion Report (PCR) is then prepared by a Program staff engineer and then independently checked by a second engineer. The engineers review the Inspection Report and decide whether any deviations noted are such that the savings calculations shown in the TAS report need to be redone, or if they are valid. If new calculations are needed, they are done by the Program staff engineers (not by the individuals who prepared the TAS report). All information is entered into the PCR, including the Inspection Report, documentation showing actual project cost, the TAS report, and any recalculation of savings and incentive amount. The PCR is then sent to Pepco for approval, and when that step is completed, the incentive check is printed and delivered to the customer.

It is anticipated that a large number of trade allies will participate in the program, each with their own way of providing information and calculating savings. Experience has shown that, without guidance, the submittals will generally be of poor quality and most will be returned for correction, which results in delays. Therefore, trade allies are required to use the algorithms in this document to the extent practical. Deviations from these algorithms will be considered with sufficient technical justification.

A high-quality program that produces savings that can be verified by the Evaluation Contractor must have complete and accurate documentation. Our experience shows that when trade allies are informed in advance concerning quality standards, they will readily comply and “do it right the first time,” which is to everyone’s advantage.

2. Packaged Air Conditioners and Heat Pumps (RTUs, ASHPs, WSHPs, GSHPs)

This section covers packaged air conditioners and heat pumps not covered by the HVAC Program such as: RTUs, ASHPs, WSHPs, GSHPs. It is recommended that savings be estimated using a computer simulation (eQuest, EnergyPlus, or software developed by HVAC manufacturers such as Trane), but as an alternative the savings can be calculated using the following method:

\[
\text{Demand Savings} = \frac{\text{Btu/hour}}{1000} \times \left( \frac{1}{\text{EER}_b} - \frac{1}{\text{EER}_q} \right) \times \text{CF}
\]

\[
\text{Energy Savings} = \frac{\text{Btu/hour}}{1000} \times \left( \frac{1}{\text{EER}_b} - \frac{1}{\text{EER}_q} \right) \times \text{EFLH}
\]

**Definition of Variables:**

- **Btu/h =** Cooling capacity in Btu/hour – This value comes from ARI or AHAM rating or manufacturer data.
- **EER\textsubscript{b} =** Efficacy rating of the baseline unit. This data is found in the HVAC and Heat Pump verification summary table. For units < 65,000, SEER and HSPF should be used for cooling and heating savings, respectively.
- **EER\textsubscript{q} =** Efficacy rating of the high Efficiency unit – This value comes from the ARI or AHAM directories or manufacturer data. For units < 65,000, SEER and HSPF should be used for cooling and heating savings, respectively.
- **CF =** Coincidence Factor – This value represents the percentage of the total load which is on during electric system’s Peak Window. This value will be based on existing measured usage and determined as the average number of operating hours during the peak window period.
- **EFLH =** Equivalent Full Load Hours – This represents a measure of energy use by season during the on-peak and off peak periods. This value will be determined by existing measured data of kWh during the period divided by kW at design conditions.
3. Chillers
This measure involves replacing an existing chiller with a high efficiency chiller. Energy is saved as a result of increasing the efficiency of the chiller system.

Baseline Calculation: There have been significant advancements in recent years in the efficiency of cooling equipment. The simple baseline calculation is to utilize the full load efficiency from the chiller manufacturer’s specifications. This is considered a conservative calculation since more savings are likely achieved during part load conditions. The equation for this calculation is:

\[ \text{kWh}_{\text{Base}} = T \cdot (\text{OH}) \cdot (\eta_{\text{Ex}}) \]

Where:
- \(\text{kWh}_{\text{Base}}\) = Energy consumption of existing equipment (kWh)
- \(T\) = Capacity of chiller (tons)
- \(\text{OH}\) = Equivalent full load annual operating hours (hr)
- \(\eta_{\text{Ex}}\) = Full load efficacy of existing chiller (kW/ton)

A complex analysis requires a distribution of operation at part load conditions. The efficiency of the chiller will change depending on the percent loading on the chiller. Manufacturer’s specifications may include part load efficiencies. Alternatively, ASHRAE 90.1 generic chiller curves can be used to develop part-load efficiencies.

For weather-dependent loads, a weather BIN analysis is a common method to apply accurate operating hours within part load conditions. Typical Meteorological Year (TMY) weather data should be examined in comparison with trend data to evaluate the chiller load and annual hours in each weather BIN. In many industrial facilities, the chiller load is dependent on the production. In this case, production records can be used in conjunction with trend data to develop the annual load profile.

Alternatively, if trend data does not exist, assumption can be made based on interviews with facility personnel and observations of chiller operation during facility audits. The equation above is carried out in each load bin.

\[ \sum \text{kWh}_{\text{Base}} = \sum T \cdot (\text{OH}) \cdot (\eta_{\text{Ex}}) \]

Where:
- \(\text{kWh}_{\text{Base}}\) = Energy consumption of existing equipment (kWh)
- \(T\) = Cooling load at given part load condition (tons)
- \(\text{OH}\) = Annual operating hours at given part load condition (hr)
- \(\eta_{\text{Ex}}\) = Efficacy of existing chiller at given part-load condition (kW/ton)

Measure Life: 20 years with proper maintenance.

Retrofit Electricity Demand and Energy Consumption: The existing operating profile is the basis for the retrofit consumption. Since the installation of the chiller will not affect the building load or operating hours, these parameters are identical to the existing analysis. The identical equations are used above with the insertion of the retrofit efficacy.

\[ \text{kWh}_{\text{Ret}} = T \cdot (\text{OH}) \cdot (\eta_{\text{Ret}}) \]

Where:
- \(\text{kWh}_{\text{Ret}}\) = Retrofit energy consumption (kWh)
T = Capacity of chiller (tons)
OH = Equivalent full load annual operating hours (hr)
\( \eta_{\text{Ret}} \) = Full-load efficacy for retrofit chiller (kW/ton)

Or:

\[ kWh_{\text{Ret}} = \sum T(OH)\left(\eta_{\text{Ret}}\right) \]

Where:

- \( kWh_{\text{Ret}} \) = Retrofit energy consumption (kWh)
- T = Cooling load at given part load condition (tons)
- OH = Annual operating hours at given part load condition (hr)
- \( \eta_{\text{Ret}} \) = Efficacy of retrofit chiller at given part load condition (kW/ton)

The electricity demand and energy savings are calculated as follows.

\[ kW_{\text{Saved}} = kW_{\text{base}} - kW_{\text{Ret}} \]
\[ kWh_{\text{Saved}} = kWh_{\text{base}} - kWh_{\text{Ret}} \]

**Chiller Replacement**

This measure involves the replacement of an existing chiller with a more efficient chiller. The following equation applies.

\[ kW_{\text{Saved}} = (\eta_{\text{Ext}} - \eta_{\text{Ret}})T \]

The kWh energy savings should be estimated based on an assumed annual load factor of 55%.

\[ kWh_{\text{Saved}} = (\eta_{\text{Saved}}T)(LF)(Hr) \]

**Free Cooling**

Weather data is used to identify the annual hours in which outdoor air conditions are sufficient to provide water at a low enough temperature to cool equipment that is ordinarily cooled with chilled water. Typically, demand savings may not be present with this measure because the process systems require water temperatures around 55-65°F and a cooling tower cannot meet these temperatures during the peak period. However, in many industrial facilities, air compressors are currently being cooled by chilled water. This equipment can be cooled with as high as 90°F water.

\[ kWh_{\text{Save}} = Tons\left(\frac{kW}{Ton}\right)_{\text{Chill}}(Hr)_{\text{Free}} \]

**Chilled Water Pipe Insulation**

The industry standard 3E+ insulation software can be used as the basis. This program calculates the heat loss in bare and insulated pipes and is identified by the DOE Industrial Technologies Program as an assessment tool for insulation.

\[ kW_{\text{Saved}} = (HL_{3E+})(\eta_{\text{Chill}}) \]
\[ kWh_{\text{Saved}} = (kW_{\text{Saved}})(Hr) \]
Install VSD on Chiller
The installation of a VSD on a chiller will improve the efficiency of the chiller especially at part loads. The methodology is very similar to the chiller retrofit. We assume that there is some excess capacity in the chiller system during peak periods and demand savings will be realized.

\[ kW_{\text{Saved}} = (\eta_{\text{Exist}} - \eta_{\text{VSD}})(T_{\text{Peak}}) \]

Energy savings should be estimated with a load bin analysis with a typical load profile.

\[ kWh_{\text{Saved}} = \Sigma(kW_{\text{Saved}})(Hr) \]

Cooling Tower Replacement
This measure involves the complete replacement of the cooling tower. Savings are based on an improvement in heat exchanging efficiency and an improvement of the chiller efficiency with a lower condenser water temperature.

\[ kW_{\text{Saved}} = (\eta_{\text{Exist}} - \eta_{\text{Prop}})(T_{\text{Peak}}) \]

\[ kWh_{\text{Saved}} = (kW_{\text{Saved}})(Hr) \]

4. LARGE MOTORS
Premium Efficiency motors can provide significant energy savings when an existing motor is old or has been rewound. This measure involves replacing an existing motor with a premium-efficiency motor. Energy is saved as a result of increasing the efficiency of the motor. This measure could also involve downsizing the motor and may be combined with a VSD installation. The efficiencies of permanently wired, poly-phase motors that are at least one horsepower in size and that are used for fan, pumping, and conveyance applications, will be based on information from the National Electric Manufacturers Association (NEMA). Exhibit 1 (below) lists the NEMA motor efficiencies.

