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# Bangladesh Industrial Energy Efficiency Opportunities Assessment

## Phase 1: Industry Energy Use Profile and Opportunities Analysis

August 25, 2012

This document was prepared for the United States Agency for International Development (USAID) by ICF International under Cooperative Agreement No. AID-OAA-L-11-00003-00.

**Bangladesh Industrial Energy Efficiency Opportunities Assessment**

**Deliverable 3: Industry Energy Use Profile and Opportunities Analysis Report**



August 2012

This document was prepared for the United States Agency for International Development (USAID) by ICF International under Cooperative Agreement No. AID-OAA-L-11-00003000.

# EXECUTIVE SUMMARY

This report is prepared under USAID's "**Industrial Energy Efficiency Opportunities Assessments in Bangladesh,"** a project under ICF's current Leader with Associates Cooperative Agreement with USAID entitled *Energy Efficiency for Clean Development Program (EECDP), No. AID-OAA-L-11-00003-00*. It accompanies the **Task 1: Industry Opportunities and Profile Report,** prepared in March 2012, and presents a summary of Phase I activities and findings of the assessment.

This Phase I report includes the following elements:

- ***Energy use profiles of four selected sectors.*** The energy use profiles are presented in terms of energy use by process end use (such as motors, boilers, compressed air, etc.), and by energy source (such as electricity, natural gas and fuel oil). In Task I four sectors were selected for the detailed assessment of energy efficiency opportunities, and these sectors include the following manufacturing sectors: textile, jute, steel re-rolling and frozen food.
- ***Estimated implementation of energy efficient opportunities (EE).*** Based on site-assessments of a sample of plants in each of the four sectors the implementation of EE opportunities in these was defined. This section also provides an indication of the opportunity to implement EE opportunities where they are not yet implemented.
- ***Estimated energy savings if EE opportunities are implemented.*** The potential energy savings were estimated for the scenario where all the identified technically feasible opportunities are implemented.
- ***Cost-benefit analysis of top EE opportunities.*** The EE opportunities with the largest technical savings potentials were identified and associated cost-benefit analysis was conducted for each top opportunity.

The scope of the study included the development of broad profiles for the top eight energy-consuming industrial sectors within Bangladesh, from which four sectors were selected for more detailed analysis of energy-saving opportunities. A separate report, titled: *Task I: Industry Opportunities and Profile Report* (dated March 25, 2012), provides the industry sector profiles of the top eight energy-consuming industrial sectors, and the selected four sectors together with the selection methodology.

The four sectors selected for the more detailed analysis of energy-savings opportunities are assessed in this Phase I report. These four Bangladesh industrial sectors include:

- Textile manufacturing (textile dyeing and processing, exclusively)
- Steel re-rolling
- Jute manufacturing
- Frozen food processing

Together, textiles, jute, and frozen foods constitute more than 85 percent of total exports from Bangladesh and are vital to Bangladesh's export earnings. Though steel re-rolling mills are not direct export contributors, they are important for domestic infrastructure development and growth of the country's light engineering industries. These four sectors have seen rapid growth in the past few years and are expected to continue on their present growth trajectories.

The comprehensive methodology employed in this study integrates two areas of energy management analysis: (1) Energy ***performance benchmarking***; and (2) Energy conservation ***potential analysis***.

A key element in the study is the assessment of a sample of plants in each of the four sectors. The plant assessments were performed according to the following main steps: (1) industry recruitment; (2) on-site assessments; and (3) data collection from secondary sources. A total of 15 plants participated in the study.

The results of the benchmarking analysis provide an indication of how many best practices are currently implemented in the selected Bangladesh industrial sectors and how many best practices can still be implemented. These market penetration rates are used to inform the energy conservation potential analysis.

In this study energy performance considers two performance indicators:

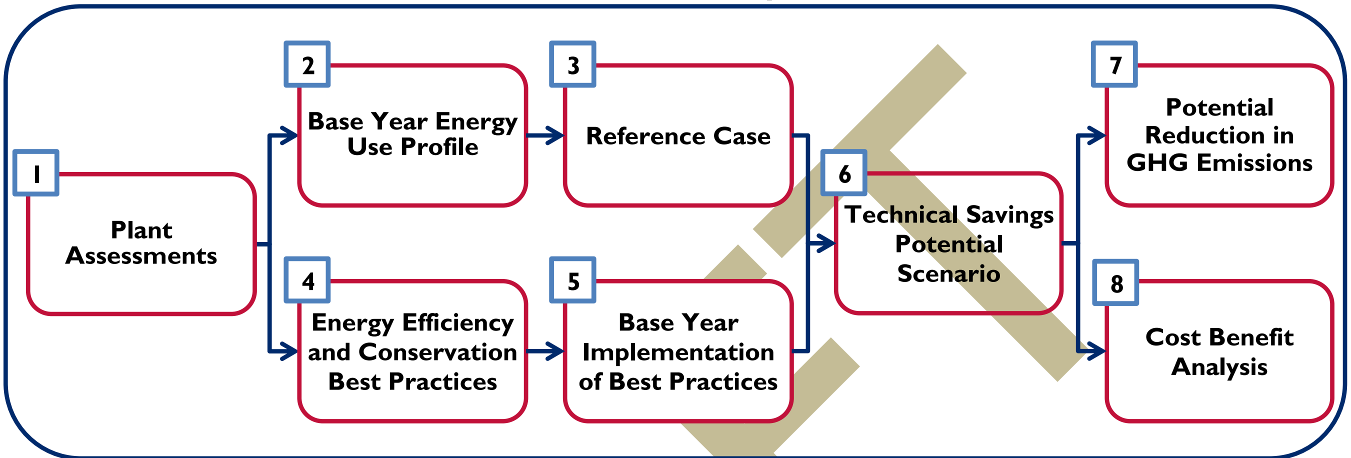
- ***Energy intensity***, a performance based metric that relates energy use to production output. The performance metric can be expressed in metrics such as equivalent kilowatt-hour per tonne (kWh/t) of product produced, or an energy efficiency index.

- ***Technical best practices*** (TBPs), which are production system and efficiency measures that reduce energy use per unit of production. An example of a TBP is installing a heat recovery system on a process exhaust stream to pre-heat a feed stream, resulting in reduced process energy use per unit of output. The TBP performance indicator is the total number of applicable TBPs that are implemented at a plant.

The energy conservation potential for the four selected Bangladesh industrial sectors is generated from the perspective of a Technical Conservation Potential scenario. In this scenario all ***technically feasible*** opportunities (also referred to as measures) are implemented. The Technical Conservation Potential scenario estimates the level of energy consumption that would occur when all industrial processes, equipment and buildings are upgraded with energy efficiency and conservation measures that are technical feasible to be implemented. The energy conservation potential under this scenario is defined as the amount of energy that is estimated to be conserved, compared to a Reference Case projection of energy use in the four Bangladesh industrial sectors over a defined study period.

Integrating energy management performance benchmarking and energy management potential analysis is accomplished with eight steps, as illustrated in Exhibit 9. Each of these steps is elaborated on below.

**Exhibit 1: Integrated Energy Performance Benchmarking and Energy Conservation Potential Analysis**




## Step 1 - Plant Assessments

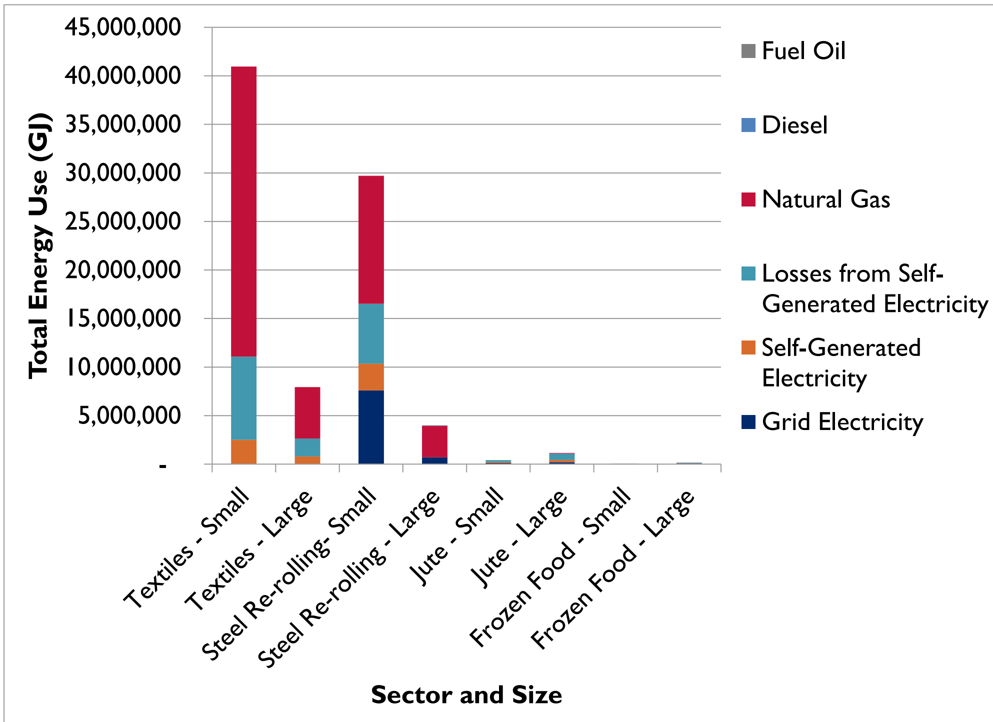
The primary form of data collection was through on-site plant assessments. Data on energy use and the implementation of energy use best practices was collected using a customised assessment instrument. A total of 15 facilities participated in the study: four each in the textile, steel re-rolling and jute manufacturing sectors; and in the frozen food processing sector two plants participated in on-site assessments and one plant in a remote assessment.

## Step 2 - Base Year Energy Use Profile

The Base Year is the starting point for the analysis and provides a detailed description of "where" and "how" energy is currently used in the selected industrial sectors. In this study the Base Year is 2011.

The first step in developing the Base Year energy use profile was to calculate the average plant energy use, by sector, size, fuel type, and end use. This task was completed using the results of the site assessments. Next, an estimate of the total number of plants per sector was developed. The average plant energy use was then multiplied by the total number of plants per sector to get the total sector energy use, as shown in Exhibit 11. The total energy use by sector takes into consideration the portion of purchased natural gas converted on-site to electricity, and defines the power generation losses.

**Exhibit 2: Base Year Total Energy Use by Sector**



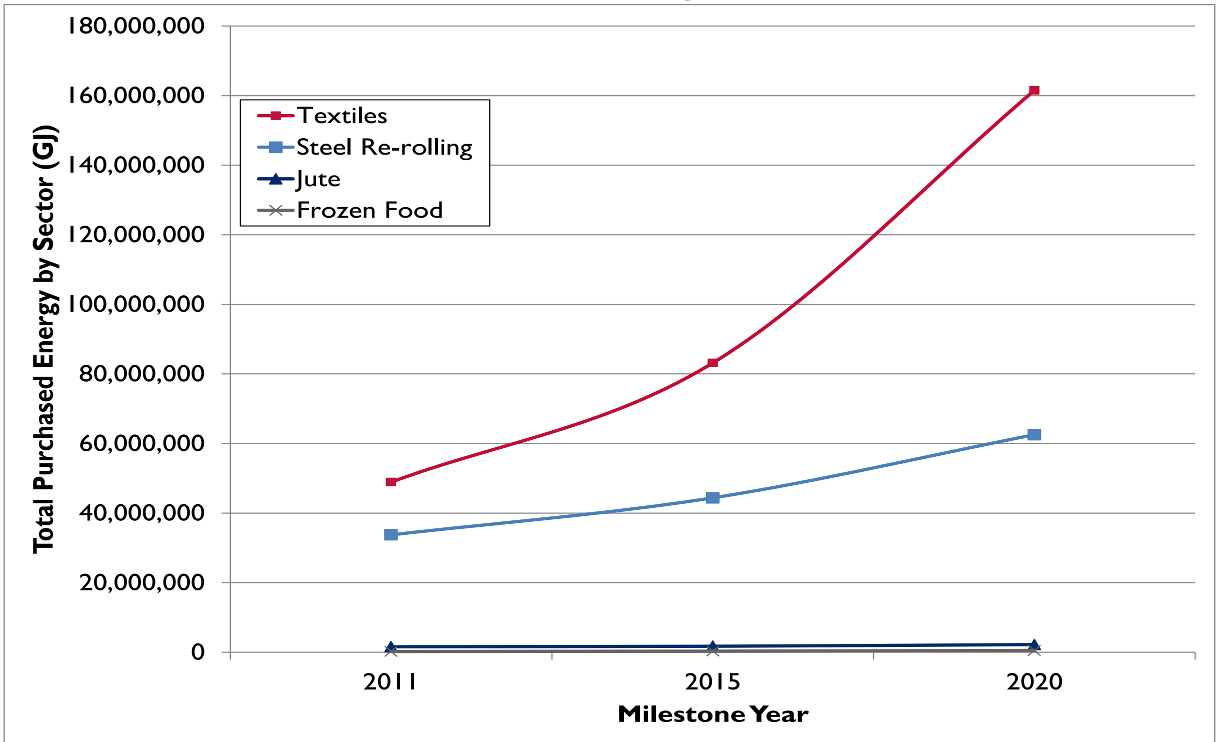

## Step 3 - Reference Case

The Reference Case is a projection of energy use to 2020, in the absence of any new energy management market interventions after 2011 (i.e., incremental to what utilities and government have already planned for this period). The Reference Case is the baseline against which the scenarios of energy savings are calculated.

It was assumed that growth rates will remain constant for the length of the study period and all fuel types will grow at the same rate within each. This means each sector's energy use profile remains constant in terms of percent breakdown between end uses and fuel types.

The Reference Case total energy use is estimated to increase by 169 percent from 2011 to 2020, as shown in Exhibit 21. In absolute terms the increase is over 142.3 PJ. The energy use in the textile industry is forecasted to increase by roughly 14 percent per year and represents the largest growth sector in this study.

**Exhibit 3: Total Purchased Energy Reference Case**






## Step 4 – Energy Efficiency and Conservation Best Practices

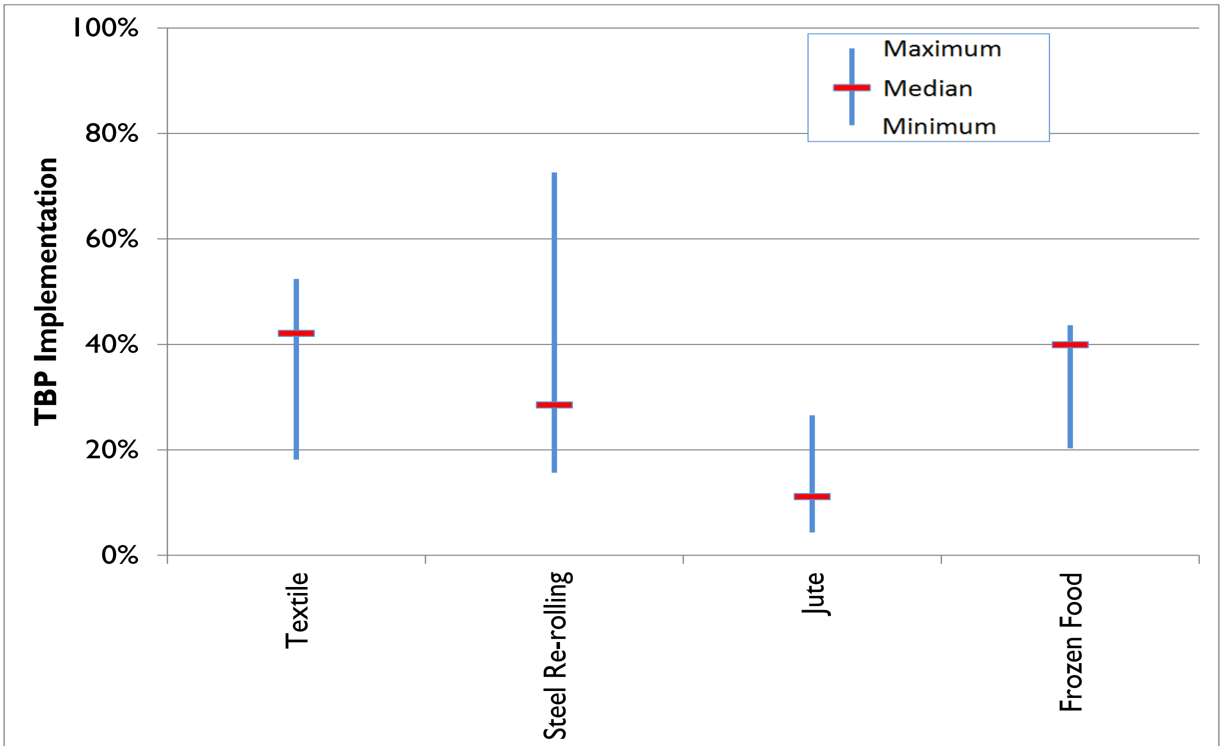
Industrial energy efficiency and conservation best practices, or technical best practices (TBPs), were identified using secondary sources, and ICF's extensive databases. Technical best practices include production systems, equipment, methods, and employed practices that result in advanced levels of energy use performance. Both generic and sector-specific TBPs were identified.

## Step 5 – Base Year Implementation of Best Practices

The market penetration rates of the best practices in the Base Year were determined through an energy performance benchmarking analysis. This analysis included an assessment of industrial facilities to determine implementation levels of best practices in the Base Year.

The implementation of TBPs in the plants in each of the four sectors is presented in Exhibit 29, while implementation of TBPs by end use is per sector is presented in Exhibit 30.

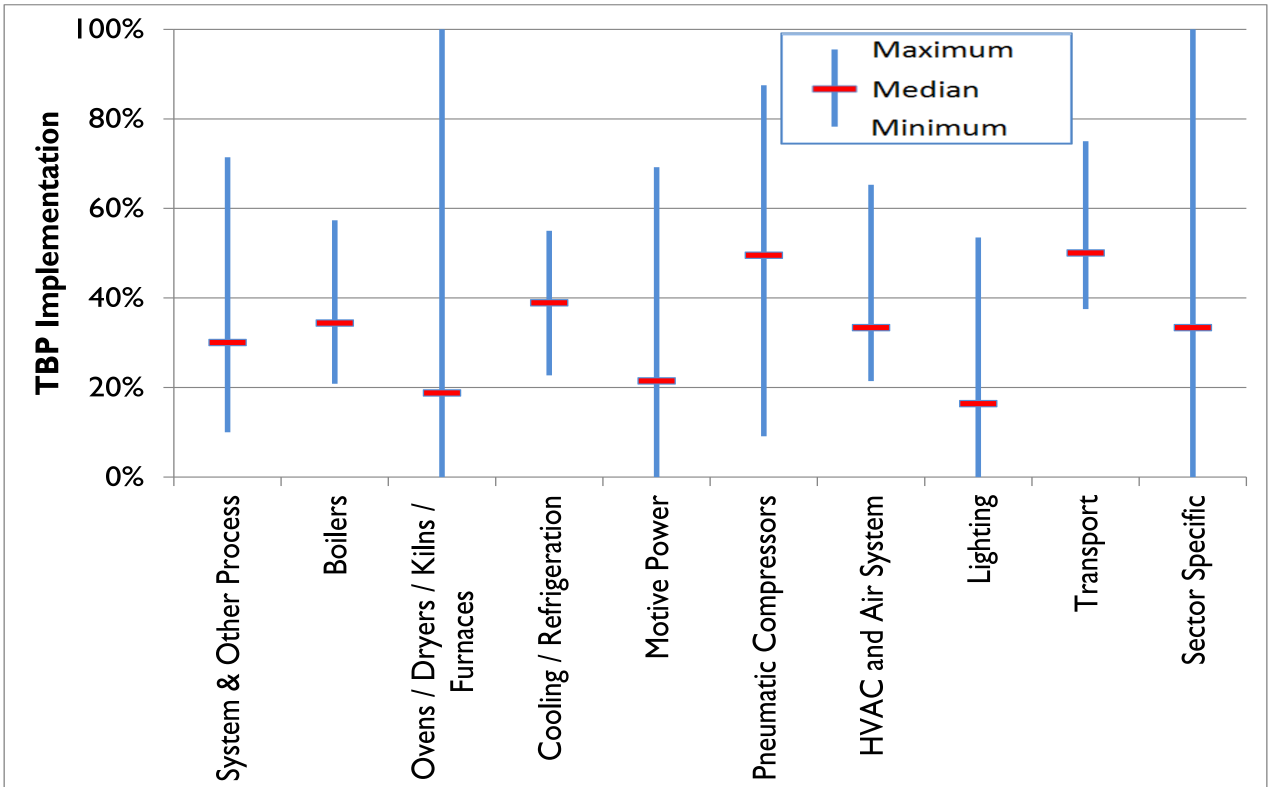
**Exhibit 4: Implementation of TBPs by Sector**




These results indicate there is a large potential to implement EE opportunities (TBPs) in all sectors:

- The ***jute manufacturing*** sector shows the largest potential to increase implementation of EE opportunities (TBPs). None of the plants have implemented more than 30% of the available opportunities, indicating that 70% of technical feasible opportunities can still be implemented in the sector.
- In the ***textile manufacturing*** sector none of the plants have implemented more than 55% of the technically feasible opportunities, indicating that about 45% of available EE opportunities can still be implemented in the sector.
- The ***steel re-rolling*** sectors shows the largest range in implementation of EE opportunities. The best performing plant(s) has achieved an implementation of close to 75% of the technically feasible opportunities, but more than half of the plants have implemented less than 30% of the available EE opportunities. This indicates that half of the plants can still implement 70% of the available opportunities.
- In the ***frozen food*** manufacturing sector the plants have implemented between 20% and 45% of the technically feasible opportunities. This means that there is still a potential to implement 55% or more EE opportunities in frozen food plants.