<table>
<thead>
<tr>
<th>hp</th>
<th>Standard</th>
<th>New Open Drip-Proof</th>
<th>New Totally Enclosed Fan-Cooled</th>
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<td>6-Pole</td>
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Exhibit 1: Nominal Efficiencies for NEMA Premium™ Induction Motors

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<th>New Open Drip-Proof</th>
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</table>

Baseline Calculation: The baseline power demand (kW) is typically constant during operation. This value would be determined with standard engineering equations or a spot measurement. In the case of the calculated approach, the general engineering equation is:

\[
K_{W_{Base}} = 0.746 \left( \frac{HP}{\eta} \right) (LF)
\]

Where:
- \( K_{W_{Base}} \) = Demand of existing motor
- \( HP \) = Horsepower rating of the existing motor from nameplate
- \( \eta \) = Efficiency of existing motor or NEMA efficiency if motor is replaced
- \( LF \) = Load factor (ratio of actual shaft hp vs. rated hp)
- 0.746 = Conversion factor (hp to kW)

This demand is then multiplied by the annual operating hours (OH) of the motor to estimate the baseline annual energy consumption (kWh). The operating hours may be determined through short-term, run-time monitoring, examination of historical records, or interviews with facility personnel.

\[
kWh_{Base} = K_{W_{Base}} (OH)
\]

In the event that the existing motor’s efficiency is less than the NEMA standard, the baseline will be adjusted to reflect the NEMA Standard Efficiency.

Measure Life: Application specific, life of motor will depend on duty cycle and loading. However, a 15 year average measure life is typical.
Retrofit Power Demand and Energy Consumption: The retrofit power demand and energy consumption are calculated in the identical manner as the baseline demand and consumption.

\[ kW_{Ret} = 0.746 \left( \frac{HP}{\eta} \right) (LF) \]

Where:
- \( kW_{Ret} \) = Demand of retrofit motor (kW)
- \( HP \) = Horsepower rating of the retrofit motor from nameplate (hp)
- \( \eta \) = Efficiency of retrofit motor
- \( LF \) = Load factor (ratio of actual shaft hp vs. rated hp)
- 0.746 = Conversion factor (hp to kW)

This demand is then multiplied by the annual operating hours (OH) of the motor to estimate the baseline annual energy consumption (kWh). This measure does not affect the operating hours of the motor. Thus, the retrofit operating hours should be identical to the baseline operating hours.

\[ kWh_{Saved} = kW_{Ret} (OH) \]

Energy Savings: The energy savings result for the baseline consumption less the total retrofit consumption.

\[ kWh_{Saved} = kWh_{Base} - kWh_{Ret} \]

Demand Reduction: Demand savings result when the power (kW) of the system is reduced during the summer peak period. Since the measure results in a consistent reduction in power during all periods of operation, demand savings will be realized.

\[ kW_{Saved} = kW_{Base} - kW_{Ret} \]

5. ENERGY MANAGEMENT SYSTEMS

Energy Savings Methodologies: In determining the energy savings associated with a Building Automation System (BAS) or Energy Management System (EMS), one must first determine the level of automation. Typically, the BAS controls HVAC systems from a demand perspective (ON/OFF) as well as an energy perspective. The following formulas are representative of the implementation of typical sequences of operation:

\[ \text{Savings} = \text{Motor Savings} + \text{Heating Savings} + \text{Cooling Savings} \]

\[ \text{Motor Savings} = \text{Motor Cost}_{base} - \text{Motor Cost}_{prop} \]

For constant volume fans:

\[ \text{Motor Energy}_{base} = \sum_{\text{motor}} \frac{\text{motor hp x load factor x 0.746 kW / bhp x motor op hrs}_{base}}{\eta_{motor}} \]

\[ \text{Motor Energy}_{prop} = \sum_{\text{motor}} \frac{\text{motor hp x load factor x 0.746 kW / bhp x motor op hrs}_{prop}}{\eta_{motor}} \]
For VAV fans:

\[
\text{Motor Energy}_{\text{base}} = \sum_{\text{motor}} \left( \frac{\text{motor hp} \times \text{load factor} \times 0.746 \text{ kW} / \text{bhp}}{\eta} \right) \times (\% \text{ load}) \times \text{factor}_{\text{base}} \times \text{motor op hrs}_{\text{base}}
\]

\[
\text{Motor Energy}_{\text{prop}} = \sum_{\text{motor}} \left( \frac{\text{motor hp} \times \text{load factor} \times 0.746 \text{ kW} / \text{bhp}}{\eta} \right) \times (\% \text{ load}) \times \text{factor}_{\text{prop}} \times \text{motor op hrs}_{\text{prop}}
\]

\[
\text{Heat Load}_{\text{base}} = \sum \frac{(1.08 \times \text{mixed cfm}_{\text{base}} \times (\text{temp}_{MA_{\text{base}}} - \text{temp}_{DA_{\text{base}}}) \times \text{bin hrs}_{\text{base}})}{\eta_{\text{heating}}} \times 10^6 \text{ Btu/MMBtu}
\]

\[
\text{Heat Load}_{\text{prop}} = \sum \frac{(1.08 \times \text{mixed cfm}_{\text{prop}} \times (\text{temp}_{MA_{\text{prop}}} - \text{temp}_{DA_{\text{prop}}}) \times \text{bin hrs}_{\text{prop}})}{\eta_{\text{heating}}} \times 10^6 \text{ Btu/MMBtu}
\]

\[
\text{Cooling Savings} = \text{Cool Cost}_{\text{base}} + \text{Cool Cost}_{\text{prop}}
\]

\[
\text{Cool Cost} = \text{Cool Load} \times \text{Elec Util Rate}\]

\[
\text{Cool Load}_{\text{elec}} = \sum \frac{(4.5 \times \text{mixed cfm}_{\text{base}} \times (H_{DA_{\text{base}}} - H_{MA_{\text{base}}}) \times \text{bin hrs}_{\text{base}} \times \eta_{\text{cooling elec}})}{12,000 \text{ Btu/ton} - \text{hr}}
\]

\[
\text{Cool Load}_{\text{elec}} = \sum \frac{(4.5 \times \text{mixed cfm}_{\text{prop}} \times (H_{DA_{\text{prop}}} - H_{MA_{\text{prop}}}) \times \text{bin hrs}_{\text{prop}} \times \eta_{\text{cooling elec}})}{12,000 \text{ Btu/ton} - \text{hr}}
\]

\[
\text{mixed cfm}_{\text{base/prop}} = \text{vent cfm}_{\text{base/prop}} + \text{return cfm}_{\text{base/prop}}
\]

Where:

Motor hp = Horsepower of motor
\n\eta_{\text{motor}} = Efficiency of motor from manufacturer published data and verified during the pre-installation inspection
% load = Ratio of the flow in the current bin to the full load capability of the fan or pump
\text{factor}_{\text{base/prop}} = Affinity law relationship between flow and power for the pump or fan
vent cfm_{\text{base}} = Existing ventilation cfm
vent cfm_{\text{prop}} = Proposed ventilation cfm (reduced for some AHUs)
temp_{DA} = Discharge air temperature
temp_{MA} = Temperature of mixed air in temperature bin
H_{DA} = Discharge air enthalpy
H_{MA} = Enthalpy of mixed air in temperature bin
\eta_{\text{heating}} = Efficiency of heating equipment, assuming electrical heating
\eta_{\text{cooling}} = Efficiency of cooling equipment, kW/ton for electric cooling
6. COMPRESSED AIR SYSTEMS

End Use Description: This measure involves a modification of the compressed air system at the facility. Typical measures include installing more efficient equipment, reducing the operating pressure, and/or reducing facility plant air needs.

The end-use can be broken into the two separate systems, supply-side and demand-side. The supply side typically consists of an air compressor, air dryer (for moisture sensitive products and lines), and a storage tank. The three basic types of compressors are rotary screw, reciprocating, and centrifugal. Exhibit 2 (below) compares the options for each type of compressor.

Additionally, the type of control can vary. These include: 1) inlet modulation with unloading, 2) inlet modulation without unloading, 3) load/unload, and 4) on/off. The higher the output pressure, the more work is required by the compressor to deliver the required flow (scfm) to the facility. Thus, the operating pressure will affect the energy consumption of the system. All these factors will result in a different overall efficiency (kW/scfm).

Also, examination of the uses for compressed air could lead to measures to reduce compressed air consumption. Some of these include, using blowers rather than compressed air when high pressure air is not necessary, replacing nozzles, using pressure sensors rather than timed intervals to only purge when necessary, and using water mists to cool hot products rather than compressed air.

<table>
<thead>
<tr>
<th>Compressor Type</th>
<th>Number of Stages</th>
<th>Cooling Method</th>
<th>Lubrication Option</th>
<th>Control Strategy</th>
<th>Typical Specifications</th>
</tr>
</thead>
</table>
| Rotary Screw (Positive Displacement) | • One  
• Two | • Air  
• Water | • Oil  
• Oil-Free | • Automatic Start/Stop  
• Two Step  
• Inlet Modulation w/Unloading  
• Variable Displacement  
• Variable Speed | • 5-600 hp  
• 14-3000 SCFM |
| Reciprocating (Positive Displacement) | • One  
• Two | • <100 hp Air  
• > 75 hp Water | • Oil  
• Oil-Free | • Automatic Start/Stop  
• Two Step  
• Three and Five Step | • 1-600 hp  
• 1-3000 SCFM |
| Centrifugal (Dynamic Displacement) | • Two  
• Four | • Water | • Oil-Free | • Automatic Start/Stop  
• Two Step | • 125-6,000 hp  
• 400-25,000 SCFM |

Energy Efficiency Measures: There are many potential measures associated with the air compressor end-use. However, the measure can be broken down into four distinct categories. These include:

- **Air Compressor Replacement:** A minimum efficiency baseline adjustment may apply depending on the efficiency of the existing equipment.
- **Air Compressor Controls:** This applies to multiple compressor systems and will optimize the operation of the system to operate the most efficient compressor at a given time.
- **Air Compressor Pressure Reduction:** A general rule of thumb is that energy consumption is reduced 1% for every 2 psig of pressure reduction. However, a larger storage-tank volume may be needed to effectively reduce the compressor discharge pressure.
- **Reduction of Air Demand:** Several methods may be used to reduce the air demand of the plant. One of these is the replacement of existing nozzles with nozzles that require less air (such as venturi nozzles), and also to resize the nozzles for the specific application. Another is to use a blower for low pressure applications rather than high pressure compressed air. If air pressure regulators do not exist in the plant, the installation of individual machine pressure...
regulators will reduce the air demand for the system. And, finally, a leak management program should always be instituted and maintained. Although the amount of air leakage is always identified when the compressed air system is analyzed, this measure is not eligible for incentives and savings from these measures are not proposed in this program.

**♦ Install Compressor Air Intake in the Coolest Location:** Whenever feasible, the intake air for an air compressor should come from the coolest source possible. Because cool air is more dense than warm air, a compressor will work less to compress a specific volume of air if the air is cooler. Since the average outdoor temperature is usually well below that in the compressor room, it normally pays to take cool air from outdoors.

**Baseline Calculation:** The power demand of an air compressor is dependent on the air requirements at the facility. The requirements can fluctuate drastically throughout the day. Thus, the facility’s air profile is typically estimated through short-term monitoring of the true RMS kW of the air compressors at the facility. The preferred method is to calculate the annual power demand and energy consumption is with the DOE AirMaster+ software. These programs require an hourly demand profile in power (kW) or flow (scfm). Alternatively, the consumption can be calculated with the manufacturer’s specifications and engineering equations.

Industry standard efficiencies exist for typical compressor and control types. Baseline adjustments only apply to air compressor retrofits when the equipment is replaced. Since other components within the compressed air system are modified when the operating compressor size is reduced, baseline adjustments do not apply.

The baseline AirMaster+ model is used as a basis for the retrofit power demand (kW) and energy (kWh) consumption. The load profile will be modified based on the amount of air reduced through energy efficiency efforts. Parameters such as orifice diameter, pressure and volumetric flow can be used to calculate the reduction in air.

**Retrofit Calculations:** For measures that will install equipment to replace the compressor (e.g., replacing with a blower), the power demand of the blower will be accounted for with the following equation:

$$kW_b = 0.746 \left( \frac{HP}{\eta} \right) (LF)$$

Where:

- $kW_b$ = Power demand of retrofit blower motor (kW)
- $HP$ = Horsepower rating of the retrofit blower motor from nameplate
- $\eta$ = Efficiency of retrofit blower motor
- $LF$ = Load factor (ratio of actual shaft hp vs. rated hp)
- $0.746$ = Conversion factor (hp to kW)

$$kWh_b = kW_b (OH)$$

Where:

- $kWh_b$ = Annual energy consumption of the retrofit blower (kWh)
- $OH$ = Annual operating hours of the blower (hr)

**Demand Reduction:** The demand on the air compressors is permanently reduced and is not weather dependent. Thus, power demand (kW) savings will be achieved. The total demand saved would be determined by the subtracting the demand of any auxiliary equipment added as part of the retrofit from
the electricity demand saved by the air compressors. The air compressor demands are based on
engineering calculations or outputs from the AirMaster+ modeling software.

**Energy Savings:** Energy savings are the Baseline energy consumption minus the Retrofit consumption. The net energy savings results from subtracting the consumption of the auxiliary equipment installed from the energy consumption outputs form the AirMaster+ model.

**Load Shape:** Trended data is used to establish the load shape. This is input into AirMaster+ model or an equivalent calculation methodology and is used as a basis for the retrofit power demand (kW) and energy (kWh) consumption. The load profile will be modified based on the amount of air reduced through energy efficiency efforts. Manufacturer specifications can be used in the case of the replacement of nozzles or demand side equipment.

**Measure Cost:** The measure cost will include the cost of the installation of the demand reducing equipment and any other modifications that may be required to the system to ensure the process is not affected with the retrofit.

**Compressed Air Pressure Reduction**

This measure involves the installation of equipment to allow for the reduction in the discharge. This equipment could be additional storage for the compressed air system or equipment within the system to reduce the overall pressure drop. The rule of thumb is that for every two psi reduction the energy consumption is reduced by 1%.

\[
\text{kW}_{\text{Saved}} \approx (\text{kW}_{\text{Exist}}) \left( \frac{1}{2 \text{psi}} \right) (P)
\]

The demand reduction will occur at all times the system operates. Thus, the kWh energy savings are:

\[
\text{kWh}_{\text{Saved}} = (\text{kW}_{\text{Saved}}) (Hr)
\]

**Compressed Air System Controls**

This measure involves the installation of controls to optimize the operation air compressors in systems with multiple machines. These control systems have the ability to trend data and continue to monitor the demand to ensure that the most efficient compressor is being utilized at any one time. Additionally, the system will help to manage correct system pressure automatically. The existing compressor system must be monitored for a representative period of time and analyzed to completely understand the air demand on the system. Each distinct period of existing operation \((\Sigma \text{kW}_{\text{Exist-i}})\) is analyzed to determine the optimum operating sequence \((\Sigma \text{kW}_{\text{Post-i}})\).

\[
\text{kW}_{\text{Saved}} = \Sigma \text{kW}_{\text{Exist-i}} - \Sigma \text{kW}_{\text{Post-i}}
\]

\[
\text{kW}_{\text{Saved}} = \Sigma [(\text{kW}_{\text{Exist-i}}) (Hr_i)] - \Sigma [(\text{kW}_{\text{Post-i}}) (Hr_i)]
\]

**Air Compressor Replacement**

This measure involves the replacement of an existing air compressor with a more efficient model. In many instances, the retrofit model will be controlled with a variable speed drive. As we expect the air compressor package power (kW/100 cfm) to vary as a function of load, a complete understanding of the system air profile is necessary to estimate the energy savings potential. Since the air compressor’s energy consumption is typically not driven by outdoor air temperature, a weighted average of hours at each specific air demand can be used to estimate the expected peak kW reduction.
Compressed Air Demand Side Retrofit
Several methods may be used to reduce the air demand of the plant. One of these is the replacement of nozzles that require less air, such as venturi nozzles, and also to resize the nozzles for the specific application. Another is to use a blower for low pressure applications rather than high pressure compressed air. If regulators do not exist in the plant, the installation of individual machine pressure regulators will reduce the air demand for the system. And, finally, a leak management program should always be instituted and maintained. Although the amount of air leakage is always identified when the compressed air system is analyzed, this measure is not eligible for incentives and savings have not been proposed with this program.