**Exhibit 5: Implementation of TBPs by End Use in All Sectors**






An assessment of the implementation of EE opportunities (TBPs) by end use in all sectors, shows a large potential exists in all end use, and specifically in:

- ***Ovens/dryers/kilns/furnaces, motive power*** and ***lighting***. In all three these end uses, half of the plants have implemented less than about 20% of the technically feasible EE opportunities, and these plants can still implement 80% of the available EE opportunities.

The end uses where most EE opportunities are implemented include:

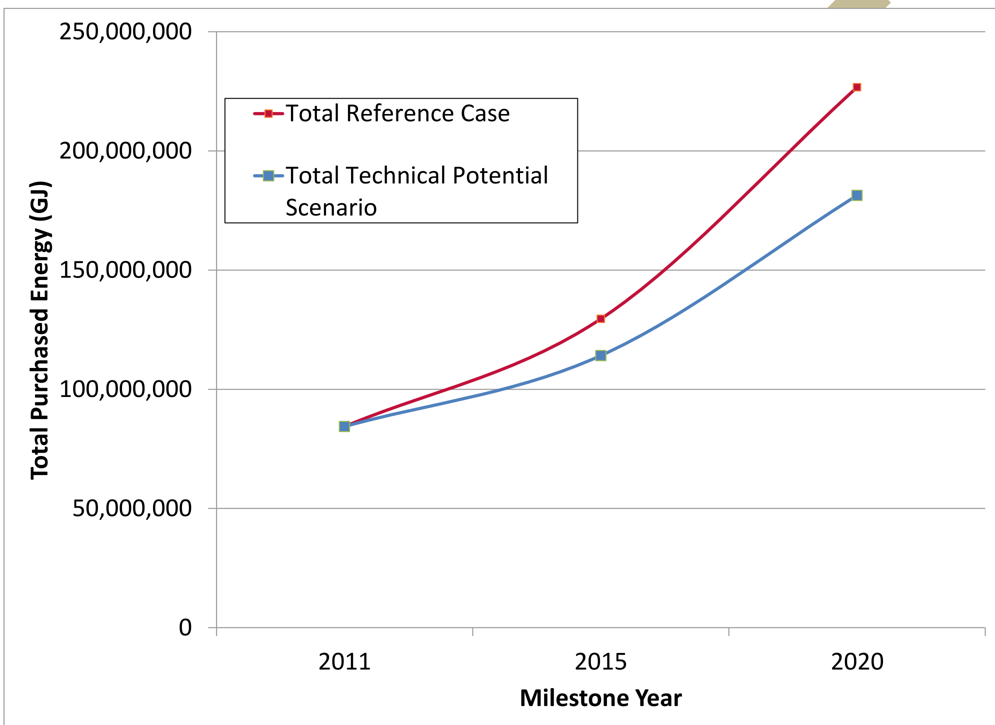
- ***Pneumatic compressors*** and ***transport***, where half of the plants have implemented more than about 50% of the available EE opportunities. Even though many EE opportunities are implemented in these end uses, a large potential still exist for half of the plants implemented less than 50% the EE opportunities.

## Step 6 – Technical Savings Potential Scenario

The Technical Savings Potential scenario estimates the level of savings that would occur if all the technical best practices that are technically feasible to be implemented are applied to the industry sectors.

If all the technically feasible TBPs were implemented, it is estimated that the total energy use of the four selected industrial sectors would increase by about 97 PJ from 2011 to 2020. As shown in Exhibit 35, the estimated energy use in 2020 would be 181.3 PJ, or 20 percent (45.4PJ) less than the Reference Case energy use in 2020.

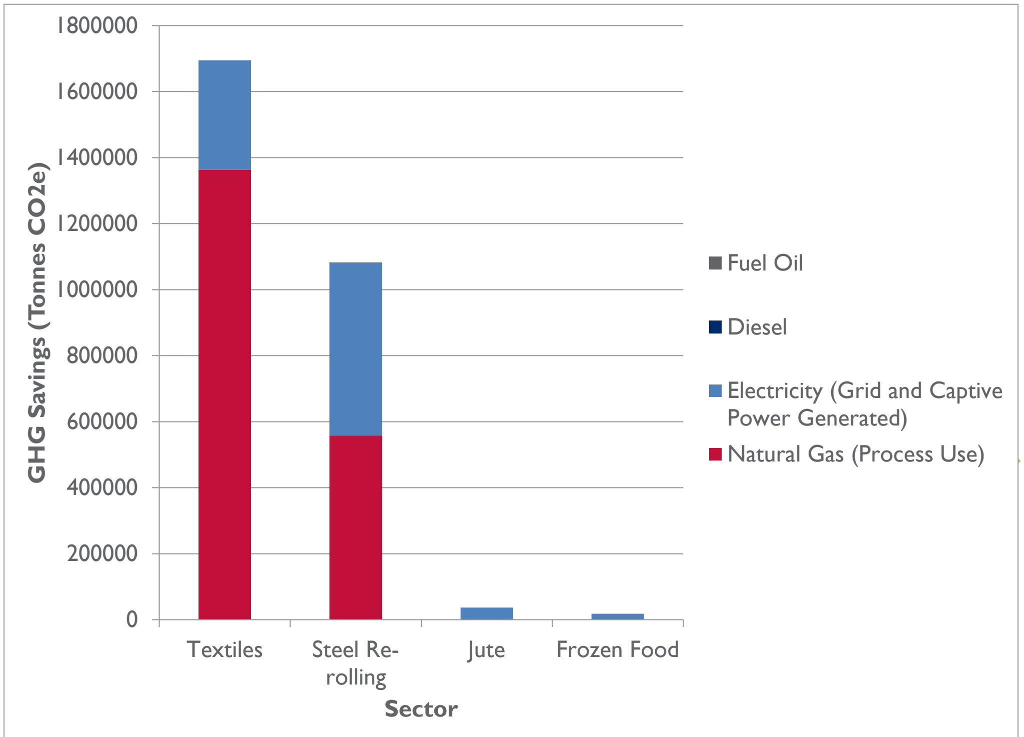
**Exhibit 6: Total Reference Case and Technical Potential Scenario Energy Use**




Step 7 – Potential Reduction in GHG EmissionsThe energy savings estimated in the Technical Savings Potential scenario are associated with a reduction in greenhouse gas (GHG) emissions. Emission factors are used to estimate the potential reduction in GHG emissions due to reduced energy use in this scenario.

If all the technically feasible energy efficiency were implemented, as per the Technical Potential scenario, it is estimated that the annual reduction in GHG emissions would be 2.83 million tonnes $CO_2e$ as compared to the Reference Case in 2020, as shown in Exhibit 39.

**Exhibit 7: Total Technical Potential Scenario GHG Savings by Sector for 2020**






## Step 8 – Cost-Benefit Analysis

A number of opportunities were selected to define the associated investment costs, and evaluate the costs against the benefits.

The analysis is executed for two scenarios:

- ***Technical Savings Potential:*** The economic savings benefits associated with the implementation of all technically feasible best practises.
- ***Selected Opportunities:*** The costs and savings analysis of 15 cross-cutting end use TBPs and 8 TBPs per sector.

If all the technically feasible energy efficiency best practices were implemented, as per the Technical Potential scenario, it is estimated that the annual cost savings for 2020, in fuel costs alone, would be 15,157 Million BDT.

The results of the economic analysis of the selected opportunities indicate that the costs and savings for all 15 cross-cutting opportunities result in simple payback periods of less than five years. Most of the opportunities (11 out of 15) have payback periods of less than two years, which is often reported as the desired maximum payback period to implement projects. This illustrates there is a significant economically feasible opportunity to improve energy efficiency in the Bangladesh industry.

In terms of the process specific opportunities, more than 50 percent of the opportunities identified for the textile and steel re-rolling sectors have simple payback periods of less than two years. In the frozen food sector most of the opportunities have simple payback periods of less than three years, while in the jute sector most of the opportunities have payback periods of more than three years. This analysis indicates that:

- Textile and steel re-rolling sectors have a significant amount of opportunities that are economically feasible.
- Most opportunities in the jute sector will require financial support to make the opportunities economically feasible.
- The frozen food sector has many economically feasible opportunities, but may require some financial support to make the payback period more attractive.

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## List of Exhibits

# ACRONYMS

| | |
|---|---|
| ASD | Adjustable speed drive |
| BJMA | Bangladesh Jute Manufacturing Association |
| BDT | Bangladeshi Taka |
| $CO_2$ | Carbon dioxide |
| $CO_2e$ | Equivalent carbon dioxide |
| EE | Energy efficiency |
| EECDP | Energy Efficiency for Clean Development Program |
| GHG | Greenhouse gas |
| GJ | Gigajoule |
| GoB | Government of Bangladesh |
| HVAC | Heating, ventilation, and air conditioning |
| kWh/t | kilowatt-hour per tonne |
| MW | Megawatt |
| NPV | Net present value |
| PJ | Petajoule |
| SME | Small and medium enterprise |
| TBP | Technical Best Practices |
| USAID | United States Agency for International Development |
| VFD | Variable frequency drive |

# 1. INTRODUCTION

This report is prepared under USAID's "**Industrial Energy Efficiency Opportunities Assessments in Bangladesh,"** a project under ICF's current Leader with Associates Cooperative Agreement with USAID entitled *Energy Efficiency for Clean Development Program (EECDP), No. AID-OAA-L-11-00003-00*. It accompanies the **Task 1: Industry Opportunities and Profile Report** prepared in March 2012 and presents a summary of Phase I activities and findings of the assessment. This Phase I report includes the following elements:

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- ***Estimated implementation of energy efficient opportunities (EE).*** Based on site-assessments of a sample of plants in each of the four sectors the implementation of EE opportunities in these was defined. This also provides an indication of the opportunity to implement EE opportunities where it is not yet implemented.
- ***Estimated energy savings if EE opportunities are implemented.*** The potential energy savings were estimated for the scenario where all the identified technically feasible opportunities are implemented.
- ***Cost-benefit analysis of top EE opportunities.*** The EE opportunities with the largest technical savings potentials were identified and associated cost-benefit analysis was conducted for each top opportunity.

To advance the implementation of the identified opportunities, the subsequent phase of the project, i.e. Phase II, includes follow-up with industry to identify the barriers and challenges industry faces in implementing the opportunities. Potential solutions to address these challenges and barriers are identified and lead to the development of a framework and strategies for financing options and potential donor intervention. A combined Phase I and Phase II report will be developed and submitted to USAID for review as a final deliverable for this assessment.

## 1.1 Background and Objectives

Bangladesh currently faces energy shortages that can be attributed to its rapid economic and industrial growth over the past ten years. While the demand for natural gas, which is the primary domestic energy resource, has increased with growth, actions to increase its generating capacity have lagged behind. The situation is exacerbated by natural gas demand from the power sector, which uses natural gas to generate electricity. In addition, the current low price of natural gas creates an environment conducive to rapid and usually inefficient consumption across all sectors, further diminishing the natural gas supply. With the inability for natural gas production and supply to meet demand, industries and power utilities, which are the primary consumers, have begun to experience more frequent shortages. Reduced availability of gas for power generation leads to frequent power outages across the country, which become prolonged during the peak summer months. Among its many impacts, this adversely affects the agriculture sector which requires power for irrigation, as well as small and medium industries that do not have an alternate power supply. To address the frequent power shortages on the grid, various consumer sectors have resorted to back-up or captive power generation in the form of gas engines. This has further exacerbated the problem of insufficient gas availability, where the textile sector alone has 1,200 MW of aggregate captive power generation capacity to meet its energy requirements. Acute shortages of natural gas have occurred since 2009. As the Government of Bangladesh (GoB) and industries look for ways to resolve the situation, efficient energy end-use emerges as a viable option to sustain the growing demand.

The many industry sectors in Bangladesh collectively represent one of the largest consumers of natural gas and electric energy in Bangladesh. This project therefore focuses on industrial contributions to energy consumption and seeks to achieve the following objectives:

- Identify, analyze, and prioritize opportunities for energy efficiency improvements in private industrial sectors in Bangladesh.
- Determine the industrial sectors with the greatest opportunities for energy efficiency (EE).
- Identify the key interventions within the selected sectors to advance improvement in EE.
- Identify options and strategies where donor assistance and existing credit facilities can help industries implement these interventions and realize EE potential.

These objectives are covered in two phases of the project, where Phase I addresses the first two objectives mentioned above, and Phase II addresses the objectives in the last two bullet points listed above. This report is the deliverable for Phase I.

## 1.2 Scope of Study

The scope of the study included the development of broad profiles for the top eight energy-consuming industrial sectors within Bangladesh, from which four sectors were selected for more detailed analysis of energy-saving opportunities. A separate report, titled: *Task I: Industry Opportunities and Profile Report* (dated March 25, 2012), provides the industry sector profiles of the top eight energy-consuming industrial sectors, and the selected four sectors together with the selection methodology. The four sectors selected for the more detailed analysis of energy-savings opportunities are assessed in this Phase I report, and the four Bangladesh industrial sectors include:

- Textile manufacturing (textile dyeing and processing, exclusively)
- Steel re-rolling
- Jute manufacturing
- Frozen food processing

Together, textiles, jute and frozen foods constitute more than 85 percent of total exports from Bangladesh and are vital to Bangladesh's export earnings. Though steel re-rolling mills are not direct export contributors, they are important for domestic infrastructure development and growth of the country's light engineering industries. These four sectors have seen rapid growth in the past few years and are expected to continue on their present growth trajectories.

## 1.3 Report Presentation

The remainder of the report is structured to present:

- The methodologies, definitions, and plant assessments in Section 2, 3, and 4;
- The 2011 Base Year and Reference Case energy use profiles in Sections 5 and 6;
- The energy efficiency and conservation best practices, and the Base Year implementation of the best practices in Sections 7 and 8;
- The Technical Savings Potential scenario in Section 9;
- The greenhouse gas (GHG) emissions associated with the energy use and savings potential in Section 10; and
- The cost-benefit analysis in Section 11.

# 2. METHODOLOGY

The comprehensive methodology employed in this study is unique in that it integrates two areas of energy management analysis: (1) Energy ***performance benchmarking***; and (2) Energy conservation ***potential analysis***. Other studies generally conduct energy performance benchmarking and energy conservation potential analysis as two separate and isolated assessment studies. The main benefits of this integrated methodology are:

- Industry participants gain valuable insights on the management and technical factors affecting their energy use performance, as well as the opportunities to improve performance (through confidential benchmark reports and the market assessment level benchmark and energy efficiency potentials results).

- Policy and program decision-makers gain access to a robust, defensible analysis platform as well as the insights and recommendations of industry participants (through the market assessment level benchmark and energy management potentials results).

Each of these analysis streams is discussed in this section, with additional supporting documentation found in the appendices. The method used to integrate the two streams of analysis as well as details on the overall execution of the study are also described.

A key element in the study is the assessment of a sample of plants in each of the four sectors. The plant assessments were performed according to the following main steps: (1) industry recruitment; (2) on-site assessments; and (3) data collection from secondary sources.  A total of 15 plants participated in the study. A detail discussion regarding the assessment methodology, sample of plants assessed and results are presented in Section 4.

## 2.1 Energy Performance Benchmarking

An energy performance benchmarking analysis, as applied in this study, generates three important perspectives:

- It provides an overview of how well a particular industrial sector is managing energy.
- It enables company participants in the benchmarking exercise to compare the performance of their own plant(s) with the overall industry performance indicators.
- It provides insight into the reasons why a plant's performance is high or low.

The results of the benchmarking analysis provide an indication of how many best practices are currently implemented in the selected Bangladesh industrial sectors and how many best practices can still be implemented. These market penetration rates are used to inform the energy conservation potential analysis described in the next sub-section.

In this study energy performance considers two performance indicators:

- ***Energy intensity***, a performance based metric that relates energy use to production output. The performance metric can be expressed in metrics such as equivalent kilowatt-hour per tonne (kWh/t) of product produced, or an energy efficiency index.

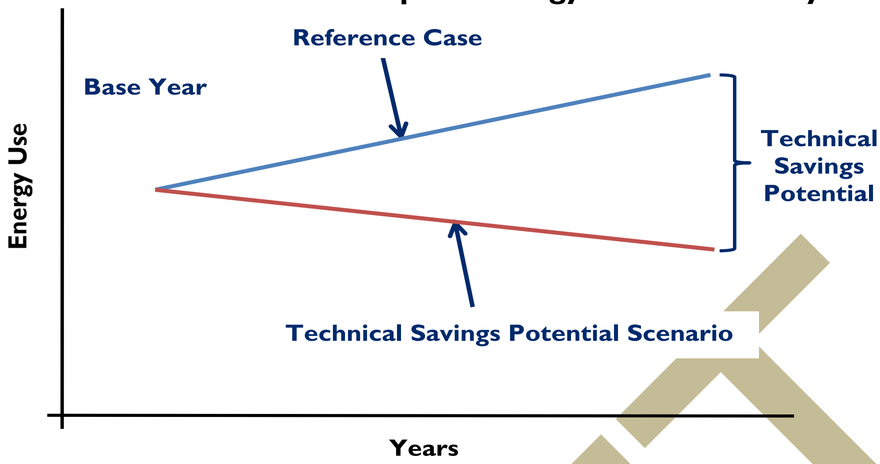
- ***Technical best practices*** (TBPs), which are production system and efficiency measures that reduce energy use per unit of production. An example of a TBP is installing a heat recovery system on a process exhaust stream to pre-heat a feed stream, resulting in reduced process energy use per unit of output. The TBP performance indicator is the total number of applicable TBPs that are implemented at a plant.

Due to confidentiality agreements with individual plants and the relatively small sample size in each sector, individual plant data is not presented in this report. To protect the confidentiality of the individual plant data, this report contains only the aggregated, sector level energy performance benchmarking results pertaining to the implementation of technical best practices.

## 2.2 Energy Conservation Potential Analysis

The energy conservation potential for the four selected Bangladesh industrial sectors is generated from the perspective of a Technical Conservation Potential scenario. In this scenario all ***technically feasible*** opportunities (also referred to as measures) are implemented. The Technical Conservation Potential scenario estimates the level of energy consumption that would occur when all industrial processes, equipment and buildings are upgraded with energy efficiency and conservation measures that are technical feasible to be implemented. The energy conservation potential under this scenario is defined as the amount of energy that is estimated to be conserved, compared to a Reference Case projection of energy use in the four Bangladesh industrial sectors over a defined study period. Exhibit 8 illustrates the generic concepts that define the energy management potential analysis: (1) Base Year; (2) Reference Case; and (3) Technical Potential Scenario. These concepts are defined in Section 2.3.

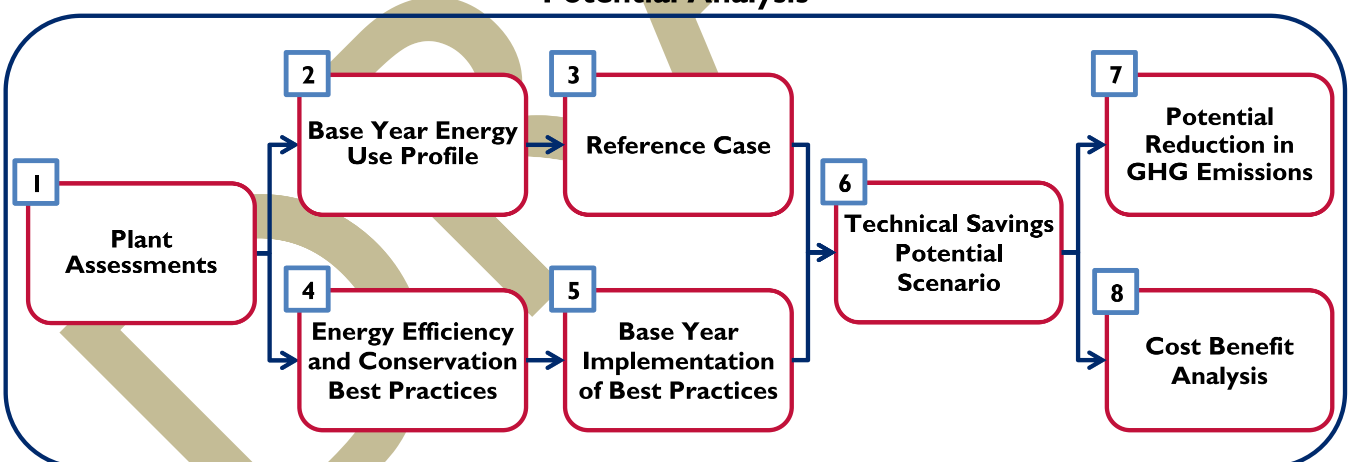
**Exhibit 8: Generic Concept of Energy Potential Analysis**




## 2.3 Integrating Energy Performance Benchmarking and Energy Conservation Potential Analysis

Integrating energy management performance benchmarking and energy management potential analysis is accomplished with eight steps, as illustrated in Exhibit 9 and described below. The report chapters from Section 4 to Section 11 follow the logical flow outlined in Exhibit 9.