The average reduction in air use (CFM\textsubscript{Red}) through the installation of equipment is a permanent reduction in energy use. The estimated energy savings relates to the expected air profile after the installation. A complete understanding of the system air profile is necessary to estimate the energy savings potential.

\[
kW_{\text{Saved}} = \sum \left( PP_{\text{Exist} - i} - PP_{\text{Ret} - i} \right) \left( CFM_i \right) \left( Hr_i \right)
\]

\[
kWh_{\text{Save}} = \sum \left( PP_{\text{Exist} - i} - PP_{\text{Ret} - i} \right) \left( CFM_i \right) \left( Hr_i \right)
\]

Install Compressor Air Intake in the Coolest Location

\textbf{Percentage of Savings:} \quad \% = \left( \frac{A_1 - A_2}{A_1} \right) \times 100

Where
\% = Percentage of savings
A\textsubscript{1} = Data from Table 1 = The intake volume required to deliver 1000 cubic feet of free air at the average present temperature in the air compressor room.
A\textsubscript{2} = Data from Table 1 = The intake volume required to deliver 1000 cubic feet of free air at the average annual ambient temperature.
100 = To convert decimal to percentage.

\textbf{Dollar Savings:} \quad $ = \left( \% \times P \times H \times .746 \times C \right) / 100

Where
$ = Dollars saved
\% = Percentage of savings
P = Horsepower of Air Compressor
H = Number of hours per year the air compressor operates
.746 = Conversion Factor = kW/hp
C = $/kWh for electricity
100 = To convert percentage to decimal
## Exhibit 3: Intake Volume Required to Deliver 1000 Cubic Feet of Free Air at 70°F

<table>
<thead>
<tr>
<th>Temp. (°F)</th>
<th>Volume (ft³)</th>
<th>Temp. (°F)</th>
<th>Volume (ft³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>40</td>
<td>943</td>
<td>70</td>
<td>1000</td>
</tr>
<tr>
<td>41</td>
<td>945</td>
<td>71</td>
<td>1002</td>
</tr>
<tr>
<td>42</td>
<td>947</td>
<td>72</td>
<td>1004</td>
</tr>
<tr>
<td>43</td>
<td>949</td>
<td>73</td>
<td>1006</td>
</tr>
<tr>
<td>44</td>
<td>951</td>
<td>74</td>
<td>1008</td>
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<td>1051</td>
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<td>996</td>
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<td>1053</td>
</tr>
<tr>
<td>69</td>
<td>998</td>
<td>99</td>
<td>1055</td>
</tr>
</tbody>
</table>

### Methodology:

Volume = \( 1000 \times (\text{Temp} + 460)/(70 + 460) \)

### Note:

If the existing compressor air intake temperature is within plus or minus 10°F of 70°F, the error introduced by using this table is less than 4%.
7. VFDs on Pumps

**VFD - Centrifugal Pumps**

The measure involves installing a VFD on a centrifugal pump. This measure slows the speed of the pump motor to only supply the necessary fluid to meet the demand of the system. The energy consumption of the system is reduced when the flow of the system is reduced.

**Baseline Power Demand and Energy Consumption:** The baseline power demand (kW) is typically constant during operation. This value would be determined with standard engineering equations or a spot measurement. In the case of the calculated approach, the general engineering equation is:

\[
kw_{\text{Base}} = 0.746 \left( \frac{HP}{\eta} \right) (LF)
\]

Where:

- \( kw_{\text{Base}} = \) Demand of existing motor
- HP = Horsepower rating of the existing motor from nameplate
- \( \eta = \) Efficiency of existing motor or NEMA efficiency if motor is replaced
- LF = Load factor (ratio of actual shaft hp vs. rated hp)
- 0.746 = Conversion factor (hp to kW)

This demand is then multiplied by the annual operating hours (OH) of the motor to estimate the baseline annual energy consumption (kWh). The operating hours may be determined through short-term, run-time monitoring, examination of historical records, or interviews with facility personnel.

\[
kWh_{\text{Base}} = kw_{\text{Base}} (OH)
\]

**Baseline Adjustments:** In general, baseline adjustments do not apply with this measure. There are instances when the Customer may replace the existing motor with a Premium Efficiency motor at the same time the VFD is installed. In the event that the existing motor’s efficiency is less than the NEMA standard, the baseline will be adjusted to reflect the NEMA Standard Efficiency.

**Retrofit Power Demand and Energy Consumption:** The VFD will control the speed of the motor to match the desired flow profile of the system. A centrifugal pump follows the affinity laws relating the flow directly proportional to the speed and power and speed by the theoretical cube root. However, in practice, inefficiencies exist and this relationship is typically equivalent to an exponent of 2.5.

\[
kW_2 = kW_1 \left( \frac{n_2}{n_1} \right)^{2.5}
\]

Where:

- \( kW_1 = \) Known energy demand (kW), typically at 100% speed or flow
- \( kW_2 = \) Energy demand (kW) at different speed, \( n_2 \)
- \( n_1 = \) Speed at condition 1, expressed as a percent
- \( n_2 = \) Speed at condition 2, expressed as a percent
VFD’s exhibit energy and power losses of approximately 2% in larger motors and 5% in smaller motors. Therefore, the VFD controlled 100% flow is typically, less efficient than the baseline condition. Any operation in this region will result in negative savings.

The operating load profile in the retrofit system will vary depending on the application. A pump is usually weather-dependent if it is used for space conditioning. However, a process pump profile may be based on the production rate at the facility. The determination of an accurate assessment for the retrofit operating profile, including flow control methodology, is critical to the retrofit consumption. This activity may include a load analysis, examination of historical weather data, data logging, and/or interviews with facility personnel.

The retrofit energy consumption follows as the sum of the energy consumptions in each flow region.

**Demand and Energy Savings:** Demand savings result when the power (kW) of the system is reduced during the summer peak period. Demand savings will be present in many VFD pumping applications. The system is investigated to estimate the highest possible retrofit demand during the peak period. This value is subtracted from the baseline kW to estimate the demand savings. Demand savings typically do not exist for space conditioning applications. The energy savings are calculated by subtracting the retrofit consumption from the baseline.

**VFDs on Fans**

The measure involves installing a VFD on a ventilation fan. This measure slows the speed of the fan motor to only supply the necessary air flow to meet the demand of the system. The energy consumption of the system is reduced when the flow of the system is reduced.

**Baseline Power Demand and Energy Consumption:** If there is not a mechanism, such as guide vanes or dampers, to restrict the fan flow, the baseline kW demand will be constant for this measure. This value would be determined with standard engineering equations or a spot measurement. In the case of the calculated approach, the general engineering equation is:

\[
kW_{Base} = 0.746 \frac{HP}{\eta} (LF)
\]

Where:

- \( kW_{Base} \) = Demand of existing motor
- \( hp \) = Horsepower rating of the existing motor from nameplate
- \( \eta \) = Efficiency of existing motor or NEMA efficiency if motor is replaced
- \( LF \) = Load factor (ratio of actual shaft hp vs. rated hp)
- 0.746 = Conversion factor (hp to kW)

This demand is then multiplied by the annual operating hours (OH) of the motor to estimate the baseline energy consumption (kWh). The operating hours may be determined through short-term, run-time monitoring, examination of historical records, or interviews with facility personnel.

\[
kWh_{Base} = kW_{Base} (OH)
\]

If guide vanes or dampers exist to restrict the flow, the demand at different flow regions will vary. In this case, ASHRAE fan curves will be used to determine the demand in each flow region.
The operating profile of the fan is critical to achieving an accurate assessment of the baseline consumption. A ventilation fan is almost always weather dependent if it is used for space conditioning. However, a process oriented fan profile may be based on the production rate of the facility. This activity may include a load analysis, examination of historical weather data, data logging, and/or interviews with facility personnel.

**Baseline Adjustments:** In general, baseline adjustments do not apply with this measure. There are instances when the Customer may replace the existing motor with a Premium Efficiency motor at the same time the VFD is installed. In the event that the existing motor’s efficiency is less than the NEMA standard, the baseline will be adjusted to reflect the NEMA Standard Efficiency.

**Retrofit Power Demand and Energy Consumption:** The VFD will control the speed of the motor to match the desired air flow requirements of the ventilation system. A centrifugal fan follows the affinity laws relating the flow directly proportional to the speed and power and speed by the theoretical cube root. However, in practice, inefficiencies exist and this relationship is typically equivalent to an exponent of 2.5.

\[
kW_2 = kW_1 \left(\frac{n_2}{n_1}\right)^{2.5}
\]

Where:
- \(kW_1\) = Known energy demand (kW), typically at 100% speed or flow
- \(kW_2\) = Energy demand (kW) at different speed, \(n_2\)
- \(n_1\) = Speed at condition 1, expressed as a percent
- \(n_2\) = Speed at condition 2, expressed as a percent

VSD’s exhibit energy and power losses of approximately 2% in larger motors, and 5% in smaller ones. Therefore, the VSD controlled 100% flow is typically, less efficient than the baseline condition. Any operation in this region will result in negative savings. If a mechanism to restrict the air flow did not exist in the baseline case, the operating hours flow profile will be determined in the same manner as described above. If a mechanism was present, the retrofit profile is typically identical to the baseline.

The retrofit energy consumption follows as the sum of the energy consumptions in each flow region.

**Demand and Energy Savings:** Demand savings result when the power (kW) of the system is reduced during the summer peak period. Demand savings will be present in many VSD ventilation applications. The system is investigated to estimate the highest possible retrofit demand during the peak period. This value is subtracted from the baseline kW to estimate the demand savings. Demand savings typically do not exist for space conditioning applications.

The energy savings is calculated by subtracting the retrofit consumption form the baseline.

**9. Domestic Water Heating**

The major focus for all measures is electricity savings, but when peripheral fuel savings occur, they should be estimated so the associated cost savings can be taken into account in the measure’s economic analysis. Therefore, the computations are general so as to include electric and fuel-fired heaters. Water heating measures include:

- Insulating the hot water storage tank
Insulating bare hot water circulating lines
Repairing hot water leaks
Lowering hot water temperature settings
Installing a summer hot water heater
Recovering waste heat to heat water
Installing a high efficiency water heater or tankless water heater
Installing faucet flow restrictors.

Insulate Hot Water Storage Tank

An un-insulated or lightly insulated hot water storage tank will lose heat continuously to the surrounding air. To maintain the desired temperature in the tank, the loss must be offset by the addition of more heat. Therefore, extra insulation could be added which would reduce the additional heat required to maintain the desired tank temperature. Tank insulation can be the type that is made for a particular tank model or it can be improvised by wrapping rolled insulation around the tank. In either case, a few precautions should be observed. When insulating a stand-alone hot water storage tank that is fossil fuel fired, the insulation should be installed so that the flue vent and combustion air vents are not blocked. On all types of hot water tanks the insulation should be installed so that it does not impede the function of the safety valve or the drain valve. Additionally, temperature controls should remain uncovered when insulating the tank.

Calculations:

Energy Saved: \[ Q = (A_1 - A_2) \times L \times H \times T_d \]
Where:
- \( Q \) = Btu saved
- \( A_1 \) = From Exhibits 4, 5, or 6 under original heat loss for present diameter of tank
- \( A_2 \) = From Exhibits 4, 5, or 6 on same row under amount of insulation to be installed
- \( L \) = Height of tank that is to be insulated (in feet)
- \( H \) = Hours of operation per year (For continuous: 8,760 hours)
- \( T_d \) = Temperature Difference (°F) = Hot water temperature – Average room temperature

Dollars Saved: \[ $ = \frac{Q \times C}{F \times Eff} \]
Where:
- \( $ \) = Dollars saved per year
- \( Q \) = Btu saved
- \( F \) = Btu factor for electricity: 3413 Btu/kWh
- \( C \) = Cost per unit of fuel
- \( Eff \) = Unit efficiency
## Exhibit 4: Existing Condition – Bare Tank

<table>
<thead>
<tr>
<th>Tank Diameter</th>
<th>Original Heat Loss (Btu.hr⁻¹°F-ft)</th>
<th>New Heat Loss (Btu.hr⁻¹°F-ft)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Addition of 1” Fiberglass*</td>
</tr>
<tr>
<td>1ft - 0 in</td>
<td>5.27</td>
<td>1.03</td>
</tr>
<tr>
<td>2</td>
<td>6.12</td>
<td>1.18</td>
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<tr>
<td>4</td>
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<td>2ft - 0 in</td>
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<td>3ft - 0 in</td>
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<td>3.29</td>
</tr>
<tr>
<td>8</td>
<td>18.77</td>
<td>3.44</td>
</tr>
<tr>
<td>10</td>
<td>19.61</td>
<td>3.59</td>
</tr>
<tr>
<td>4ft – 0 in</td>
<td>20.46</td>
<td>3.74</td>
</tr>
</tbody>
</table>

*Fiberglass: K = 0.35 Btu/hr⁻¹°F-ft²
### Exhibit 5: Existing Condition – Standard Tank (2” Fiberglass)

<table>
<thead>
<tr>
<th>Tank Diameter</th>
<th>Original Heat Loss (Btu.hr⁻¹°F-ft)</th>
<th>New Heat Loss (Btu.hr⁻¹°F-ft)</th>
<th>Addition of 1” Fiberglass</th>
<th>Addition of 2” Fiberglass</th>
<th>Addition of 3” Fiberglass</th>
</tr>
</thead>
<tbody>
<tr>
<td>1ft - 0 in</td>
<td>0.60</td>
<td></td>
<td>0.44</td>
<td>0.36</td>
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<tr>
<td>2</td>
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<td>0.50</td>
<td>0.40</td>
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</tr>
<tr>
<td>4</td>
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<td></td>
<td>0.56</td>
<td>0.44</td>
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</tr>
<tr>
<td>6</td>
<td>0.85</td>
<td></td>
<td>0.61</td>
<td>0.49</td>
<td>0.41</td>
</tr>
<tr>
<td>8</td>
<td>0.94</td>
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<td>0.67</td>
<td>0.53</td>
<td>0.45</td>
</tr>
<tr>
<td>10</td>
<td>1.02</td>
<td></td>
<td>0.73</td>
<td>0.58</td>
<td>0.48</td>
</tr>
<tr>
<td>2ft - 0 in</td>
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<td></td>
<td>0.79</td>
<td>0.62</td>
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<tr>
<td>8</td>
<td>1.43</td>
<td></td>
<td>1.01</td>
<td>0.79</td>
<td>0.66</td>
</tr>
<tr>
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<td>1.51</td>
<td></td>
<td>1.07</td>
<td>0.87</td>
<td>0.69</td>
</tr>
<tr>
<td>3ft - 0 in</td>
<td>1.60</td>
<td></td>
<td>1.13</td>
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<td>0.73</td>
</tr>
<tr>
<td>2</td>
<td>1.68</td>
<td></td>
<td>1.19</td>
<td>0.93</td>
<td>0.76</td>
</tr>
<tr>
<td>4</td>
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<td>1.01</td>
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<tr>
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<td></td>
<td>1.36</td>
<td>1.06</td>
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</tr>
<tr>
<td>10</td>
<td>2.01</td>
<td></td>
<td>1.41</td>
<td>1.10</td>
<td>0.91</td>
</tr>
<tr>
<td>4ft – 0 in</td>
<td>2.09</td>
<td></td>
<td>1.47</td>
<td>1.14</td>
<td>0.94</td>
</tr>
</tbody>
</table>