**Exhibit 9: Integrated Energy Performance Benchmarking and Energy Conservation Potential Analysis**




- ***Step 1 - Plant Assessments:*** The primary form of data collection was through on-site plant assessments. Data on energy use and the implementation of energy use best practices was collected using a customised assessment instrument.

- ***Step 2 - Base Year Energy Use Profile:*** The Base Year is the starting point for the analysis and provides a detailed description of "where" and "how" energy is currently used in the selected industrial sectors. In this study the Base Year is 2011.

- ***Step 3 - Reference Case:*** This is a projection of energy use to 2020, in the absence of any new energy management market interventions after 2011 (i.e., incremental to what utilities and government have already planned for this period). The Reference Case is the baseline against which the scenarios of energy savings are calculated.

- ***Step 4 – Energy Efficiency and Conservation Best Practices:*** The best practices that result in energy reduction in the selected industrial sectors are defined, and include technical best practices (TBP).

- ***Step 5 – Base Year Implementation of Best Practices:*** The market penetration rates of the best practices in the Base Year were determined through an energy performance benchmarking analysis. This analysis included an assessment of industrial facilities to determine implementation levels of best practices in the Base Year.

- ***Step 6 – Technical Savings Potential Scenario:*** The Technical Savings Potential scenario estimates the level of savings that would occur if all the technical best practices that are technically feasible to be implemented are applied to the industry sectors.

- ***Step 7 – Potential Reduction in GHG Emissions:*** The energy savings estimated in the Technical Savings Potential scenario are associated with a reduction in greenhouse gas (GHG) emissions. Emission factors are used to estimate the potential reduction in GHG emissions due to reduced energy use in this scenario.

- ***Step 8 – Cost-Benefit Analysis:*** A number of opportunities were selected to define the associated investment costs, and evaluate the costs against the benefits.

# 3. DEFINITIONS

## 3.1 Energy Conservation

The focus of the energy conservation potential analysis is to quantify the potential reduction in energy consumption due to energy management actions. In this context, energy conservation addresses energy consumption and not energy demand, and includes the following elements:

- Energy Efficiency, including technical best practices to reduce energy use. These practices include improvement in efficiency and practices to eliminate or curtail energy use.

- Associated GHG emission reduction, which are quantified by applying the appropriate emission factors to each of the types of on-site fuel savings. For electricity savings, equivalent emissions are calculated for electricity generation.

## 3.2 Milestone Years

The energy conservation potential analysis is conducted for the following milestone years:

- The base year of 2011
- Milestone years of 2015 and 2020

## 3.3 Coverage of Energy Supply

The energy conservation potential analysis addresses all forms of energy used by the four industrial sectors in Bangladesh according to the following energy supply categories: (1) electricity; (2) natural gas; (3) diesel; and (4) fuel oil. For ease of comparison and modelling, all energy sources were converted to the same unit of measure, gigajoules (GJ). The energy content conversion factors used are summarized in Appendix A.

## 3.4 GHG Emission Factors

The energy conservation potential analysis includes an estimation of the potential greenhouse gas (GHG) emissions reduction. The GHG amounts are expressed in tonnes of equivalent carbon dioxide ($CO_2e$). The GHG emission factors used in the study are summarized in Appendix A. The energy conservation potential analysis assesses energy use at the energy end use level, which is profiled in Exhibit 10 and described in more detail below.

**Exhibit 10: End Uses**

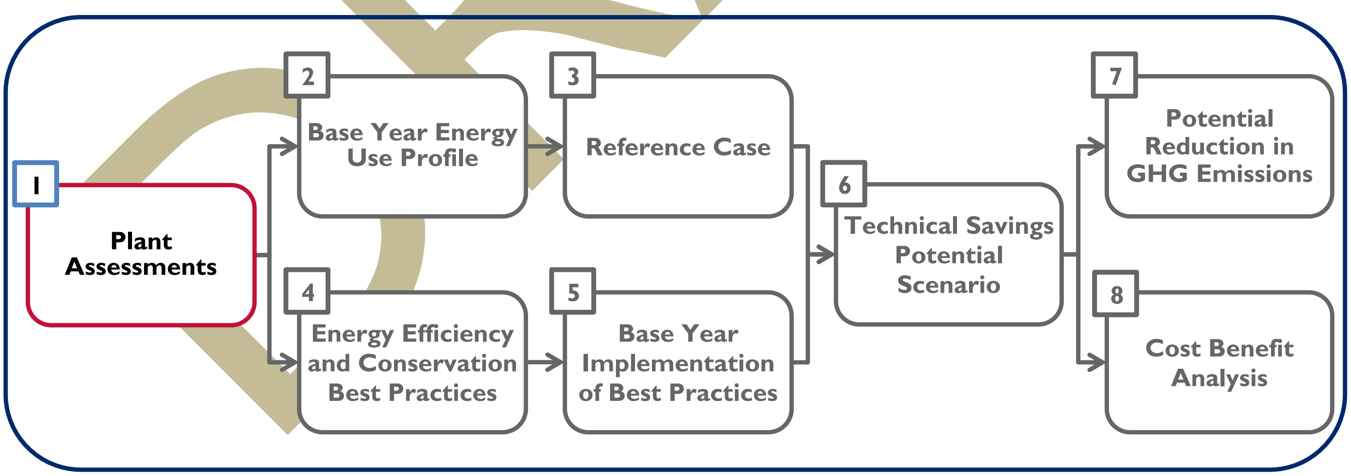
| End Use Level 1 | End Use Level 2 |
| --- | --- |
| System and Other Process | |
| Process Heating | Indirect heating<br>(i.e. Boiler, Steam, and Hot Water Systems)<br>Direct heating<br>(i.e. Furnaces, Ovens, Kilns, and Dryers) |
| Process Cooling and Refrigeration | |
| Motive Power | Pumps<br>Fans<br>Other Motors |
| Compressed Air System | |
| Heating, Ventilation, and Air Conditioning | |
| Lighting | |
| Transport | |
| Process Specific | |

- ***System and Other Process:*** This end use includes all cross-cutting measures, which are those measures that are applicable to more than one end use. For example, sub-metering would be considered a system measure.

- ***Process Heating:*** The end use includes all process heating systems and differentiates between indirect and direct heating end uses. Indirect heating refers to systems where an intermediate heat transfer medium is used, such as steam or hot water. Direct heating systems do not have an intermediate heat transfer medium and include ovens, dryers, furnaces and kilns.

- ***Process Cooling and Refrigeration:*** All process cooling and refrigeration systems are included in the end use, for example: cooling towers, freezers, chillers and associated refrigeration compressors.
- ***Motive Power*** The end use includes all motive power equipment and is sub-divided into: pumps, fans/blowers, and all other motors. Other motors include, for example, conveyors, non-pneumatic metal forming machines, saws, and vibrating screens.
- ***Compressed Air Systems:*** Both the compressor and the associated distribution system form part of the compressed air system.
- ***Heating, Ventilation and Air Conditioning:*** Comfort heating and cooling systems are included in the end use, together with all ventilation systems. Ventilation systems that are included can be associated with a process, such as ventilation of paint booths, and/or comfort, for example ventilation of air in a production area to maintain adequate air quality levels.
- ***Lighting:*** All indoor and outdoor lighting systems are included in the end use.
- ***Transport:*** Forms of material transport used within a facility, such as propane or natural gas forklifts.
- ***Process Specific:*** All process that use energy and are not included in the process heating, process cooling, motor driven, and ventilation end uses, are included in the process specific end use. Each sector has its own specific processes, and example for the textile sector include: weaving machines, calendaring machines, and printing machines.

# 4. PLANT ASSESSMENTS




Energy conservation performance benchmarking analysis is informed by the acquisition of primary data, and supplemented by secondary data to fill gaps. As such, the data collection and data analysis stages are key elements in the successful implementation of the study. This section describes the methodology to recruit industry participants, conducting on-site assessments and data collection from secondary sources. The section also presents the sample representation in terms of representing the sectors and the size of plants in the sectors.

Each participating plant received an individual confidential report card with the results of the plant assessments. Due to the confidentiality of the plant data and results, this report presents only the aggregated data and results in Sections 5 to 11.

## 4.1 Methodology

The plant assessments were performed according to the following main steps: (1) industry recruitment; (2) on-site assessments; and (3) data collection from secondary sources. These areas are discussed in further detail below.

### Industry Recruitment

There were two goals to the industry recruitment process:

- To ensure a representative sample of each of the four selected sectors, in terms of its energy end use profile and implementation of best practices.
- To ensure a representative sample in terms of small and medium enterprises (SME) and large industry, where the size is defined by production volume, as is further discussed in Section 4.3.

Recruitment was accomplished through targeted marketing campaigns and networking, involving associations representing the sectors and the Bangladesh University of Engineering and Technology. A total of 15 facilities participated in the study and an analysis of this sample is provided in Section 4.2.

### On-Site Assessments

The necessary primary data was obtained from participants through on-site plant assessments. The on-site assessments facilitated expert review of the energy use in the facility, assessed implementation of best practices, and identified best practices not yet implemented. The assessment protocol used for the on-site assessments consisted of the following assessment instrument:

- ***Energy Use and Technical Best Practice Assessment:*** This assessment includes questions pertaining to energy use and equipment, and the implementation of technical best practices.

The assessments were developed from extensive literature research and the project team's experience with similar projects. The literature references together with the best practices are discussed in Section 7, while the energy use profiles are discussed in Section 5. The assessment instrument was sent to each plant in advance of the site visit to enable plant representatives to prepare for the site assessment. The assessment was completed during the site visit, with the assistance of the designated personnel.

### Data Collection from Secondary Sources

In addition to the primary data and the resources to develop the best practices profiles, the study also required secondary data and input from external sources. The elements that required information from secondary sources are summarized in Exhibit 4.

**Exhibit 11: Elements Informed by Secondary Sources**

| Element | Applicable Section with Detailed References |
|---|---|
| Base Year 2011: Total number of plants per sector, by production volume range | Section 5.1 |
| Reference Case: Projected energy use by sectors from 2011 to 2020. | Section 6.1 |
| Energy content conversion factors | Appendix A |
| GHG emission factors | Appendix A |
| Fuel Prices | Appendix A |

## 4.2 Sample Representation

### Sector Representation

Based on the project team's past experience with similar studies it was determined that the ideal sample size per industrial sector is in the range of 10 to 15 facility assessments. This sample size generally provides a sufficient level of accuracy for this type of energy efficiency opportunity identification and energy conservation potential analysis. The higher end of the sample size range is applicable to more complex and diverse sectors, while smaller sample sizes are appropriate for more homogenous and less complex sectors.

In this study all four selected sectors are considered to be relatively homogenous and with a relatively low complexity in terms of energy use processes. For a study with a sufficiently long schedule the appropriate target sample size is considered to be 10 to 12 assessments per sector. Given the timeline of this study, the schedule was reduced and an appropriate target sample was defined as four on-site assessments per sector with representation from large and small-medium sized facilities. This means the target was set for a total of 16 participating plants.

The actual number of facilities that participated in the on-site assessments was four each in the textile, steel re-rolling and jute manufacturing sectors. In the frozen food processing sector two plants participated in on-site assessments and one plant in a remote assessment. The size representation is discussed below in Section 4.2.

**Exhibit 12: Number of Assessments Completed by Sector**

| Sector | Textile | Jute | Steel Re-rolling | Frozen Food | Total |
|---|---|---|---|---|---|
| Number of On-site Assessments | 4 | 4 | 4 | 2 | 14 |
| Remote Assessments | 0 | 0 | 0 | 1 | 1 |
| Total | 4 | 4 | 4 | 3 | 15 |

## Size Representation

Annual production volume was selected as the criteria with which to categorize plants as either large or small and medium enterprise (SME). The annual production volume ranges for each of the sectors are presented in Exhibit 6.

**Exhibit 13: Size Selection Criteria**

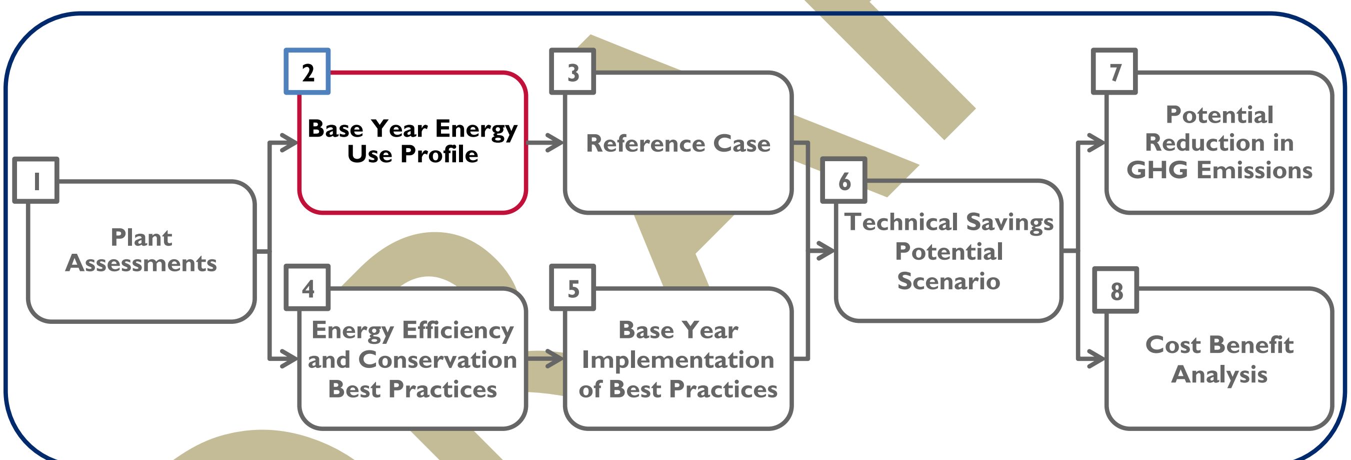
| Sector | Size | Annual Production |
|---|---|---|
| Textile | SME | Woven Dyeing: < 35 Million meters<br>Knit/ Yarn Dyeing: < 10 Million kilograms |
| | Large | Woven Dyeing: > 35 Million meters<br>Knit/ Yarn Dyeing: > 10 Million kilograms |
| Steel Re-rolling | SME | < 150,000 tonnes |
| | Large | > 150,000 tonnes |
| Jute | SME | < 25,000 tonnes |
| | Large | > 25,000 tonnes |
| Frozen Food | SME | < 500 tonnes |
| | Large | > 500 tonnes |

Using the size ranges listed in Exhibit 6, the assessed plants can be categorized as shown in Exhibit 14.

**Exhibit 14: Participating Plants by Size**

| Sector | Total number | Size | |
|---|---|---|---|
| | | SME | Large |
| Textile | 4 | 3 | 1 |
| Steel Re-rolling | 4 | 3 | 1 |
| Jute | 4 | 2 | 2 |
| Frozen Food | 3 | 1 | 2 |
| Total | 15 | 9 | 6 |
| Percentage of total | 100% | 60% | 40% |

# 5. BASE YEAR ENERGY USE PROFILE



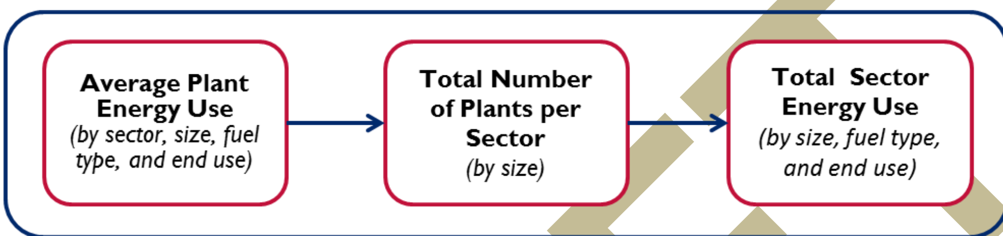

This section presents a description of the 2011 Base Year energy use in the selected Bangladesh Industrial sectors, which is the second step in the energy conservation potential analysis. The Base Year energy use profile provides an estimate of how the energy consumption is currently distributed by fuel type, sub-sector, and end use. The plant assessments, as described in Section 4, informed the development of the Base Year as described below in Section 5.1. The relevant assumptions and information applied to develop the Base Year energy use profile, and a summary of the results are presented in the following sub-sections. Detailed results, by sector, are presented in Appendix B through

Appendix E.

## 5.1 Methodology

The 2011 Base Year energy use profile, by sector, was developed using the results of the site assessments and extrapolating these results to the rest of the sector, as shown in Exhibit 15.

**Exhibit 15: Approach to Develop Sector Energy Use Profiles**




The first step in developing the Base Year energy use profile was to calculate the average plant energy use, by sector, size, fuel type, and end use. This task was completed using the results of the site assessments. Next, an estimate of the total number of plants per sector was developed, as shown in Exhibit 16[1], according to the size ranges presented in Exhibit 6.

**Exhibit 16: Plants per Sector**

| Sector | Total number | Size | |
|---|---|---|---|
| | | SME | Large |
| Textile | 229 | 201 | 28 |
| Steel Re-rolling | 250 | 245 | 5 |
| Jute | 48 | 36 | 12 |
| Frozen Food | 22 | 9 | 13 |
| Total | 549 | 491 | 58 |

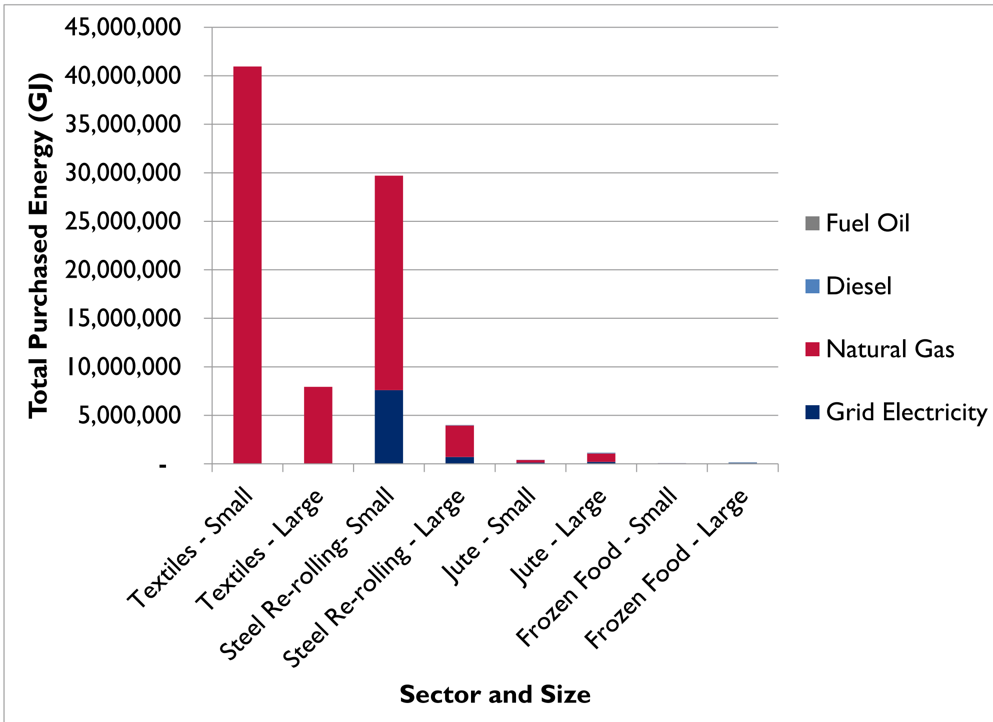
The average plant energy use was then multiplied by the total number of plants per sector to get the total sector energy use. The energy use profiles were developed separately for the SME and large sized facilities, and added together to generate the total aggregated sector energy use profiles.