### Exhibit 6: Existing Condition – Energy Efficient Tank (4” Fiberglass)

<table>
<thead>
<tr>
<th>Tank Diameter</th>
<th>Original Heat Loss (Btu.hr⁻¹°F-ft)</th>
<th>New Heat Loss (Btu.hr⁻¹°F-ft)</th>
<th>Addition of 1” Fiberglass</th>
<th>Addition of 2” Fiberglass</th>
<th>Addition of 3” Fiberglass</th>
</tr>
</thead>
<tbody>
<tr>
<td>1ft - 0 in</td>
<td>0.36</td>
<td></td>
<td>0.30</td>
<td>0.27</td>
<td>0.24</td>
</tr>
<tr>
<td>2</td>
<td>0.40</td>
<td></td>
<td>0.34</td>
<td>0.30</td>
<td>0.27</td>
</tr>
<tr>
<td>4</td>
<td>0.44</td>
<td></td>
<td>0.37</td>
<td>0.33</td>
<td>0.29</td>
</tr>
<tr>
<td>6</td>
<td>0.49</td>
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<td>0.41</td>
<td>0.36</td>
<td>0.32</td>
</tr>
<tr>
<td>8</td>
<td>0.53</td>
<td></td>
<td>0.45</td>
<td>0.39</td>
<td>0.34</td>
</tr>
<tr>
<td>10</td>
<td>0.58</td>
<td></td>
<td>0.48</td>
<td>0.42</td>
<td>0.37</td>
</tr>
<tr>
<td>2ft - 0 in</td>
<td>0.62</td>
<td></td>
<td>0.52</td>
<td>0.45</td>
<td>0.40</td>
</tr>
<tr>
<td>2</td>
<td>0.66</td>
<td></td>
<td>0.55</td>
<td>0.48</td>
<td>0.42</td>
</tr>
<tr>
<td>4</td>
<td>0.71</td>
<td></td>
<td>0.59</td>
<td>0.51</td>
<td>0.45</td>
</tr>
<tr>
<td>6</td>
<td>0.75</td>
<td></td>
<td>0.62</td>
<td>0.54</td>
<td>0.47</td>
</tr>
<tr>
<td>8</td>
<td>0.79</td>
<td></td>
<td>0.66</td>
<td>0.57</td>
<td>0.50</td>
</tr>
<tr>
<td>10</td>
<td>0.87</td>
<td></td>
<td>0.69</td>
<td>0.60</td>
<td>0.52</td>
</tr>
<tr>
<td>3ft - 0 in</td>
<td>0.88</td>
<td></td>
<td>0.73</td>
<td>0.63</td>
<td>0.55</td>
</tr>
<tr>
<td>2</td>
<td>0.93</td>
<td></td>
<td>0.76</td>
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<td>0.58</td>
</tr>
<tr>
<td>4</td>
<td>0.97</td>
<td></td>
<td>0.80</td>
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<td>0.60</td>
</tr>
<tr>
<td>6</td>
<td>1.01</td>
<td></td>
<td>0.83</td>
<td>0.71</td>
<td>0.63</td>
</tr>
<tr>
<td>8</td>
<td>1.06</td>
<td></td>
<td>0.87</td>
<td>0.74</td>
<td>0.65</td>
</tr>
<tr>
<td>10</td>
<td>1.10</td>
<td></td>
<td>0.91</td>
<td>0.77</td>
<td>0.68</td>
</tr>
<tr>
<td>4ft – 0 in</td>
<td>1.14</td>
<td></td>
<td>0.94</td>
<td>0.80</td>
<td>0.70</td>
</tr>
</tbody>
</table>
**Insulate Bare Hot Water Circulating Lines**

Many large buildings are designed with a service hot water circulating loop. In this system, hot water is continuously pumped around a piping loop within the building. This is done to insure an almost instantaneous supply of hot water whenever a water faucet is opened. In some multistory buildings, this may be the only way to supply the upper stories with a sufficient supply of hot water. Because the piping loop is always hot from the circulating water, an un-insulated loop will constantly lose heat to the building. This heat loss can be reduced by adding insulation to the pipes in the loop. Further savings can be realized if the circulating pump can be shut down during the unoccupied hours.

Energy Saved: \[ Q = (A_1 - A_2) \times B \times C \times T_d \]

Where:

- \( Q \) = Btu saved
- \( A_1 \) = See Exhibit 7 and 8 = heat loss per linear foot of bare pipe
- \( A_2 \) = See Exhibits 7 and 8 = heat loss per linear foot of bare pipe in same row under the amount of insulation to be added
- \( B \) = Linear feet of pipe
- \( H \) = Hours per year that hot water is circulating (For continuous: 8,760 hours)
- \( T_d \) = Temperature Difference (°F) = Hot water temperature – Average room temperature

See Exhibit 9 for recommended hot water temperature for domestic service.

Dollars Saved: \[ $ = \frac{Q \times C}{F \times Eff} \]

Where:

- \$ = Dollars saved per year
- \( Q \) = Btu saved
- \( F \) = Btu factor for fuel used (see Insulating Tank measure)
- \( C \) = Cost per unit of fuel
- \( Eff \) = Unit efficiency

<table>
<thead>
<tr>
<th>Nominal Size (Inches)</th>
<th>Bare Pipe (Btu/hr·°F-ft)</th>
<th>New Heat Loss (Btu/hr·°F-ft) with Fiberglass</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>1&quot;</td>
</tr>
<tr>
<td>0.50</td>
<td>0.59</td>
<td>0.10</td>
</tr>
<tr>
<td>0.75</td>
<td>0.73</td>
<td>0.12</td>
</tr>
<tr>
<td>1.00</td>
<td>0.89</td>
<td>0.13</td>
</tr>
<tr>
<td>1.25</td>
<td>1.10</td>
<td>0.15</td>
</tr>
<tr>
<td>1.50</td>
<td>1.24</td>
<td>0.17</td>
</tr>
<tr>
<td>2.00</td>
<td>1.52</td>
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<tr>
<td>2.50</td>
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<td>0.23</td>
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</tr>
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<td>0.36</td>
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<tr>
<td>5.00</td>
<td>3.30</td>
<td>0.39</td>
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<td>6.00</td>
<td>3.87</td>
<td>0.46</td>
</tr>
<tr>
<td>8.00</td>
<td>4.93</td>
<td>0.57</td>
</tr>
<tr>
<td>10.0</td>
<td>6.04</td>
<td>0.696</td>
</tr>
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</table>
### Exhibit 8: Copper Tube Heat Loss

<table>
<thead>
<tr>
<th>Nominal Size (Inches)</th>
<th>Bare Pipe (Btu/hr-°F-ft)</th>
<th>New Heat Loss (Btu/hr-°F-ft) with Fiberglass</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.50</td>
<td>0.34</td>
<td>0.08</td>
</tr>
<tr>
<td>0.75</td>
<td>0.45</td>
<td>0.09</td>
</tr>
<tr>
<td>1.00</td>
<td>0.56</td>
<td>0.11</td>
</tr>
<tr>
<td>1.25</td>
<td>0.67</td>
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<td>0.78</td>
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<td>2.00</td>
<td>0.98</td>
<td>0.17</td>
</tr>
<tr>
<td>2.50</td>
<td>1.18</td>
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</tr>
<tr>
<td>3.00</td>
<td>1.37</td>
<td>0.22</td>
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<tr>
<td>3.50</td>
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</tr>
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<td>4.00</td>
<td>1.75</td>
<td>0.28</td>
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<tr>
<td>5.00</td>
<td>2.12</td>
<td>0.35</td>
</tr>
<tr>
<td>6.00</td>
<td>2.48</td>
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</tr>
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<td>8.00</td>
<td>3.18</td>
<td>0.50</td>
</tr>
<tr>
<td>10.0</td>
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</table>

### Exhibit 9: Recommended Hot Water Temperatures for Domestic Service

<table>
<thead>
<tr>
<th></th>
<th>Temp.</th>
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<tbody>
<tr>
<td>Hand Washing</td>
<td>105°F</td>
</tr>
<tr>
<td>Shaving</td>
<td>115°F</td>
</tr>
<tr>
<td>Showers</td>
<td>110°F</td>
</tr>
</tbody>
</table>

### Repair Hot Water Leaks

Faucets can be a common source of energy loss as hot water leaks through faulty washers. Water-heating energy dollars can be saved by repairing these and other leaks.

\[
\text{Energy Saved: } H = \frac{8.33/\text{gal} \times Q \times T_d \times 60 \text{ min/hr} \times 8,760 \text{ hrs/yr}}{
\text{Where:}}
\]

\[
H = \text{heat saved, Btu/Yr} \\
Q = \text{flow from leak, gallons/minute} \\
T_d = \text{Tank water temperature minus makeup water temperature}
\]

\[
\text{Dollars saved: } S = \frac{H \times C}{F \times \text{Eff}}
\]

Where:

\[
C = \text{cost of fuel per unit} \\
F = \text{heat value of the fuel, Btu/unit (see Insulating Tank measure)} \\
\text{Eff} = \text{Efficiency of the water heater}
\]
Lower Hot Water Temperature Setting

Most often domestic hot water equipment will come from the factory with the temperature set at some arbitrary setting (most often 140°F). If the service technician that installs the equipment does not check this setting, it is often much hotter than actually needed. Substantial savings can be realized by adjusting the hot water system to the correct temperature to suit the task for which the water is intended. This adjustment can usually be done with in-house personnel in very little time, and it is an easy way to save energy and money.