## 5.2 Results

In the base year, 2011, the four selected sectors used an estimated total 67 PJ of energy. As illustrated in Exhibit 17, natural gas accounts for the majority of total energy use. Textile plants that fall within the SME category represent the largest energy users in the base year.

[1] In this study, the textile sector includes only textile dying and processing facilities

**Exhibit 17: Base Year Total Purchased Energy by Sector**




The total energy use by sector takes into consideration the portion of purchased natural gas converted on-site to electricity, and defines the power generation losses. The main difference between total base year purchased energy (shown in Exhibit 10) and total base year energy use (shown in Exhibit 11) is that some of the natural gas is replaced by equivalent amount of self-generated electricity and the associated losses." This is a result of converting natural gas to electricity. As shown in Exhibit 11, captive power generation losses[2], due to low conversion efficiency, contribute to a significant amount of total energy use. Therefore, any reductions in electricity use in plants that have on-site electricity generation actually have a higher impact on overall energy use. Detailed results, by sector, are presented in Appendix B through

[2] Captive power generation losses were calculated by estimating the conversion efficiency of a typical generator for each of the fuel types and using this factor to convert the amount of electricity used into an equivalent amount of fuel burned.

Appendix E.

As shown in Exhibit 12, three end uses account for close to 70 percent of the total energy use. These end uses are: direct process heating, in the form of ovens, dryers, kilns, and furnaces; process specific end uses; and boilers. It is apparent that losses from self-generated electricity represent a significant energy use, accounting for 21 percent of total Base Year energy use in these four sectors. The three main energy end uses together with captive power generation losses account for close to 90 percent of the total Base Year energy use. Detailed results, by sector, are presented in Appendix B through

Appendix E.

**Exhibit 18: Base Year Total Energy Use by Sector**

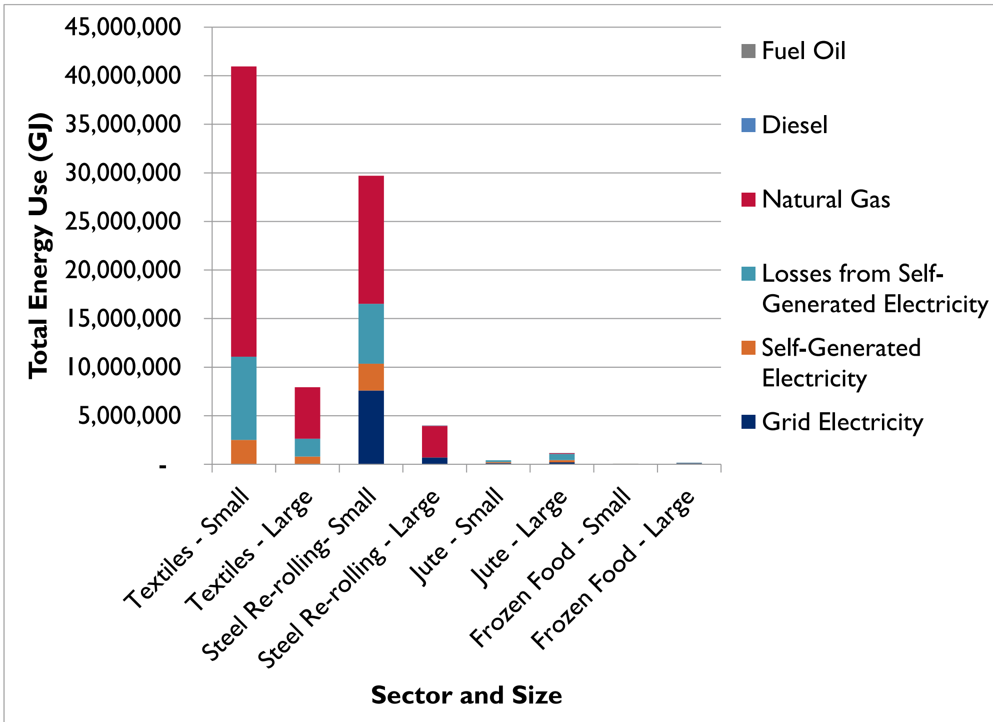
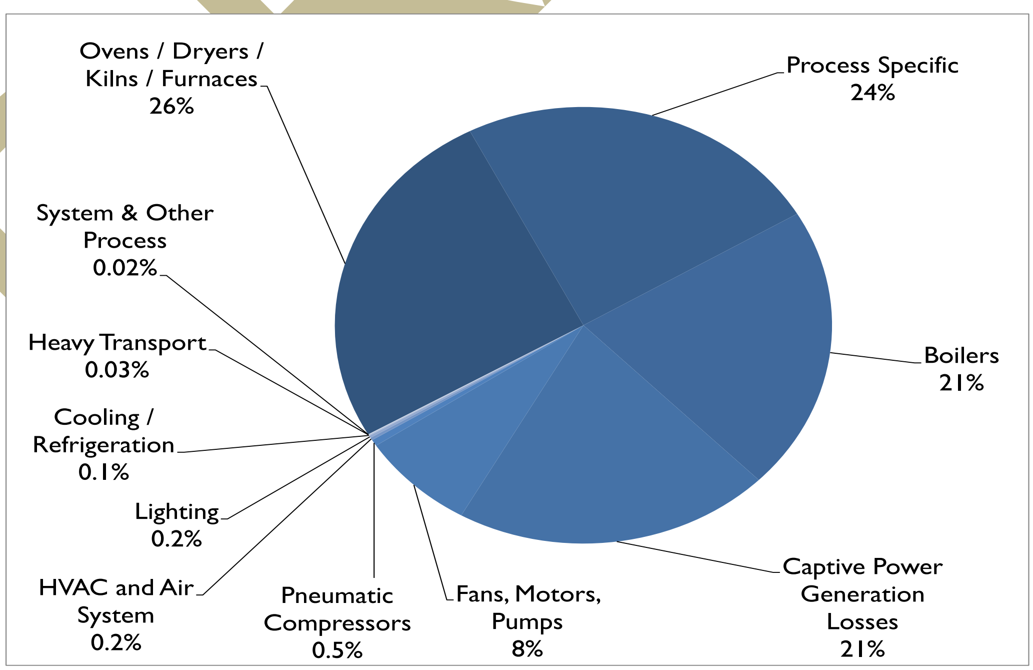
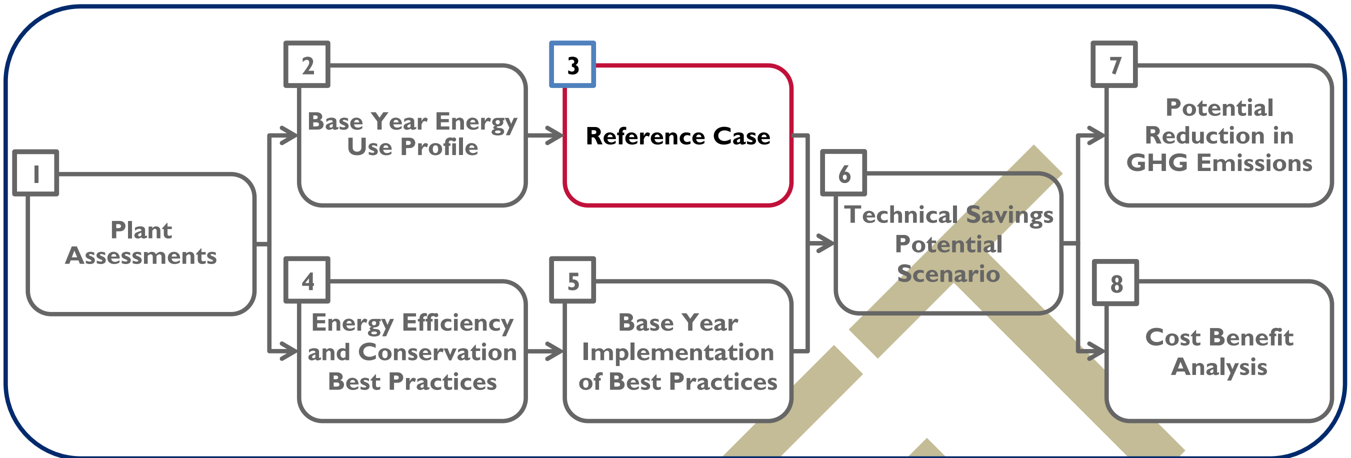



**Exhibit 19: Total Base Year Energy Use by End Use**



# 6. REFERENCE CASE




This section presents a description of the Reference Case energy use in the selected Bangladesh industrial sectors, which is the third step in the energy conservation potential analysis. The Reference Case provides a projection of energy use to 2020, in the absence of any new energy management market interventions after 2011 (i.e., incremental to what utilities and government have already planned for this period). The Reference Case is the baseline against which the scenarios of energy savings are calculated.

## 6.1 Methodology

This study does not include the development of energy use forecasts, and relies on existing forecasts to develop the projected energy use Reference Case. The energy use growth rates used in this study are listed in Exhibit 20.

Where available, Planning Commission growth rates were used. In the case of the jute industry, no such growth rates were available. Based on a literature review and consultation with the jute mills, it was found that raw jute supply has been an issue in recent years, but the Bangladesh Jute Manufacturing Association (BJMA) expects a future revival due to both an increase in demand and increased government attention. As the annual growth rate of the jute industry over the past five year, provided by the BJMA, has been approximately 3.8 percent (excluding 2010-11, which was a particularly poor year), a slightly higher growth rate of 5 percent has been assumed for this study.

It was assumed that growth rates will remain constant for the length of the study period and all fuel types will grow at the same rate within each. This means each sector's energy use profile remains constant in terms of percent breakdown between end uses and fuel types.

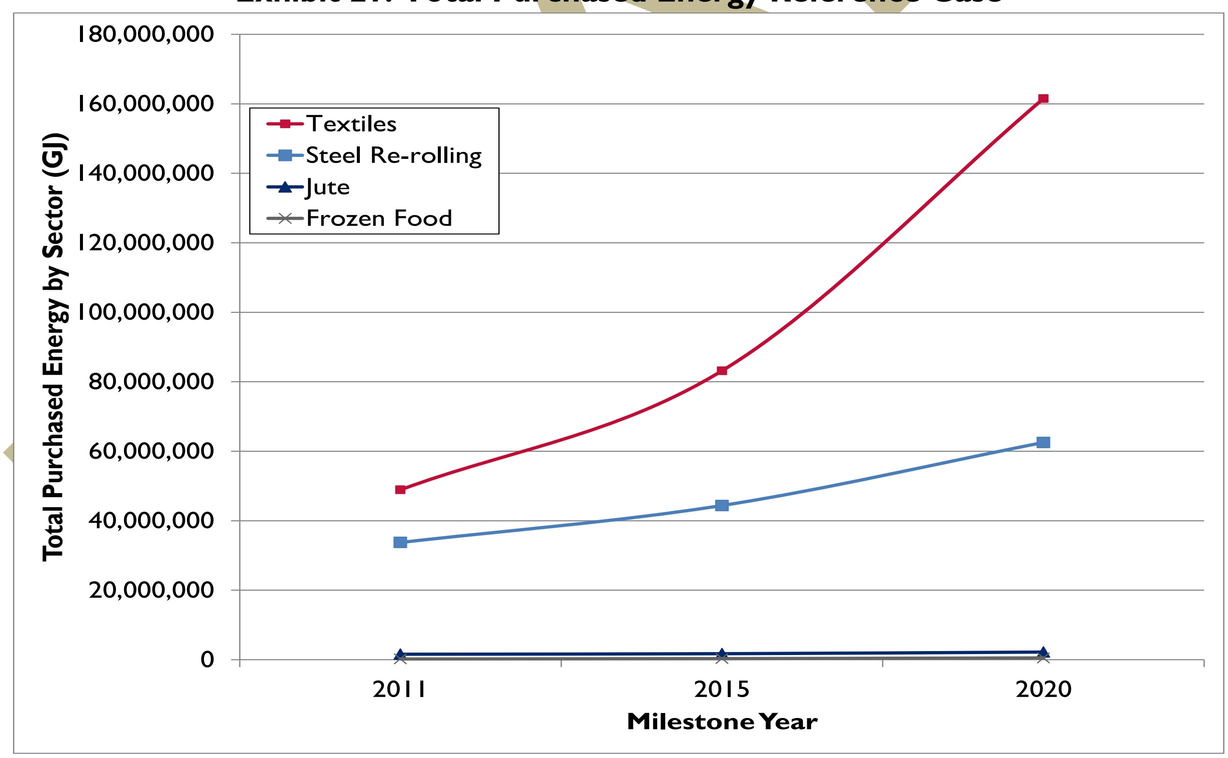
**Exhibit 20: Energy Use Growth Rates for 2011 to 2020, by Sector**

| Sector | Annual Growth Rate | Source |
|---|---|---|
| Textiles | 14.2% | Planning Commission growth figures for 'Textile and Clothing' industry. Used average of growth projections between 2011 and 2015 to cover the period from 2011 to 2020[3]. |
| Steel Re-rolling | 7.1% | Planning Commission growth figures for 'Construction' industry, since this is directly correlated. Used average of growth projections between 2011 and 2015 to cover the period from 2011 to 2020[3]. |
| Jute | 5.0% | Based on historic trends, as per the discussion above. |
| Frozen Food | 9.5% | Planning Commission growth figures for 'Other Food' industry. Used average of growth projections between 2011 and 2015 to cover the period from 2011 to 2020[3]. |

## 6.2 Results

The Reference Case total energy use is estimated to increase by 169 percent from 2011 to 2020, as shown in Exhibit 21 through Exhibit 23. In absolute terms the increase is over 142.3 PJ. The energy use in the textile industry is forecasted to increase by roughly 14 percent per year and represents the largest growth sector in this study.

**Exhibit 21: Total Purchased Energy Reference Case**




[3] Planning Commission, Ministry of Planning, Government of the People's Republic of Bangladesh. Sixth Five Year Plan FY2011-FY2012: Accelerating Growth and Reducing Poverty. www.plancomm.gov.bd

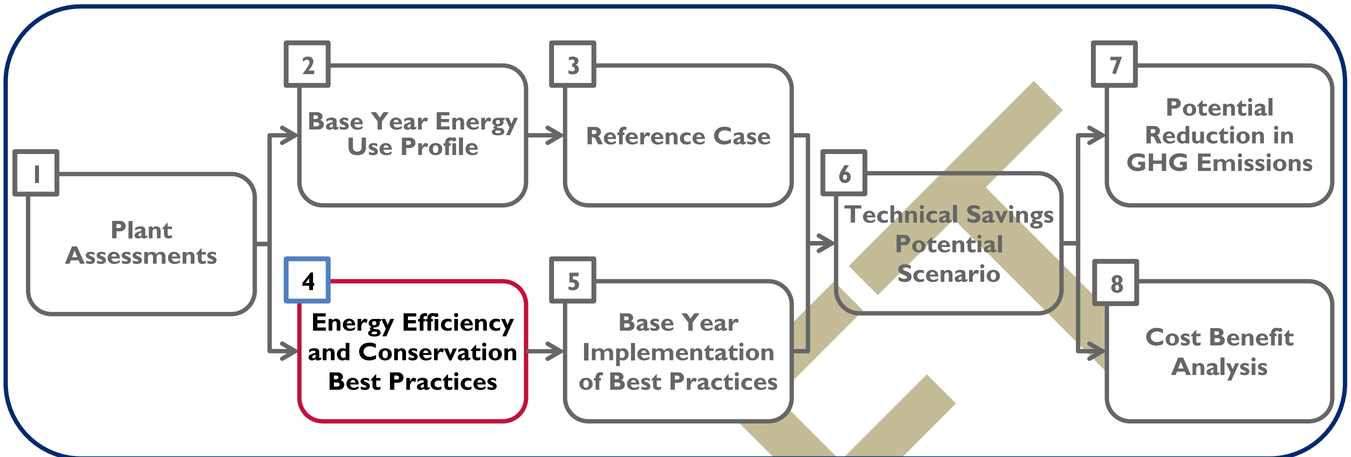
**Exhibit 22: Reference Case Energy Use by Energy Source**

| Energy Source | Energy Use (GJ) 2011 | 2015 | 2020 | Change from 2011 to 2020 |
|---|---|---|---|---|
| Natural Gas | 51,688,373 | 81,543,928 | 146,789,713 | 95,101,340 |
| Electricity | 15,211,407 | 21,240,069 | 32,859,969 | 17,648,562 |
| Fuel Oil | 33,459 | 44,563 | 63,891 | 30,432 |
| Diesel | 34,760 | 46,680 | 67,646 | 32,886 |
| Captive Power Loss | 17,418,053 | 26,664,106 | 46,917,573 | 29,499,520 |
| **Totals** | 84,386,052 | 129,539,346 | 226,698,792 | 142,312,741 |

**Exhibit 23: Reference Case Energy Use by Sector**

| Sub-sector | Energy Use (GJ) 2011 | 2015 | 2020 | Change from 2011 to 2020 |
|---|---|---|---|---|
| Textiles | 48,887,063 | 83,149,256 | 161,506,084 | 112,619,020 |
| Steel Re-rolling | 33,722,724 | 44,369,092 | 62,521,284 | 28,798,560 |
| Jute | 1,561,348 | 1,712,022 | 2,185,022 | 623,674 |
| Frozen Food | 214,916 | 308,977 | 486,403 | 271,487 |
| Total | 84,386,052 | 129,539,346 | 226,698,793 | 142,312,741 |

# 7. ENERGY EFFICIENCY AND CONSERVATION BEST PRACTICES




This section describes the energy efficiency and conservation best practices included in the study. These technical best practices (TBPs) are summarised in Section 7.2. The subsequent sections (Sections 8 and 9) will address the implementation of the best practices in Bangladesh industry and the savings potential if the technically feasible TBPs are implemented.

## 7.1 Methodology

Industrial energy efficiency and conservation best practices, or technical best practices (TBPs), were identified using secondary sources, and ICF's extensive databases. The secondary sources included literature, equipment suppliers, and industry energy management experts. Technical best practices include production systems, equipment, methods, and employed practices that result in advanced levels of energy use performance. In defining the TBPs the following items are of relevance:

- Only TBPs that are technically feasible and commercially available are included in the analysis. This would exclude measures that are still in a testing phase and are not yet commercialized.
- TBPs are included at a level of detail that is manageable within the budget and scope of the study. This necessitates that the TBPs include a degree of bundling. For example, the TBP "economizers" for steam boilers includes standard and condensing economizers.
- The list of TBPs was reviewed by industry experts.

## 7.2 Results

The generic TBPs included in this study are listed in Exhibit 24, while the sector-specific TBPs are listed in Exhibit 25 through Exhibit 28.

**Exhibit 24: Generic Technical Best Practices**

| End Use | Technical Best Practice | Relative Cost | Ease of Implementation |
|---|---|---|---|
| System and Other Process | Power factor correction | Low | Low |
| | Sub-metering and interval metering | Medium | Medium |
| | Electricity demand management control system | Low | Medium |
| | High efficiency dry-type transformer | High | High |
| | Integrated control system | High | High |
| | Heat exchanger maintenance and repair | Medium | Medium |
| | Heat exchanger optimization | High | High |
| Indirect heating | High efficiency burner | Medium | Medium |
| | Flue gas monitoring | Medium | Medium |
| | Blowdown heat recovery | Medium | Medium |
| | Boiler combustion air preheat | Medium | Medium |
| | Efficient boiler system | High | Medium |
| | Economizer | Medium | Medium |
| | Automated blowdown control | Medium | Medium |
| | Process heat recovery to preheat makeup water | Medium | Medium |
| | Load management assessment | Low | Low |
| | Boiler load management | High | Medium |
| | Insulation | Low | Low |
| | Advanced boiler controls | Medium | Medium |
| | Boiler water treatment to remove impurities | Medium | Medium |
| | Minimize de-aerator vent losses | Low | Medium |
| | Condensate return | Medium | Medium |
| | Steam trap surveys completed within past 2 years and faulty traps repaired | Low | Low |
| | Preventative boiler maintenance | Low | Low |
| Direct heating | High efficiency burner | Medium | Medium |
| | Control air-fuel ratio through flue gas monitoring | Medium | Medium |
| | Exhaust gas heat recovery | Medium | Medium |
| | Insulation | Medium | Medium |
| | Advanced heating and process control | Medium | Medium |
| | Infrared ovens and/or use of radiant heat instead of convection heating | Medium | High |
| | Air curtains | Medium | Low |
| | Combustion optimization | Low | Low |
| | Preventative maintenance | Low | Low |
| Process cooling and refrigeration | High efficiency chiller | Medium | Medium |
| | Smart defrost controls | Medium | Medium |
| | Optimized distribution system | Medium | High |
| | Improve insulation of refrigeration system | Low | Low |
| | Floating head pressure controls | Medium | Medium |
| | Premium efficiency refrigeration control system | Medium | Medium |
| | Doors, covers and curtains | Low | Low |
| | VSD on chiller compressor | Medium | Medium |

| | | | |
|---|---|---|---|
| | Optimized chilled water temperature and/or optimized condenser temperature | Medium | Medium |
| | Optimized condenser pressure | Low | Medium |
| | Free cooling | Medium | Medium |
| | Preventative refrigeration/cooling system maintenance | Low | Low |
| Motive Power | High/premium efficiency motors for pumps | Medium | Low |
| | High/premium efficiency motors for fans | Medium | Low |
| | High/premium efficiency motors for equipment | Medium | Low |
| | Premium efficiency control with ASDs | Medium | Medium |
| | Synchronous belts | Medium | Medium |
| | Optimization of pumping system | Medium | High |
| | Optimized duct design | Low | Medium |
| | Impeller trimming | Low | Low |
| | Optimized motor control | Low | Low |
| | Preventative maintenance | Low | Low |
| | Correctly sized motors | Medium | Medium |
| Compressed air system | Premium efficiency ASD compressors | Medium | Medium |
| | Premium efficiency air dryer | Medium | Medium |
| | Sequencing control | Medium | Medium |
| | Improved distribution system | Low | Medium |
| | Optimized sizes of air receiver tanks | Medium | Low |
| | Air leak survey and repair | Low | Low |
| | Minimize operating air pressure | Low | Low |
| | Preventative compressor maintenance | Low | Low |
| | Replace compressed air use with mechanical or electrical | Low | Low |
| | Optimized sizing of compressor system | Medium | Medium |
| | Use cooler air from outside for make-up air | Low | Low |
| | Compressor heat recovery | Medium | Medium |
| | Synchronous belts | Medium | Medium |
| Heating, Ventilation, and Air Conditioning | High efficiency non-packaged HVAC | Medium | Medium |
| | Ground source heat pump | Medium | High |
| | Automated temperature control | Medium | Medium |
| | Seasonal temperature setting adjustments | Low | Low |
| | Reduced temperature settings | Low | Low |
| | High/premium efficiency motors for fans | Medium | Low |
| | Free cooling | Medium | Medium |
| | Premium efficiency ventilation control with VSD | Medium | Medium |
| | Solar walls | Medium | Medium |
| | Destratification fans | Medium | Low |
| | Radiant heaters | Medium | Low |
| | Ventilation optimization | Medium | Medium |
| | Demand-controlled ventilation | Medium | Medium |
| Lighting | High efficiency lights fixtures | Low | Low |
| | Lighting controls according to occupancy | Low | Low |
| | Lighting controls according to on/off timer | Medium | Medium |
| | Use of electronic ballasts | Low | Low |
| | Lighting control according to zones | Medium | Medium |
| | Efficient lighting design | Low | Low |
| Transport | High efficiency transportation equipment | Medium | Low |
| | Alternative fuelled vehicles or hybrid technology | Medium | Low |
| | Minimal vehicle idling | Low | Low |
| | Vehicle system efficiency maintenance programs | Low | Low |
| | High efficiency battery charger (for forklifts) | Medium | Low |

## Exhibit 25: Frozen Food Sector-Specific Technical Best Practices

| Technical Best Practice | Relative Cost | Ease of Implementation |
|---|---|---|
| Energy efficiency operating procedures | Low | Low |
| Separate products and customize temperature of refrigerated spaces to suit product requirements | Medium | Low |
| Reducing heating load within the refrigerated area | Low | Low |
| Measure the temperature of incoming product to within a certain threshold | Low | Low |
| Reduce warmer air and moisture infiltration through sealing | Low | Low |
| Evaporative condensers | High | Medium |
| Installing automatic tube ice plants to replace block ice plants | High | Medium |
| Optimized cooling towers | Medium | Medium |
| Solar water pump for raw water | High | Medium |
| Central steam cooking | High | Medium |
| Installation of a refrigeration heat recovery system to preheat boiler make up water | Medium | Medium |
| Optimizing the sequencing of the compressors | Medium | High |
| Automatic star delta starter for partly loaded motors | Medium | Medium |
| VFD on condenser fan can improve heat rejection | Medium | Medium |
| Floating suction pressure control | Medium | Medium |
| VFD on evaporator fan | Medium | Low |
| Efficient compressor design | High | High |
| Optimized diesel generator operation | Low | Low |
| High efficiency back-up generators | High | Medium |
| Cooling compressor oil through a thermo-syphon | Medium | Medium |

## Exhibit 26: Jute Sector-Specific Technical Best Practices

| Technical Best Practice | Relative Cost | Ease of Implementation |
|---|---|---|
| Process steam generation by utilization of waste jute caddy | High | High |
| Modification in jute spinning frame by introducing baxter flyer and larger bobbins | Medium | Medium |
| Replacement of bailing press pump with hydraulic oil power pack | Medium | Medium |
| Replacement of old conventional card machines with new high productivity energy efficient card machines | High | High |
| Change of belts in drawing ,weaving and carding section to reduce slippage and better utilization of power | Medium | Medium |
| Modification in jute spreader or softener machine | Medium | Medium |
| Self-lubricating bushes, runners & other components | Low | Low |
| Recovery of condensate from calendaring process for use as boiler feed water | Medium | Medium |
| Modification of weaving machines | Medium | Medium |
| Modification of roll and cop winding machine | Medium | Medium |
| Replacing defective elements / steam traps | Low | Low |

**Exhibit 27: Textile Sector-Specific Technical Best Practices**

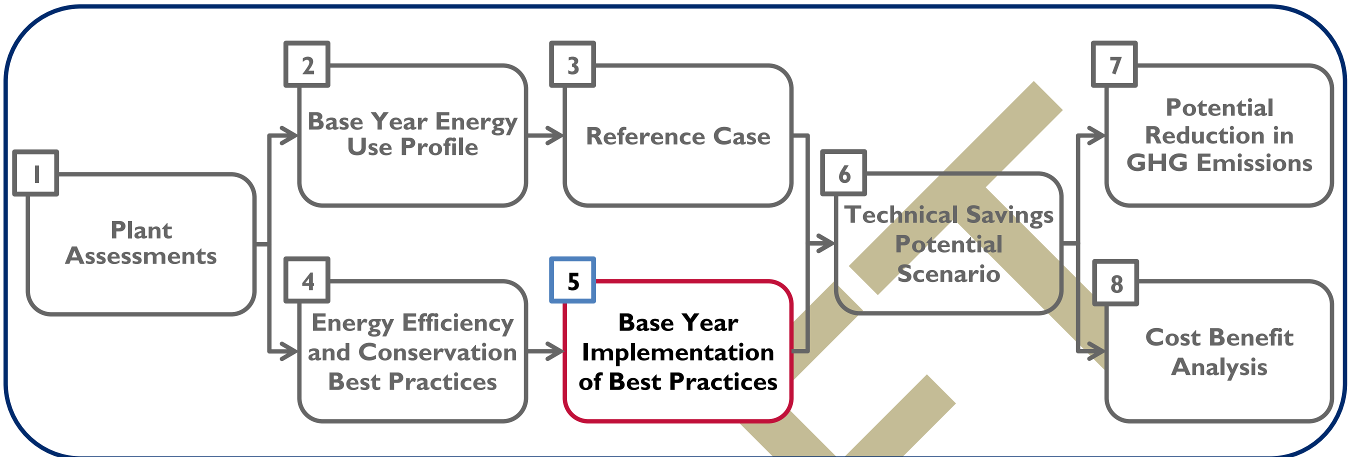
| Sub-Process | Technical Best Practice | Relative Cost | Ease of Implementation |
|---|---|---|---|
| Bleaching | 'Combined de-sizing, scouring, bleaching process', employing steam purge and cold-patch- batch technique | High | Medium |
| | Use of 'cold-pad-batch treatment' | High | High |
| | Use of 'bleach bath recovery system' | Medium | Low |
| | Installing covers on nips and tanks in continuous washing machines | Low | Low |
| | Use of automatic systems (valves) to cut off water and heat supply | Low | Low |
| | Heat recovery systems in continuous washing machines | Low | Medium |
| | Reduction in live steam pressure | Low | Low |
| | Interlocking of fans and pumps with the process machines operation | Low | Low |
| | Enzymatic removal of residual hydrogen | High | Medium |
| Drying | Utilize mechanical pre drying systems (mangles, centrifuges, suction slots, air knives) | Medium | Medium |
| | Use of directed air over the drying cylinders | Medium | Low |
| | Recover condensate and flash steam in cylinder dryer | Medium | Medium |
| | End panel insulation in cylinder dryer | Medium | Medium |
| | Avoid intermediate drying in cylinder dryer | High | High |
| | Avoid over drying in cylinders | Low | Low |
| | Careful scheduling of fabric batches arriving at the cylinders | Low | Low |
| | Make drying cylinders extra wide to allow two batches of narrow fabric to run side by side | Medium | Medium |
| | Good maintenance practices on drying cylinders to minimize steam leaks | Low | Low |
| Dyeing | Automatic systems to dispense chemicals | High | High |
| | Use of 'cold-pad-batch dyeing system' with beam washing in place of winch | High | High |
| | 'Airflow dyeing machine' in place of conventional jet dying machine | High | Medium |
| | Adoption of advanced 'air flow jet dyeing machine' | High | Medium |
| | Dyebath reuse | Low | Medium |
| | Advanced winch machines | Medium | Medium |
| | Single rope flow dyeing machine in place of conventional rope dyeing machine | High | High |
| | Microwave dyeing equipment | High | High |
| | Reduction of batch temperature in batch pressure dyeing machines | High | High |
| | Use of steam coil in batch dyeing machines (winch and jigger) in place of direct steam | Medium | Medium |
| | Reducing the process time in wet batch pressure-dyeing machines | High | High |
| | Using covers or hoods in atmospheric wet batch machines | Low | Low |
| | Control of temperature in atmospheric wet batch machines through circulators | Low | Low |
| | 'New generation of jiggers with variable liquor ratio' in place of conventional jiggers | High | High |
| | Heat recovery from hot water waste from high temperature and high pressure autoclaves | Medium | Medium |
| | Reduction of reprocessing of dyeing | Medium | Medium |
| | Reuse of washing and rinse water | Medium | Medium |

| | | | |
|---|---|---|---|
| | Reduction of rinse water temperature | Low | Low |
| | Conversion of 'thermic fluid heaters' with 'direct gas firing system' in stenters | High | High |
| | Use of mechanical dewatering systems (mangles, centrifuges, suction slots, air knives) in stenters | Medium | Medium |
| | Use of gas fired infrared drying and radio frequency drying in stenters | High | High |
| | Close exhaust streams during idle periods in stenter reduces air-heating requirements | Low | Low |
| | Avoid over drying in stenters to reduce steam use | Low | Low |
| Finishing | Close and seal side panels in stenter minimizes steam leakage | Low | Low |
| | Insulation of stenters envelope wherever feasible particularly in old machines | Medium | Medium |
| | Optimize exhaust humidity in stenter results in reduced energy consumption for air heating | High | High |
| | Installation of heat recovery in stenters exhaust for heating air or process water | High | High |
| | Installation of efficient gas burners in gas fired stenters | Medium | Low |
| | Utilization of sensors and controls for energy efficient operation of stenters | Medium | Medium |
| Washing | Use of 'counter flow current of water for fabric washing' technology | Medium | Medium |
| Scouring | Enzymatic scouring to replace alkaline scouring process | High | High |
| Printing | Automated dyestuff preparation in fabric printing plants | High | High |

### Exhibit 28: Steel Re-Rolling Sector-Specific Technical Best Practices

| Technical Best Practice | Relative Cost | Ease of Implementation |
|---|---|---|
| Automatic controls of furnace temperature and pressure | Medium | Medium |
| Change of the furnace lining | Medium | Medium |
| Energy efficient furnace | High | High |
| Rolling mill optimization | High | High |
| Maintain desired air pressure at the gas burners | Low | Low |
| Optimize temperature levels in the furnace | Low | Low |
| Minimize air infiltration in the furnace through appropriate draft control | Low | Low |
| Minimize overheating of material to reduce scale losses | Low | Low |
| Optimize furnace hearth loading in accordance with rated furnace capacity | Low | Low |
| Effective production planning schedule to optimally utilize furnace capacity | Low | Low |
| Carry out maintenance of gas burners periodically | Low | Low |
| Carry out repairs and maintenance of furnace windows and doors during long shut downs | Low | Low |
| Fix cold face insulation on furnace roof and walls | Medium | Medium |
| High-efficiency recuperators | High | High |
| Maintain insulation of ducts carrying preheated air | Low | Low |
| Clean heat transfer surfaces of recuperators during long shut downs | Low | Low |
| Monitor temperatures of flue gas and air at inlet and outlet ports in the recuperator | Low | Low |

# 8. BASE YEAR IMPLEMENTATION OF BEST PRACTICES




This section presents the implementation of best practices in the 2011 Base Year. The extent to which best practices are implemented in the Base Year reveals the opportunity that exists to increase the implementation of best practices. It defines the gap between the amount of best practices industry that has been implemented and the maximum amount of best practices that can be implemented. This section includes all the best practices described in Section 7.

## 8.1 Methodology

The extent to which TBPs are currently implemented in industry (also referred to as the 'market penetration rate') was determined through the results of the site assessments. For each TBP, the results from the site assessment provide information to define the Base Year market penetration rate and the opportunity that still remains for increased implementation.

In order to convert the data from the TBP assessments into implementation rates, each possible response was given a score, as follows:

- Applicable TBP implemented in facility: score = 2
- Applicable TBP partially implemented in facility: score = 1
- Applicable TBP not employed: score = 0

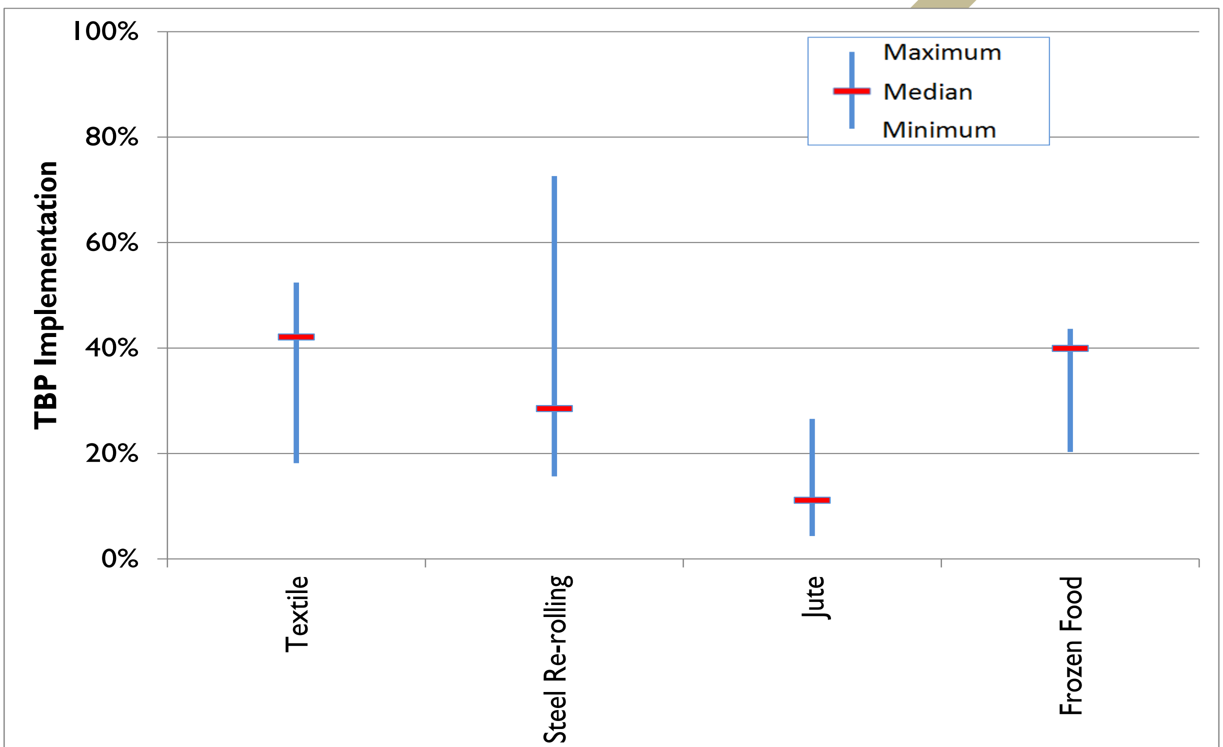
A total score was calculated, with each TBP receiving an equal weight. These scores were used to develop the market penetration rates, as follows:

- A draft set of market penetration rates was constructed using the benchmarking results of the 15 site assessments.
- The draft market penetration rates were reviewed and, minor adjustments were made to ensure the penetration rates are representative of each sector.

## 8.2 Results

The implementation of TBPs in the plants in each of the four sectors is presented in Exhibit 29, while implementation of TBPs by end use is per sector is presented in Exhibit 30.

**Exhibit 29: Implementation of TBPs by Sector**



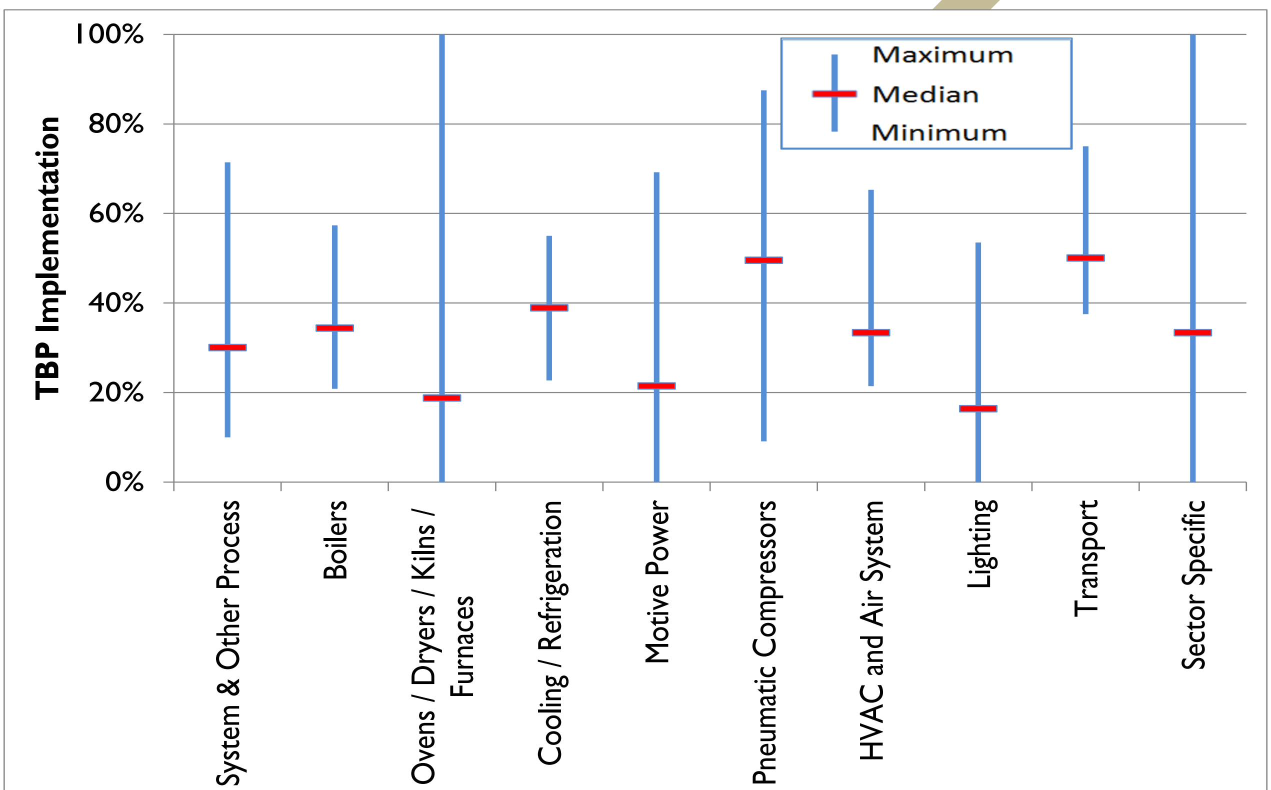

The results indicate there is a large potential to implement EE opportunities (TBPs) in all sectors:

- The ***jute manufacturing*** sector shows the largest potential to increase implementation of EE opportunities (TBPs). None of the plants have implemented more than 30% of the available opportunities, indicating that 70% of technical feasible opportunities can still be implemented in the sector.
- In the ***textile manufacturing*** sector none of the plants have implemented more than 55% of the technically feasible opportunities, indicating that about 45% of available EE opportunities can still be implemented in the sector.
- The ***steel re-rolling*** sectors shows the largest range in implementation of EE opportunities. The best performing plant(s) has achieved an implementation of close to 75% of the technically feasible opportunities, but more than half of the plants have implemented less than 30% of the available EE

opportunities. This indicates that half of the plants can still implement 70% of the available opportunities.