Energy to heat water: \[ Q_n = \frac{[A \times B \times 8.33 \times T_d]}{1,000,000} \]

Where:
- \( Q_n = \) MMBtu/Yr required for the particular temperature setting wherein
  - \( n = 1 \) for the original temperature setting
  - \( n = 2 \) for the new temperature setting
- \( A = \) gallons of hot water per day = directly from Exhibit 10 or from the following:
  - (gal. per shift per employee) x (shifts/day) x (employees/shift)
- \( B = \) days of operation per year
- 8.33 = conversion factor (Btu/gal-°F)
- \( T_d = \) Temperature difference between hot water setting and makeup water temperature

<table>
<thead>
<tr>
<th>Exhibit 10: Hot Water Consumption Rates</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Type of Building</strong></td>
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<td>----------------------</td>
</tr>
<tr>
<td>Apartment Dwellings</td>
</tr>
<tr>
<td></td>
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<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>Dormitories</td>
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<tr>
<td></td>
</tr>
<tr>
<td>Hospitals</td>
</tr>
<tr>
<td>Hotels</td>
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<tr>
<td></td>
</tr>
<tr>
<td>Motels</td>
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<td></td>
</tr>
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<td></td>
</tr>
<tr>
<td>Nursing Homes</td>
</tr>
<tr>
<td>Office Buildings</td>
</tr>
<tr>
<td>Restaurants</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>Schools</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>Industrial &amp; Commercial for standard wash fixtures</td>
</tr>
<tr>
<td></td>
</tr>
</tbody>
</table>
Cost per MMBtu: \[ M = \frac{C \times 1,000,000}{F \times \text{Eff}} \]

Where:
- \( M \) = \$/MMBtu
- \( C \) = \$/unit of fuel
- \( F \) = Fuel conversion factor (see Insulating Tank measure)
- \( \text{Eff} \) = Efficiency of the water heater

Savings in dollars from lowering hot water temperature setting: \[ S = M \times [Q_1 - Q_2] \]

Where:
- \( S \) = Cost savings
- \( M \) = Cost per MMBtu
- \( Q_1 \) = MMBtu at original temperature setting
- \( Q_2 \) = MMBtu at new temperature setting

**Install an Electric Summer Water Heater**

In many buildings, the heating systems (water or steam) provide primary heat for the domestic hot water system by means of a boiler side-arm heat exchanger. While this is satisfactory during the heating season when the boiler is firing at high efficiency, demand for boiler heat in summer will probably be limited to hot water production only. Operating large heating boilers at light loads to provide domestic hot water results in low boiler efficiency. To reduce energy losses due to low boiler efficiency in summer, install a separate hot water heater or boiler sized to the hot water demand. Shut down the heating boiler in the summer and produce domestic hot water at improved efficiency.

Energy to heat water: \[ H = [A \times B \times 8.33 \times T_d] \]

Where:
- \( H \) = Btu/Yr to heat the water
- \( A \) = gallons of hot water per day = directly from Exhibit 10 or from the following:
  - (gal. per shift per employee) x (shifts/day) x (employees/shift)
- \( B \) = days of operation per year during non-heating season
- 8.33 = conversion factor (Btu/gal-0F)
- \( T_d \) = Temperature difference between hot water setting and makeup water temperature

Total heat saved: \[ H_t = \frac{H}{\text{Boiler Efficiency at low load}} - \frac{H}{\text{Water Heater Efficiency}} \]

Dollars saved: \[ S = \frac{H_t \times C}{F} \]

Where:
- \( H_t \) = Total heat saved, Btu/Yr
- \( C \) = Cost of fuel per unit
- \( F \) = Heat value of electricity: 3,413 Btu/kWh

**Recover Waste Heat to Produce Hot Water**

Hot water for space heating, washing or process use may be preheated by using one of several low grade heat sources that are usually wasted. Such sources may be flue gas from heating equipment, boilers, and commercial ovens; heated process fluids; and refrigeration equipment. Recovery of this waste heat through the use of standard heat exchange equipment can reduce the annual costs for producing hot water.

Quotes for heat exchangers should be obtained from manufacturer’s representatives or mechanical contractors. Prices may vary greatly, depending on the type of exchangers selected and the materials.
required by the service. If condensation of an exhaust stream is expected, such as flue gas heat recovery, the exchanger will be sized based on the maximum rate of water condensation. Waste heat recovery equipment specifications will include the amount of heat produced for heating water to a specified temperature. Waste heat recovery from refrigeration compressors is widely used in the food (sales and restaurant) industry. To obtain a quote, vendors will need to know expected flows, temperatures, pressures, capacity required (Btu/hr) and nature of the fluids handled.

Install a High Efficiency Hot Water Heater

The ENERGY STAR Residential Water Heating program has established energy performance criteria for the following types of hot water heaters: electric resistance storage and tankless heaters, high efficiency gas storage and tankless heaters, heat pump water heaters, and solar water heating systems. These new products produce significant energy savings compared to older units, for they are heavily insulated and heat only the amount of water required. Furthermore, small units can be dispersed throughout a commercial or industrial building to provide hot water for local needs. This will decrease the line losses that would occur with centralized systems.

Energy to heat water:  
\[ Q = \left[ A \times 8.33 \times T_d \right] / 1,000,000 \]

Where:
- \( Q \) = MMBtu/Yr required for hot water at a given temperature
- \( A \) = gallons of hot water per day = directly from Exhibit 10 or from the following:
  \( (\text{gal. per shift per employee}) \times (\text{shifts/day}) \times (\text{employees/shift}) \)
- \( B \) = days of operation per year
- 8.33 = conversion factor (Btu/gal-0F)
- \( T_d \) = Temperature difference between hot water setting and makeup water temperature

Cost per MMBtu:  
\[ M = \left[ C \times 1,000,000 \right] / F \]

Where:
- \( M \) = $/MMBtu
- \( C \) = $/unit of fuel
- \( F \) = Fuel conversion factor (see Insulating Tank measure)

Savings in dollars with high efficiency hot water heater:  
\[ S = Q \times [M_p/E_p - M_n/E_n] \]

Where:
- \( S \) = Dollars saved
- \( Q \) = MMBtu used to heat water
- \( E_p \) = Present unit efficiency (see Exhibit 11)
- \( E_n \) = New unit efficiency (see Exhibit 11)
- \( M_p \) = Present cost per MMBtu
- \( M_n \) = New cost per MMBtu
Exhibit 11: Typical Equipment Efficiencies

<table>
<thead>
<tr>
<th>System</th>
<th>Efficiency Factor</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Old</td>
</tr>
<tr>
<td>Gas or oil-fired heating boilers used year-round but with</td>
<td>0.35</td>
</tr>
<tr>
<td>domestic hot water as the only summer load</td>
<td></td>
</tr>
<tr>
<td>Separate gas-fired water heater</td>
<td>0.55</td>
</tr>
<tr>
<td>Separate electric water heater</td>
<td>0.90</td>
</tr>
<tr>
<td>Electric heat pump water heater</td>
<td>--</td>
</tr>
<tr>
<td>Tankless electric water heater</td>
<td>--</td>
</tr>
<tr>
<td>Solar water heating systems (solar fraction = 0.50)*</td>
<td>--</td>
</tr>
<tr>
<td>Gas or oil-fired heating boilers used year-round but with</td>
<td>0.35</td>
</tr>
<tr>
<td>domestic hot water as the only summer load</td>
<td></td>
</tr>
<tr>
<td>Separate gas-fired water heater</td>
<td>0.55</td>
</tr>
</tbody>
</table>

*Solar Fraction: The fraction of the annual water heating load satisfied by solar energy.