- In the ***frozen food*** manufacturing sector the plants have implemented between 20% and 45% of the technically feasible opportunities. This means that there is still a potential to implement 55% or more EE opportunities in frozen food plants.

**Exhibit 30: Implementation of TBPs by End Use in All Sectors**




An assessment of the implementation of EE opportunities (TBPs) by end use in all sectors, shows a large potential exists in all end use, and specifically in:

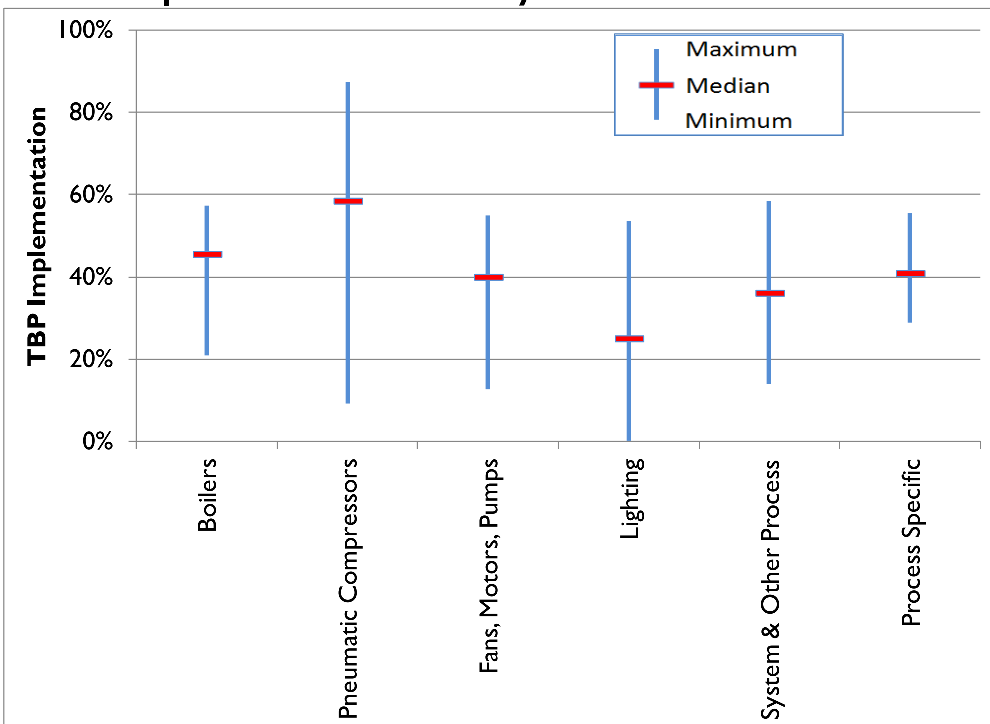
- ***Ovens/dryers/kilns/furnaces, motive power*** and ***lighting***. In all three these end uses, half of the plants have implemented less than about 20% of the technically feasible EE opportunities, and these plants can still implement 80% of the available EE opportunities.

The end uses where most EE opportunities are implemented include:

- ***Pneumatic compressors*** and ***transport***, where half of the plants have implemented more than about 50% of the available EE opportunities. Even though many EE opportunities are implemented in these end uses, a large potential still exist for half of the plants implemented less than 50% the EE opportunities.

Exhibit 31 to Exhibit 34 presents the implementation of TBPs individually for each of the sectors.

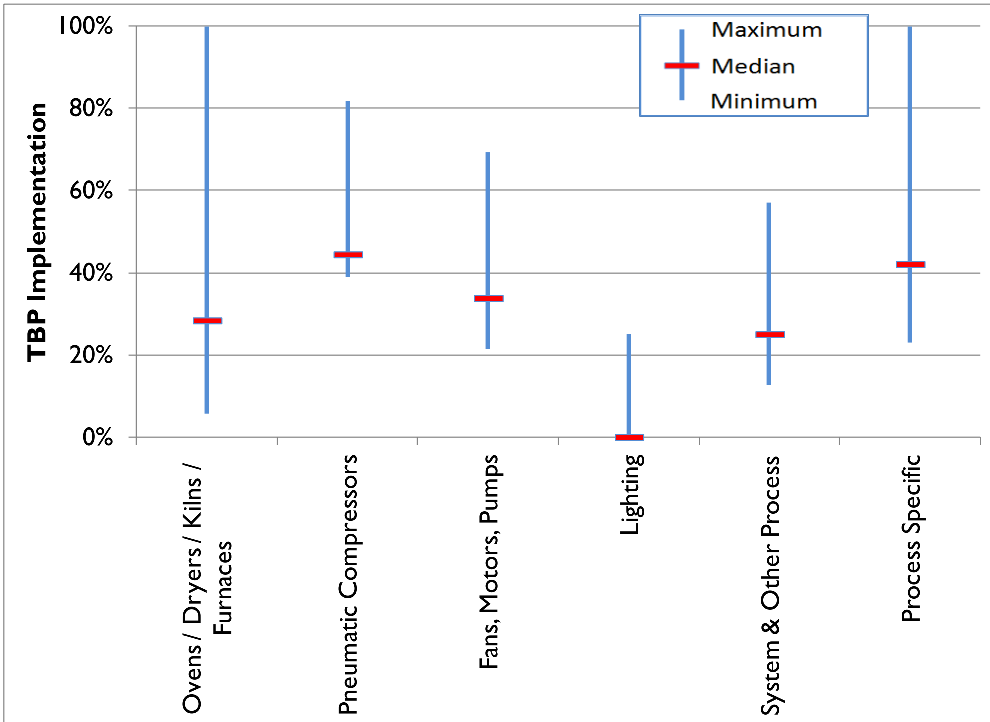
**Exhibit 31: Implementation of TBPs by End Use in Textile Manufacturing**




In the textile manufacturing sector for all end-uses, except pneumatic compressors, all the plants have implemented less than 60% of the EE opportunities and all plants can still implement the remaining 40% of EE opportunities. For lighting half of the plants have implemented less than 30% of applicable EE opportunities and a large potential exist to increase implementation of opportunities.

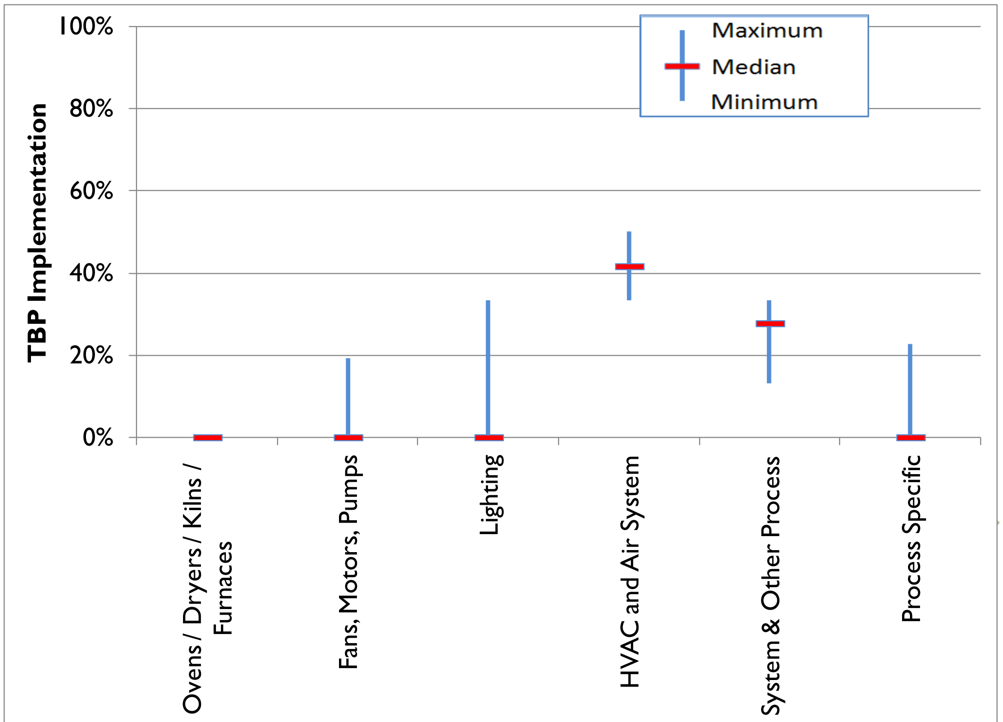
Most energy is used in the textile manufacturing sectors in the process specific (40% of total energy use) and boiler (36% of total energy use) end uses. In both these end uses half the plants can implement respectively about 60% and 55% of the applicable EE opportunities.

**Exhibit 32: Implementation of TBPs by End Use in Steel Re-rolling**



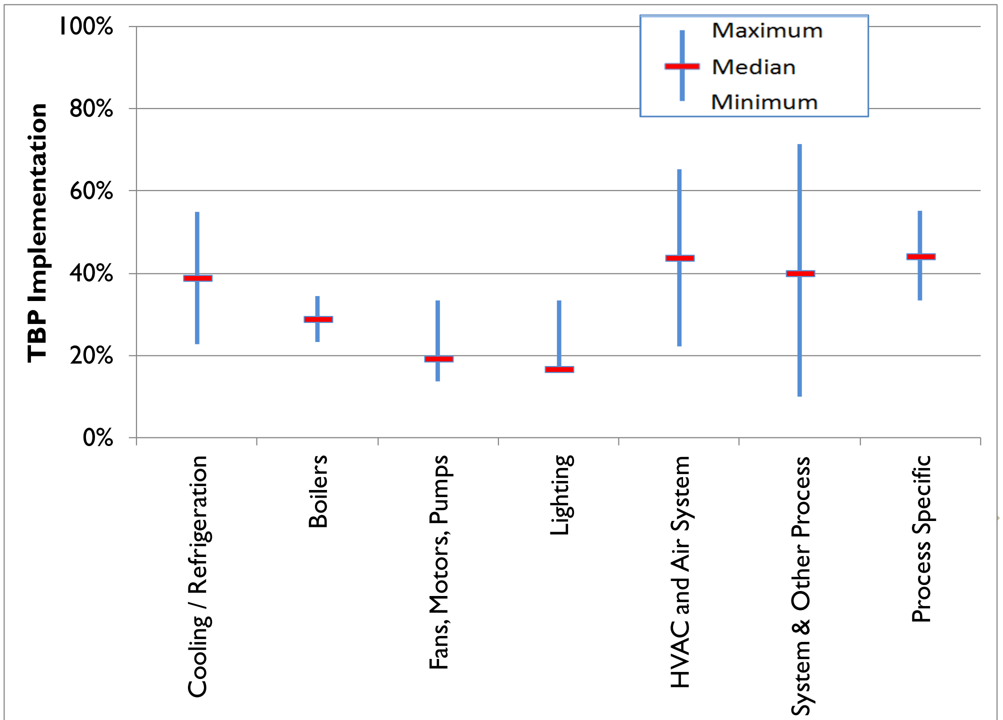

In the steel re-rolling sector close to 65% of all energy is used in ovens/furnaces and half the plants have implemented 30% or less EE opportunities applicable to ovens/furnaces. Motive power uses about 17% of the total energy in the sector and half the plants have implemented 35% or less of the applicable EE opportunities. This indicates a very large potential exists to increase the implementation in EE opportunities in end uses accounting for 82% of the energy use in the sector.

**Exhibit 33: Implementation of TBPs by End Use in Jute Manufacturing**



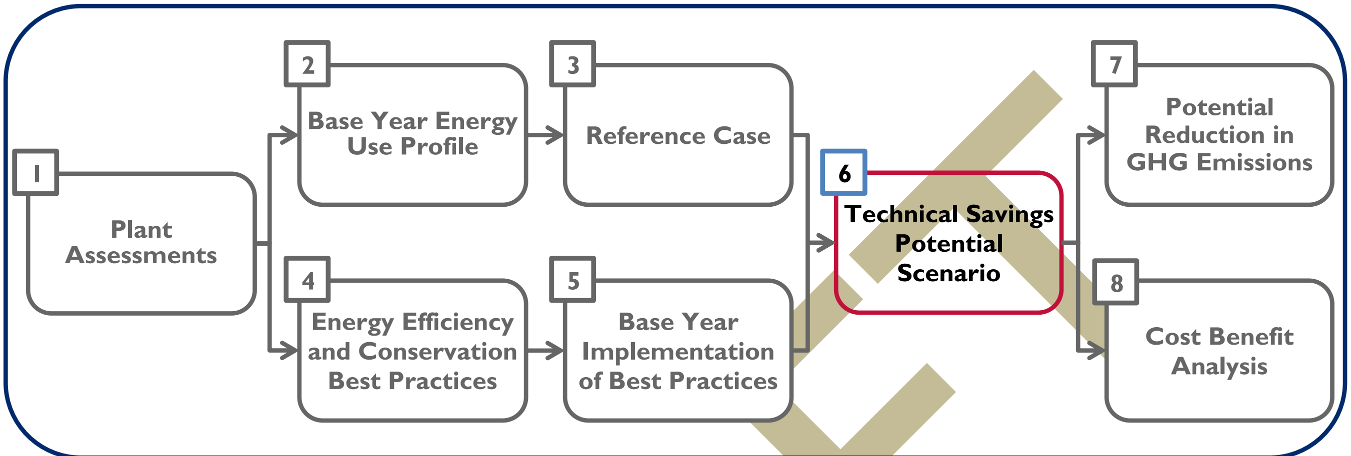

In the jute manufacturing sector there is overall very low implementation of EE opportunities and four of the six end uses, where half of the companies have not implemented any EE opportunities. These four end-uses account for about 45% of the energy use by the sector. Besides the 52% of total energy used in the sector but is lost due to captive power generation, the remaining two end uses account for less than 3% of the total energy use.

**Exhibit 34: Implementation of TBPs by End Use in Frozen Food Manufacturing**




Most energy in the frozen food manufacturing sector is used in the cooling/refrigeration (28% of total sector energy use) and HVAC and air systems (23% of total sector energy use). For both these end uses half of the plants have implemented less than 45% of the available EE opportunities and can still implement the remaining 55% of opportunities. Low implementation of EE opportunities are also observed for boilers, motive power (i.e. fans, motors and pumps) and lighting, where all the plants can still implemented 65% of the technically feasible opportunities.

# 9. TECHNICAL SAVINGS POTENTIAL SCENARIO




This section presents the Technical Savings Potential Scenario, which uses the results presented in the Reference Case and the Base Year implementation of TBPs (see Sections 7 and 8). The methodology used to calculate the Technical Savings Potential Scenario is discussed, followed by the results of the analysis.

## 9.1 Methodology

There are two types of TBPs:

- ***Replacement TBPs:*** These are measures that are implemented at the end of the equipment useful life. These measures are modelled as being implemented at natural stock turnover rates.
- ***Retrofit TBPs:*** These are measures that can be added to equipment or to the plant process at any time. These measures are modelled as being implemented at the first study milestone year, for immediate application of retrofit technologies.

The Technical Savings Potential resulting from the implementation of these two types of TBPs was modelled as follows:

- Energy use within each of the sub-sectors was modelled with the same energy models used to generate the Reference Case.
- Individual TBP savings are included within each end use. To ensure the savings are not overestimated the model calculates saving for each opportunity applicable to an end use in sequential order, with each subsequent TBP saving a percentage of the remaining energy in an end use. To estimate the maximum savings the sequential implementation of opportunities are assessed from largest savings to least mount savings. The absolute energy savings are calculated as the

difference between the Reference Case energy consumption and the Technical Potential scenario energy consumption.

## 9.2 Results

If all the technically feasible TBPs were implemented, it is estimated that the total energy use of the four selected industrial sectors would increase by about 97 PJ from 2011 to 2020. As shown in Exhibit 35, the estimated energy use in 2020 would be 181.3 PJ, or 20 percent (45.4PJ) less than the Reference Case energy use in 2020. The total estimated energy savings are summarized by sector and purchased energy type in Exhibit 36.

**Exhibit 35: Total Reference Case and Technical Potential Scenario Energy Use**

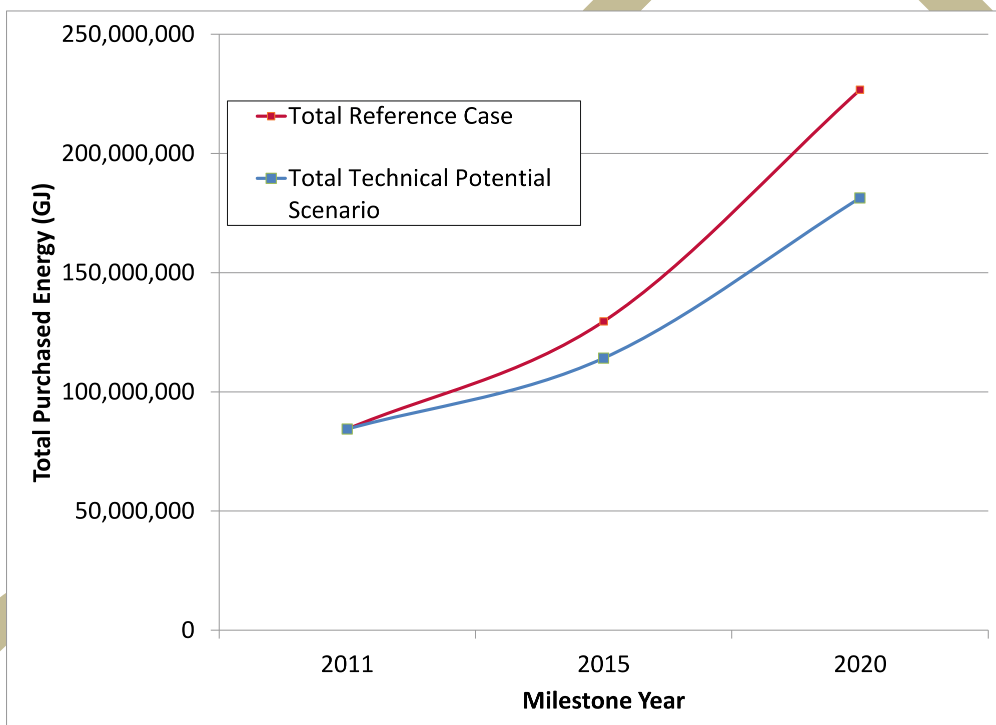
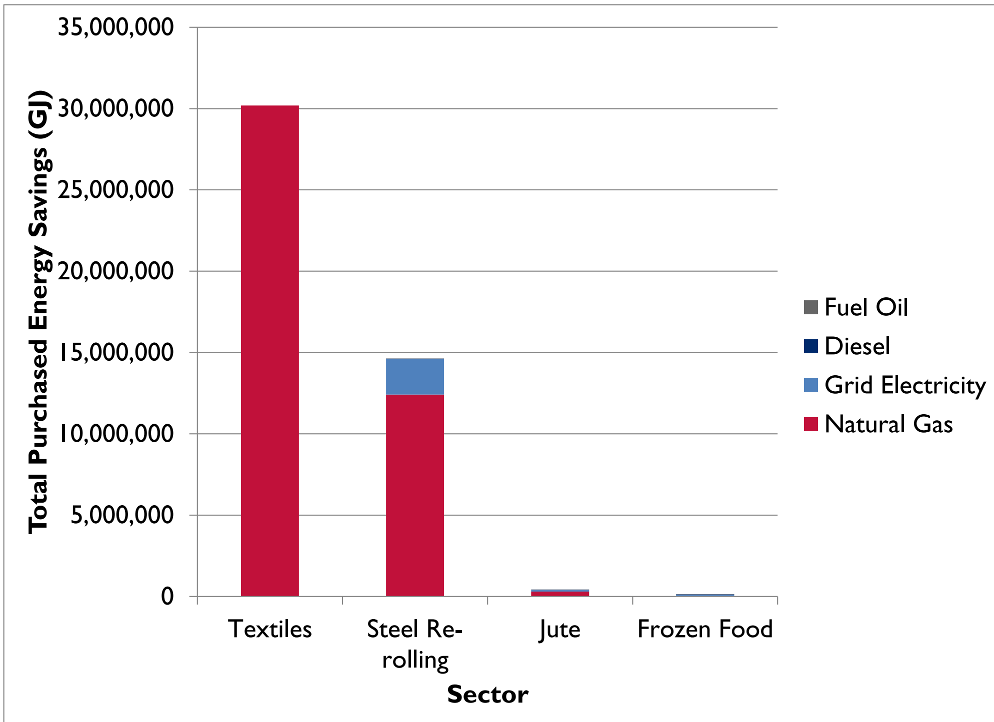
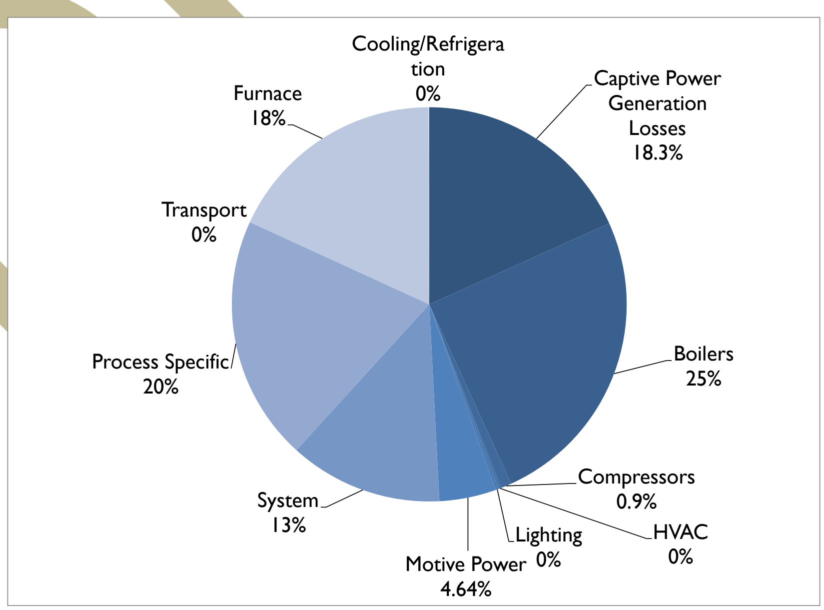


**Exhibit 36: Technical Potential Energy Savings by Sector and Energy Type for 2020**




The energy savings by end use is illustrated in Exhibit 28. Close to 63 percent of the energy savings are attributed to three end uses: boilers (25 percent), process specific (20 percent) and furnaces (18 percent). Savings at end uses where electricity is supplied by on-site power generation, accounts for 18 percent (or about 8 PJ) of total energy savings. This is the natural gas reduction associated with the captive power losses that will be avoided if the electric efficiency opportunities are implemented.