Install Faucet Flow Restrictors
Lavatory faucets generally waste water due to flow rates higher than necessary with which to wash. These excessive flow rates are usually in the range of 3 gallons per minute. By installing a flow restrictor, the rate can be lowered to 1.5 gallons per minute.

Energy saved: \[ H = [Q \times 8.33 \times T_d] \]

Where:
- \( H \) = Btu/Yr to heat the water
- \( Q \) = flow rate savings, gallons per year (Assume hand-washing at 1.5 gal/day per person)
- 8.33 = conversion factor (Btu/gal-0°F)
- \( T_d \) = Temperature difference between hot water setting and makeup water temperature

Dollars saved = \[ \frac{H \times C}{F \times \text{Eff}} \]

Where:
- \( C \) = cost of fuel per unit
- \( F \) = heat value of electricity, Btu/unit
- \( \text{Eff} \) = Unit efficiency

10. GENERIC PROCESS UPGRADES
The majority of the energy consumption and energy efficiency opportunities in industrial facilities exist within the actual production process. This end use consists of specific equipment used in the production lines at a facility and are varied depending on the applications ranging from production equipment to heat rejection equipment such as cooling towers.

Energy Efficiency Measures: There are countless measures associated with this end use depending on the specific process and facility involved. This section discusses generic process improvements that apply to a large number of industrial facilities.

♦ Facility Process Improvement: A facility process improvement involves a measure that reduces the overall production efficiency (kWh/unit produced). This will account for a retrofit that will allow for an increase in production with the same or increased energy use, but results
in a net reduction in kWh/unit production. In this instance, the difference in the overall plant or system production efficiency determines the energy savings.

♦ **Process Cooling Tower Upgrade:** This energy efficiency measure involves upgrading the existing inefficient cooling towers with energy efficient systems that have improved heat transfer enhancement.

♦ **Hydraulic Process Improvement:** A retrofit to a hydraulic pump and motor system can reduce energy consumption during the clamp period of the cycle.

**Facility Process Improvement**

This measure will pay incentives for the installation of new, high-efficiency equipment to meet the expanded process needs of an existing facility or to accommodate new production loads. Projects that involve modifying an existing operation, structure or process due to growth or expansion will also be included under this measure.

In general, the calculation methodology is the same for the specific process improvements. The calculation involves the difference in production efficiency (kW/unit, kWh/unit). The incentives for retrofit measures with increased capacity will be based on the post-installation production. In general, the following equations apply:

\[
\begin{align*}
\text{kW}_{\text{Saved}} &= \left( \frac{\text{kW}_{\text{Exist}}}{\text{Unit}_{\text{Exist}}} \right) - \left( \frac{\text{kW}_{\text{Ret}}}{\text{Unit}_{\text{Ret}}} \right) \\
\text{kWh}_{\text{Saved}} &= \left( \frac{\text{kWh}_{\text{Exist}}}{\text{Unit}_{\text{Exist}}} \right) - \left( \frac{\text{kWh}_{\text{Ret}}}{\text{Unit}_{\text{Ret}}} \right)
\end{align*}
\]

**Process Cooling Tower Upgrade**

This measure involves the upgrades of the cooling tower used to cool equipment in the process or the product. Savings are based on an improvement in heat exchanging efficiency and an improvement of the chiller efficiency, if applicable, with a lower condenser water temperature.

\[
\begin{align*}
\text{kW}_{\text{Saved}} &= (\eta_{\text{Exist}} - \eta_{\text{Prop}})(T_{\text{Peak}}) \\
\text{kWh}_{\text{Saved}} &= (\text{kW}_{\text{Saved}})(Hr)
\end{align*}
\]

**Hydraulic Process Improvement**

A hydraulic system uses significant energy to maintain pressure throughout the entire cycle. Additionally, the hydraulic fluid must be cooled. Often times, this is done by mechanical cooling. A retrofit to a hydraulic pump and motor system can reduce the energy consumption during specific periods of the cycle. This specifically occurs during the clamp period of the cycle. A torque controlled servo motor can maintain the pressure of the fluid during clamp and hold periods at almost no power consumption. The speed of the shaft is constantly monitored to maintain the pressure in the system. Additionally, the requirement for hydraulic fluid cooling is eliminated. Monitoring of the system must be performed to completely understand the cycle and when the system can save energy.

\[
\begin{align*}
\text{kW}_{\text{Saved}} &= \text{kW}_{\text{Ave–Exist–Cycle}} - \text{kW}_{\text{Ave–Ret–Cycle}} \\
\text{kWh}_{\text{Saved}} &= \sum \text{kW}_{\text{Saved–period–i}}(Hr_{\text{Period–i}})
\end{align*}
\]
APPENDIX A: Instructions for Preparing a Technical Analysis Study Report

INSTRUCTIONS FOR COMPLETING TECHNICAL ANALYSIS STUDY REPORT

The Technical Analysis Study (TAS) report is the key document in Pepco’s Custom Incentive Program application process. The TAS report is to clearly describe the energy efficiency/process improvement opportunity, with concise and well-documented presentations of the analysis method used to estimate energy savings, and the assumptions used to generate project capital cost estimates.

INSTRUCTIONS FOR EACH SECTION ARE PRESENTED HIGHLIGHTED IN GREEN ITALICS THESE INSTRUCTIONS WOULD NOT, OF COURSE, APPEAR IN THE REPORT.

AREAS WHERE THE INTERESTED PARTY MUST ENTER COMPANY SPECIFIC DATA, OR ENERGY EFFICIENCY MEASURE (EEM) DATA ARE HIGHLIGHTED IN YELLOW.

Audit-based scoping studies designed to identify all potential energy-efficiency upgrade opportunities at a facility would be inputs to the TAS report.

The principal purpose of the TAS report is to thoroughly document the engineering methods, assumptions and calculations, and the estimated project capital cost, for each measure that comprises a project. Other key points:

♦ The principal authors of the report must be named, as well as the names of individuals who reviewed and approved the report.
♦ Use the specific Section headings and Appendix titles contained in the TAS report template. This will facilitate preparation and review.
♦ Estimates of planned installation dates (project start and completion) are very important, and will be included in Section 1.2.
♦ Clear, concise, well-documented and accurate estimates of project benefits (electricity savings and productivity enhancements) are critical elements of the TAS report. A summary of the method used to estimate savings and the results will be presented in Section 1.3. Detailed calculations will be presented in Appendix E. The methods and calculation spreadsheets attached to these Instructions will form the basis for all savings estimates. These methods are presented in more detail in Section 3 of the Technical Reference Manual. Generally:
  • Simple algorithms can be used to calculate savings for all measures with savings of less than 300,000 kWh/year (incentives of less than $15,000) and for all lighting, motor replacement, and water-heating measures.
  • End-use metered data will be provided for process improvement, air compressor, HVAC, cooling tower, VFD, controls and refrigeration opportunities with savings of 300,000 kWh/year or more. Building simulation modeling (for example, eQuest, Trace or DOE-2) will be used in analyzing HVAC applications. Compressor simulation models (for example, AirMaster+) will be used in analyzing compressor applications.
♦ The Program Baseline will always be discussed (in Section 1.3.1), even if the baseline is the existing equipment. Generally, the baselines are:
  • Existing equipment for process improvements and projects (such as adding control systems) that involve enhancing existing equipment
  • Existing equipment for lighting replacements
  • ASHRAE 90.1 Standards for direct HVAC system replacement
  • NEMA Standards for motor replacement
  • MotorMaster+ for compressor replacement.
All exhibits and attachments will be clearly labeled. There will be a list of exhibits in the Table of Contents. All Excel exhibits that are pasted into the text (e.g., Exhibits 1, 2, A-1, B-1, C-1) will be included with the TAS in electronic format. Excel spreadsheets should be used to calculate savings. An electronic copy of the spreadsheet also should be provided with the TAS report.

These reports will be bound, with presentation-style report covers and backs. The reports will be printed two-sided; each section will begin on the right-hand side of a page. Subsections (e.g., 1.1 or 1.1.1) will begin at the top of a new page.
APPENDIX B:
Technical Analysis Study Report

(Provided as separate MS WORD File)