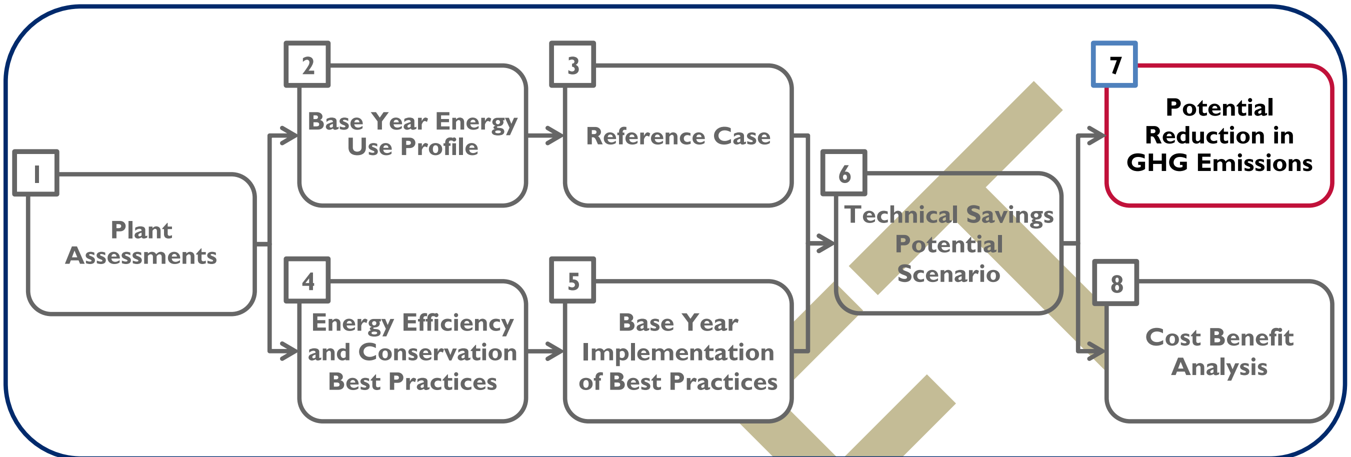
**Exhibit 37: Total Technical Potential Energy Savings by End Use for 2020**



The energy savings for each sector is presented in Appendixes B to E, and the following observations are relevant to each sector:

- In the ***textile manufacturing*** sector the largest potential savings are associated with the boilers (38% of total energy savings) and the textile processing (30% of total sector energy savings).
- In the ***steel re-rerolling*** sector most of the savings are associated with the furnaces (56% of total sector savings), and less opportunities with system wide (15% of total energy sector savings), and motive power (12% of total sector energy savings) end uses.
- In the ***jute*** sector energy lost due to captive power generation accounts for 55% of the sector's potential energy savings, while the process specific end use accounts for about 20% of the total sector energy savings.
- In the ***frozen food*** sector HVAC and cooling/refrigeration each accounts for close to 20 % of total sector savings.

# 10. POTENTIAL REDUCTION IN GHG EMISSIONS




The greenhouse gas (GHG) emissions associated with the energy savings potential are discussed in this section. The energy use and potential energy savings due to the implementation of best practices are analyzed in the previous sections.

## 10.1 Methodology

The GHG emission reductions associated with the Technical Potential energy savings, described in Section 9, were quantified by applying the appropriate emission factors to each of the types of on-site fuel savings. For electricity savings, equivalent emissions are calculated for electricity generation.

The GHG amounts are expressed in tonnes of equivalent carbon dioxide ($CO_2e$). The GHG emission factors used in the study are summarized in Appendix A.

## 10.2 Results

If all the technically feasible energy efficiency were implemented, as per the Technical Potential scenario, it is estimated that the annual reduction in GHG emissions would be 2.83 million tonnes $CO_2e$ as compared to the Reference Case in 2020. The Technical Potential GHG savings by sector are presented in Exhibit 38 for 2015 and in Exhibit 39 for 2020.

**Exhibit 38: Total Technical Potential Scenario GHG Savings by Sector for 2015**

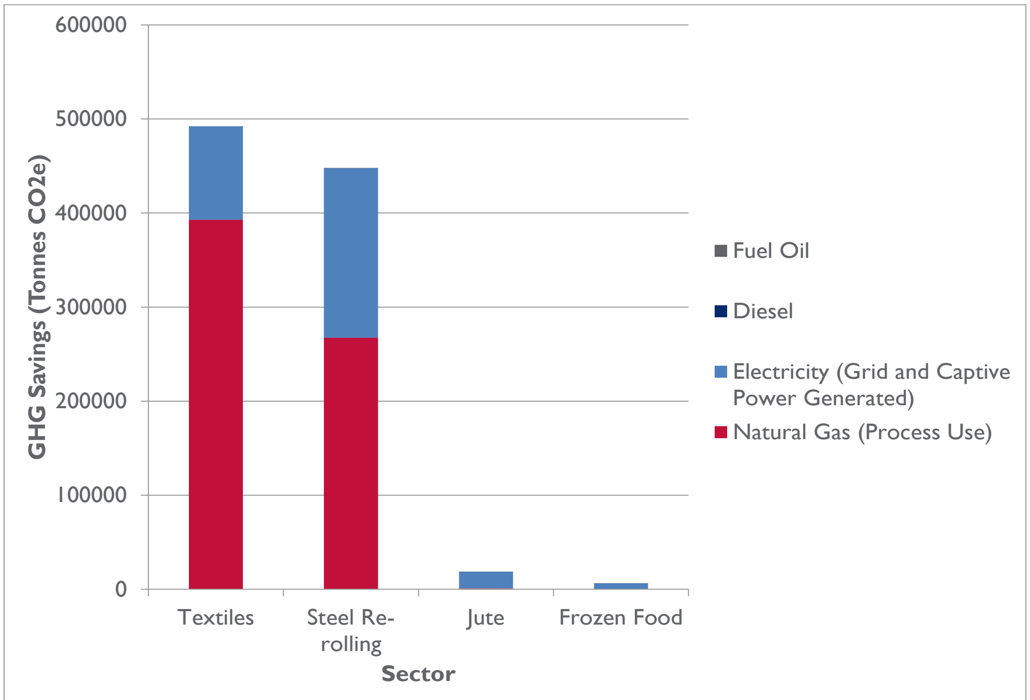
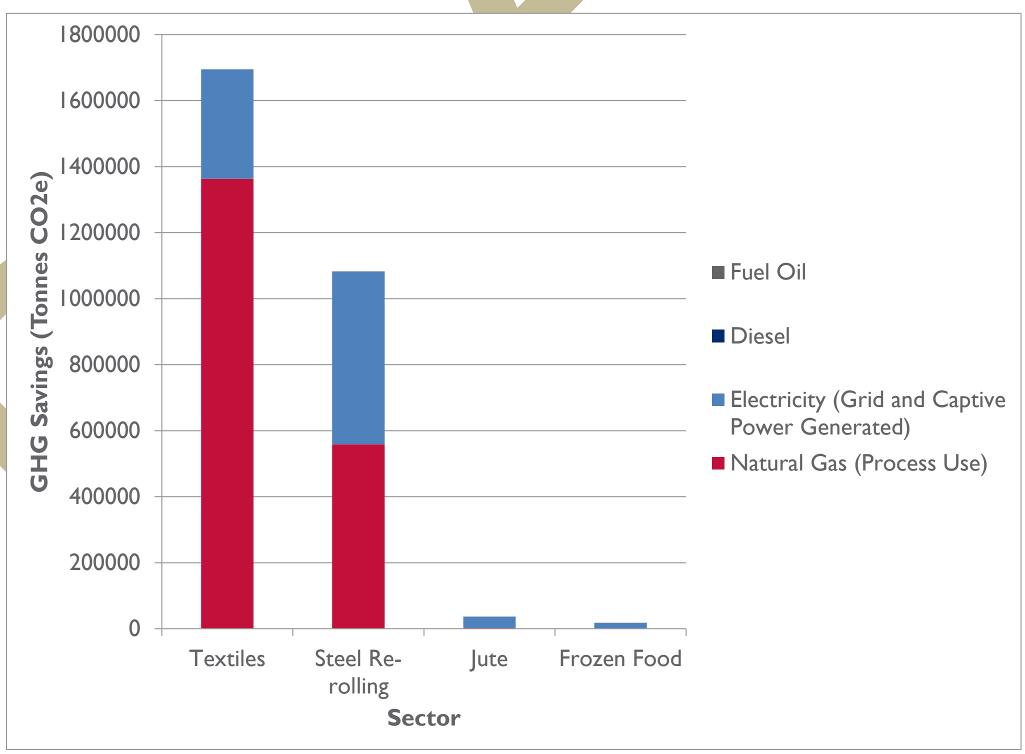
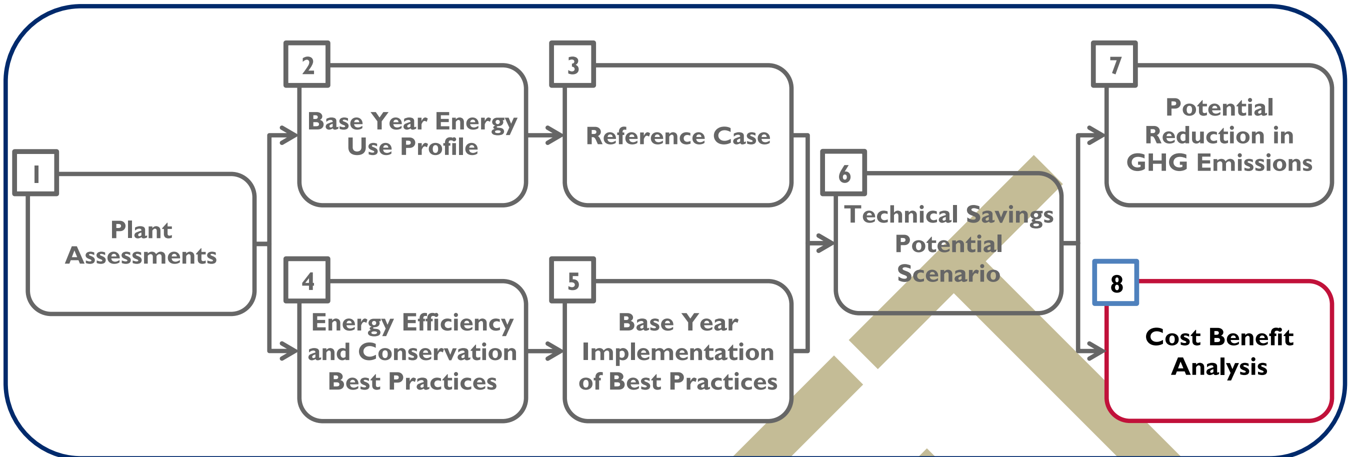



**Exhibit 39: Total Technical Potential Scenario GHG Savings by Sector for 2020**



# 11. COST BENEFIT ANALYSIS




This section provides an analysis of the costs and benefits associated with the technical best practices that show potential for implementation in the four selected Bangladesh industrial sectors. The analysis is executed for two scenarios:

- ***Technical Savings Potential:*** The economic savings benefits associated with the implementation of all technically feasible best practises. These best practices were identified and the energy savings determined in Sections 8 and 9.

- ***Selected Opportunities:*** The costs and savings analysis of 15 cross-cutting end use TBPs and 8 TBPs per sector. The selection of these TBPs is described in the methodology section below.

The results of these two scenario analyses are presented and discussed below in Sections 11.2 and 11.3 respectively.

## 11.1 Methodology

The economic value of the Technical Potential energy savings was calculated for the first scenario by multiplying the savings in each fuel type by the price of each fuel. The fuel prices used are listed in Appendix A.

Based on the results from Sections 8 and 9 the implementation of technical best practices for the second scenario were assessed to select 15 cross-cutting opportunities and 8 process specific opportunities per sector (i.e. 47 cross-cutting and process specific opportunities, in total), to determine the associated costs and simple payback periods. The following approach and criteria were used in selecting these opportunities:

- ***Cross cutting opportunities:***
  - A list of opportunities applicable to the majority of sectors was developed.

  - Priority was given to measures that were found to have the largest potential energy savings in the sectors.
  - At least one measure from each equipment category that was applicable to more than one sector was included.

- ***Process specific opportunities:***

  - A list of opportunities applicable to the majority of sites within the sector was developed.
  - Priority was given to measures that were found to have the largest potential energy savings in the sectors.
  - Priority was given to opportunities identified as the top opportunities within each of the plants assessed during the site assessments.
  - Opportunities with very long payback periods, more than 20 years, were excluded.

Cost data were obtained from the following sources:

- Published documents from:

  - Equipment manufacturers and suppliers
  - Bureau of Energy Efficiency, Government of India
  - The World Bank
  - United Nations Development Program
  - Natural Resources and Defence Council, People's Republic of China
  - Australian Industry Group
  - United States Department of Energy
  - Lawrence Berkley National Laboratory, United States of America

- Information obtained directly from equipment manufacturers and suppliers.

Relevant exchange rates were applied when needed and the costs were reviewed to consider difference in costs due to local conditions in Bangladesh. It is important to interpret the costs with the following caveats:

- The cost assessment is a high level assessment and is considered to be 40 percent to 50 percent accurate.

- Costs are very site specific, due to difference in sizes and site specific process conditions. The costs are provided in ranges to reflect these differences in site specific costs.

## 11.2 Results – Scenario One: Technical Saving Potential Analysis

If all the technically feasible energy efficiency best practices were implemented, as per the Technical Potential scenario, it is estimated that the annual cost savings for 2020, in fuel costs alone, would be

15,157 Million BDT. The Technical Potential energy cost savings by sector are presented in Exhibit 40 for 2015 and in Exhibit 41 for 2020.

**Exhibit 40: Total Technical Potential Scenario Energy Cost Savings by Sector for 2015**

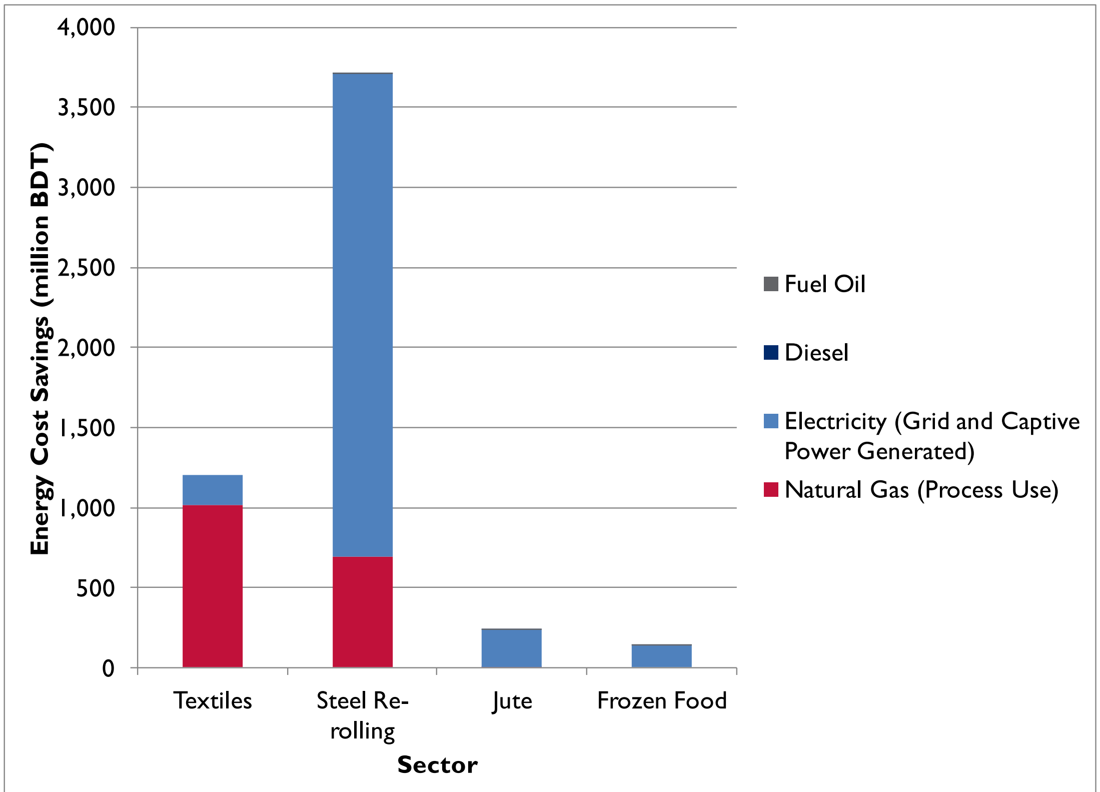
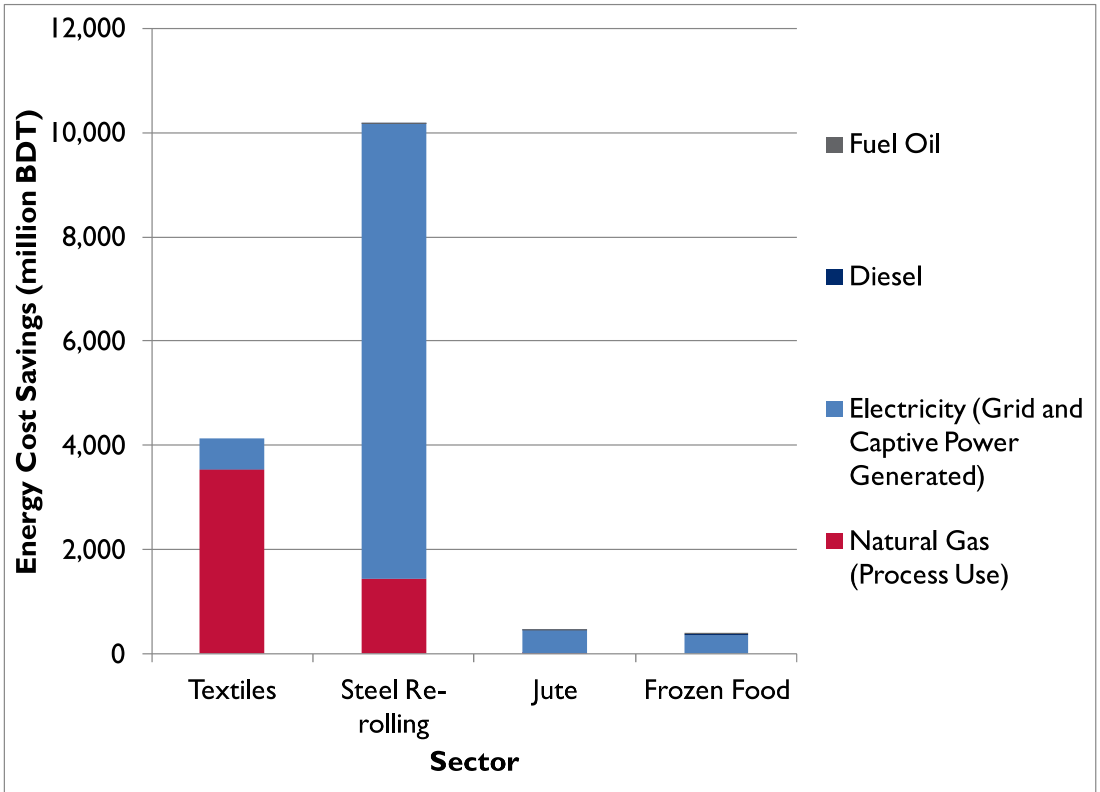


**Exhibit 41: Total Technical Potential Scenario Energy Cost Savings by Sector for 2020**




## 11.3 Results – Scenario Two: Selected Opportunities

The costs and savings of the 47 selected opportunities are presented in Exhibit 42. Unless specified to be incremental costs, all the costs represent the full cost to implement the opportunities. Implementation includes equipment installation for both retrofit and replacement measures. A retrofit measure is where equipment is added, while replacement is when existing equipment is exchanged for new equipment. Incremental cost is applicable to replacement of existing equipment and is defined as the cost difference between a standard efficiency equipment and more efficient equipment. Full costs will provide a longer payback period, while shorter payback periods will result if incremental costs are considered.

As shown in Exhibit 33 below, the costs and savings for all 15 cross-cutting opportunities result in simple payback periods of less than five years. Most of the opportunities (11 out of 15) have payback periods of less than two years, which is often reported as the desired maximum payback period to implement projects. This illustrates there is a significant economically feasible opportunity to improve energy efficiency in the Bangladesh industry.

The costs and savings associated with the process specific opportunities are summarised in Exhibit 43 tot Exhibit 46. Both the textile and steel re-rolling sectors have more than 50 percent of the opportunities with simple payback periods of less than two years. In the frozen food sector most of the opportunities have simple payback periods of less than three years, while in the jute sector most of the opportunities have payback periods of more than three years. This analysis indicates that:

- Textile and steel re-rolling sectors have a significant amount of opportunities that are economically feasible.
- Most opportunities in the jute sector will require financial support to make the opportunities economically feasible.
- The frozen food sector has many economically feasible opportunities, but may require some financial support to make the payback period more attractive.

**Exhibit 42: Summary of Cost Benefit Analysis for top Cross-Cutting Opportunities**

| Measure | Energy Savings[4] | Capital Cost - including Installation (BDT) | Incremental O&M Cost (BDT/year) | Payback Period (Years) |
|---|---|---|---|---|
| **Sub-metering and interval metering** | 5% | 2,050,000 to 5,494,000 (USD 25,000 to 67,540) | N/A | 0.5 to 2 |
| **Efficient lighting design** | 15% | 164,000 to 328,000 (USD 2,020 to 4,030) | N/A | 0.5 to 2 |
| **High efficiency lighting fixtures** | 50% | 492,000 to 861,000 (USD 6,050 to 10,580) | N/A | 0.5 to 2 |
| **Correctly sized motors** | 2% | 3,000 to 6,000 per motor[5] (USD 40 to 70) | N/A | Less than 0.25 |
| **High/premium efficiency motors** | 2% | 6,000 to 20,000 per motor[5] (USD 70 to 250)) | N/A | 0.5 to 2 |
| **Minimize operating air pressure** | 20% | 24,000 to 48,000 (USD 300 to 590) | N/A | Less than 0.25 |
| **Combustion optimization** | 10% | 440,000 (USD 5,410) | N/A | 0.5 to 1.5 |
| **Insulation - Furnaces** | 5% | 691,250 (USD 8,500) | N/A | 1.5 to 3.5 |
| **High Efficiency Burner** | 5% | 68,000 to 136,000 (USD 840 to 1,670) | N/A | 2 to 4.5 |
| **Flue gas monitoring** | 7% | 80,000 (USD 980) | 150,000 to 200,000 | 0.25 to 0.75 |
| **Boiler combustion air preheat** | 5% | 414,750 (USD 5,100) | N/A | 0.75 to 1.5 |
| **Economizer** | 4% | 691,250 to 1,036,875 (USD 8,500 to 12,750) | N/A | 2 to 4 |
| **Process heat recovery to preheat makeup water** | 6% | 800,000 to 4,000,000 (USD 9,830 to 49,170) | N/A | 2 to 5 |

[4] Percent savings of energy from end-use where this measure is applicable
[5] Motor figures shown are incremental costs. This means that they represent the difference in cost between implementing the measures and purchasing new motors without following the measures, and as such apply at motor end of life.

| | | | | |
|---|---|---|---|---|
| **Improve insulation of refrigeration system** | 5% | 320,000 to 400,000 (USD 3,930 to 4,920) | N/A | 0.5 to 1.5 |
| **Preventative Maintenance** | 5% | N/A | 150,000 to 200,000 | Immediate |

**Exhibit 43: Summary of Cost Benefit Analysis for top Textile Specific Opportunities**

| Measure | Energy Savings[6] | Capital Cost - including Installation (BDT) | Incremental O&M Cost (BDT/year) | Payback Period (Years) |
|---|---|---|---|---|
| Use of Mechanical dewatering systems (mangles, centrifuges, suction slots, air knives) in stenters | 15% | 120,000 (USD 1,480) | 112,000 | 0.5 to 1 |
| Use of directed air over the drying cylinders | 17% | 700,000 to 1,400,000 (USD 8,600 to 17,210) | N/A | 2.5 to 5 |
| Recover condensate and flash steam in cylinder dryers | 12% | 320,000 to 400,000 (USD 3,930 to 4,920) | N/A | 1 to 2 |
| End panel insulation in cylinder dryer | 5% | 80,000 to 160,000 (USD 980 to 1,970) | N/A | 1 to 2 |
| Close exhaust streams during idle periods in stenter | 5% | N/A | N/A | Immediate |
| Installation of heat recovery in stenter exhaust for heating air or process water | 30% | 6,160,000 (USD 75,720) | N/A | 2 to 5 |
| Use of 'Counter flow current of water for fabric washing' technology | 45% | 756,000 to 1,080,000 (USD 9,290 to 13,280) | N/A | 1 to 2.5 |
| Heat recovery systems in continuous washing machines | 50% | 880,000 to 1,900,000 (USD 10,820 to 23,360) | N/A | 2 to 3 |
| 'Airflow dyeing machine' in place of conventional jet dying machine | 60% | 15,240,000 (USD 187, 340) | N/A | 5 to 9 |

**Exhibit 44: Summary of Cost Benefit Analysis for top Steel Re-Rolling Specific Opportunities**

| Measure | Energy Savings[6] | Capital Cost - including Installation (BDT) | Incremental O&M Cost (BDT/year) | Payback Period (Years) |
|---|---|---|---|---|
| Advanced heating and process control | 10% | 510,000 to 4,000,000 (USD 6,270 to 49,170) | N/A | 1 to 3.5 |
| Change of the furnace lining | 13% | 800,000 to 2,000,000 (USD 9,830 to 24,590) | N/A | 1 to 2 |
| Rolling mill optimization | 15% | 600,000 to 1,400,000 (USD 7,380 to 17,210) | N/A | 0.5 to 1 |

[6] Percent savings of energy from end-use where this measure is applicable

| | | | | |
|---|---|---|---|---|
| Control air-fuel ratio through flue gas monitoring | 7% | 80,000 (USD 980) | 150,000 to 200,000 | 0.25 to 1 |
| Minimize air infiltration in the furnace through appropriate draft control, such as air curtains | 15% | 240,000 to 480,000 (USD 2,950 to 5,900) | N/A | 0.25 to 1 |
| Minimize overheating of material to reduce scale losses | 6% | N/A | 150,000 to 200,000 | 0.25 to 0.75 |
| High-efficiency recuperators | 12% | 480,000 to 2,900,000 (USD 5,900 to 35,650) | N/A | 1 to 2 |
| Preventative maintenance of gas burners | 5% | N/A | 150,000 to 200,000 | 0.25 to 0.75 |

**Exhibit 45: Summary of Cost Benefit Analysis for top Jute Specific Opportunities**

| Measure | Energy Savings[7] | Capital Cost - including Installation[8] (BDT) | Incremental O&M Cost (BDT/year) | Payback Period (Years) |
|---|---|---|---|---|
| Process steam generation by utilization of waste jute caddy | 10% | 8,000,000 (USD 98,340) | N/A | 4.5 to 6 |
| Modification in Jute spinning frame by introducing baxter flyer and larger bobbins | 10% | 140,000 (USD 1,720) | N/A | 3 to 4 |
| Replacement of old conventional card machine with new high productivity energy efficient card machine | 10% | 400,000 (USD 4,920) | N/A | 5 to 10 |
| Change of belts in drawing ,weaving and carding section to reduce slippage and better utilization of power | 5% | 80,000 (USD 980) | N/A | 2 to 4 |
| Modification in Jute Spreader or softener machine | 5% | 160,000 (USD 1,970) | N/A | 5 to 9 |
| Self-lubricating bushes, runners & other components | 5% | 3,200 to 8,000 (USD 40 to 100) | N/A | 1 to 2 |
| Modification of weaving machine | 5% | 20,000 to 40,000 (USD 250 to 490) | N/A | 8 to 14 |
| Modification of roll and cop winding machine | 15% | 40,000 to 160,000 (USD 490 to 1,970) | N/A | 2 to 4.5 |



[7] Percent savings of energy from end-use where this measure is applicable
[8] Costs are presented per machine

**Exhibit 46: Summary of Cost Benefit Analysis for top Frozen Food Specific Opportunities**

| Measure | Energy Savings[9] | Capital Cost - including Installation (BDT) | Incremental O&M Cost (BDT/year) | Payback Period (Years) |
|---|---|---|---|---|
| **Energy efficiency operating procedures** | 5% | N/A | N/A | Immediate |
| **Installing automatic tube ice plants to replace block or flake ice plants** | 20% | 600,000 to 1,600,000 (USD 7,380 to 19,670) | N/A | 2.5 to 5 [10] |
| **Optimized cooling towers** | 10% | 160,000 to 320,000 (USD 1,970 to 3,930) | N/A | 1 to 2 |
| **Installation of a refrigeration heat recovery system to preheat boiler make up water** | 5% | 400,000 to 800,000 (USD 4,920 to 9,830) | N/A | 0.5 to 3 |
| **VFD on condenser fan** | 5% | 80,000 to 96,000 (USD 980 to 1,180) | N/A | 1 to 2 |
| **Floating suction or floating head pressure controls** | 10% | 120,000 to 240,000 (USD 1,480 to 2,950) | N/A | 0.25 to 0.75 |
| **Efficient compressor system design** | 10% | 790,000 to 1,185,000 (USD 9,710 to 14,570) | N/A | 2 to 3[11] |
| **VSD on chiller compressor** | 25% | 240,000 to 400,000 (USD 2,950 to 4,920) | N/A | 0.5 to 1.5 |

# 12. CONCLUSION

Based on the assessment the following observations and results are highlighted:

- If all the technically feasible EE opportunities (TBPs) were implemented, it estimated energy use will be 20 percent (or 45.4PJ) less in 2020 compared to a Reference Case where EE opportunities are not implemented.
- Close to 63 percent of the energy savings are attributed to three end uses: boilers (25 percent), process specific (20 percent) and furnaces (18 percent).
- Savings at end uses where electricity is supplied by on-site power generation, accounts for 18 percent (or about 8 PJ) of total energy savings.

[9] Percent savings of energy from end-use where this measure is applicable
[10] The payback period provided is based on the full cost of a new tube ice plant. If only the incremental cost of a tube ice plant over a new flake ice plant is considered, the payback period would be less than 1 year.
[11] The payback period provided is based on the full cost of a new high efficiency compressor. If a new compressor is required, the incremental cost of selecting a high efficiency compressor over a standard efficiency one will be very small, and will have a payback period below 0.5 years.

- If all the technically feasible energy efficiency best practices were implemented, as per the Technical Potential scenario, it is estimated that the annual cost savings for 2020, in fuel costs alone, would be 15,157 Million BDT (or about US$ 185 Million).

For each of the four sectors the largest potential energy savings are as follows:

- In the ***textile manufacturing*** sector the largest potential savings are associated with the boilers (38% of total energy savings) and the textile processing (30% of total sector energy savings).
- In the ***steel re-rerolling*** sector most of the savings are associated with the furnaces (56% of total sector savings), and less opportunities with system wide (15% of total energy sector savings), and motive power (12% of total sector energy savings) end uses.
- In the ***jute*** sector energy lost due to captive power generation accounts for 55% of the sector's potential energy savings, while the process specific end use accounts for about 20% of the total sector energy savings.
- In the ***frozen food*** sector HVAC and cooling/refrigeration each accounts for close to 20 % of total sector savings.

The following table summarizes the top 15 cross cutting EE opportunities and top eight opportunities applicable to each of the four sectors.

| Generic | Textile | Steel Re-rolling | Jute | Frozen Food |
|---|---|---|---|---|
| Sub-metering and interval metering | Use of Mechanical dewatering systems (mangles, centrifuges, suction slots, air knives) in stenters | Advanced heating and process control | Process steam generation by utilization of waste jute caddy | Energy efficiency operating procedures |
| Efficient lighting design | Use of directed air over the drying cylinders | Change of the furnace lining | Modification in Jute spinning frame by introducing baxter flyer and larger bobbins | Installing automatic tube ice plants to replace block or flake ice plants |
| High efficiency lighting fixtures | Recover condensate and flash steam in cylinder dryers | Rolling mill optimization | Replacement of old conventional card machine with new high productivity energy efficient card machine | Optimized cooling towers |
| Correctly sized motors | End panel insulation in cylinder dryer | Control air-fuel ratio through flue gas monitoring | Change of belts in drawing ,weaving and carding section to reduce slippage and | Installation of a refrigeration heat recovery system to preheat boiler make up water |

| | | | | |
|---|---|---|---|---|
| | | | better utilization of power | |
| High/premium efficiency motors | Close exhaust streams during idle periods in stenter | Minimize air infiltration in the furnace through appropriate draft control, such as air curtains | Modification in Jute Spreader or softener machine | VFD on condenser fan |
| Minimize operating air pressure | Installation of heat recovery in stenter exhaust for heating air or process water | Minimize overheating of material to reduce scale losses | Self-lubricating bushes, runners & other components | Floating suction or floating head pressure controls |
| Combustion optimization | Use of 'Counter flow current of water for fabric washing' technology | High-efficiency recuperators | Modification of weaving machine | Efficient compressor system design |
| Insulation - Furnaces | Heat recovery systems in continuous washing machines | Preventative maintenance of gas burners | Modification of roll and cop winding machine | VSD on chiller compressor |
| High Efficiency Burner | | | | |
| Flue gas monitoring | | | | |
| Boiler combustion air preheat | | | | |
| Economizer | | | | |
| Process heat recovery to preheat makeup water | | | | |
| Improve insulation of refrigeration system | | | | |
| Preventative Maintenance | | | | |

# 13. GLOSSARY

***Baseline technology:*** The existing equipment against which upgrade technologies are compared and to which measures are applied.

***Base Year:*** The year against which all potential scenarios are compared. For this study, the Base Year is the 2011 calendar year.

***Cost-benefit analysis:*** Provides a comparison of the costs and benefits of a project in order to determine if the project is a sound investment decision. The costs considered in this analysis are capital costs, installation costs, and operating and maintenance costs. The benefits considered in this analysis are energy savings and reduced operating and maintenance costs.

***Energy end use profile:*** The percentage breakdown, by fuel type and end use, of energy use in a given sector.

***Equivalent carbon dioxide:*** The concentration of carbon dioxide that would cause the same level of greenhouse gas effect as a given type and concentration of another greenhouse gas, such as methane.

***Greenhouse gas emissions:*** The emission of gases, most often through the burning of fossil fuels, that act to trap heat in the atmosphere (known as the greenhouse gas effect), contributing to global warming.

***Market penetration rate:*** The level at which a given measure is adopted in the market place.

***Milestone years:*** Key years over the study period at which energy reduction potentials are estimated through modelling.

***Replacement measure/technology:*** An energy efficiency measure/technology that can be installed to replace a less efficient piece of equipment. Replacement measures are usually applied on an incremental cost basis, as they are most often installed once the existing piece of equipment has reached the end of its useful life and is due for replacement.

***Reference Case:*** A projection of energy use to 2020, in the absence of any new energy management market interventions after the base year (i.e., incremental to what utilities and government have already planned for this period). The Reference Case is the period against which the scenarios of energy savings are calculated.

***Retrofit measure/technology:*** An energy efficiency measure/technology that can be used to upgrade an existing piece of equipment, as opposed to replacing it. Retrofit measures are applied on a full cost basis and may be implemented immediately.

***Technical best practices:*** A set of measures that represent the most energy efficiency technologies available.

# Appendix A: Conversion Factors

### Exhibit 47: Energy Content Conversion Factors

| Fuel | LHV Factor | Source |
|---|---|---|
| Natural Gas | 0.03897 GJ/$m^3$ | "BEST Cement for China" tool developed by Lawrence Berkeley National Laboratory |
| Fuel Oil | 0.04186 GJ/kg | |
| Diesel | 0.04269 GJ/kg | |

### Exhibit 48: GHG Emission Factors

| Fuel | Emission Factor (kg $CO_2$e/GJ) | Source |
|---|---|---|
| Grid Electricity | 172.2 | Improving Kiln Efficiency in the Brick Making Industry in Bangladesh, CDM - Executive Board, United Nations Framework Convention on Climate Change, 30/10/2009 |
| Natural Gas Stationary Combustion | 56.2 | 2006 IPCC Guidelines for National Greenhouse Gas Inventories, Table 2.3: Default Emission Factors for Stationary Combustion in Manufacturing Industries and Construction, Intergovernmental Panel on Climate Change |
| Fuel Oil Stationary Combustion | 77.6 | |
| Diesel Stationary Combustion | 74.3 | |

### Exhibit 49: Fuel Prices

| Fuel | Price | Source |
|---|---|---|
| Grid Electricity | 13.88 BDT/kWh | Bangladesh Power Development Board. Large industry rate. http://www.bpdb.gov.bd/download/All_Retail_Tariff_01-12-2011.pdf |
| Natural Gas (industrial use) | 165.91 BDT/MCF | Petrobangla. http://www.petrobangla.org.bd/ |
| Natural Gas (captive power use) | 118.26 BDT/MCF | |
| Fuel Oil | 60 BDT/L | Bangladesh Petroleum Corporation website. "Local Selling Price of Petroleum Products" http://www.bpc.gov.bd/contactus.php?id=39 |
| Diesel | 61 BDT/L | |

# Appendix B: Textile Manufacturing Sector Detailed Results

The textile manufacturing sector obtains almost all of its energy from natural gas and generate its own electricity. Almost no electricity is purchased from the grid.

**Exhibit 50: Textile Sector Base Year Energy Use**

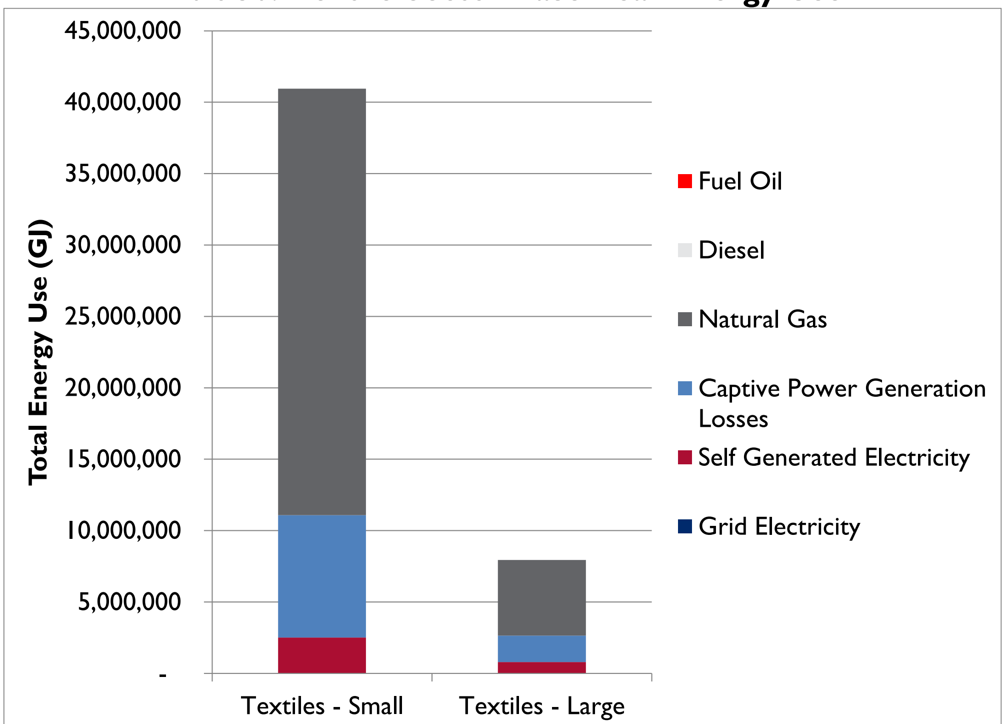
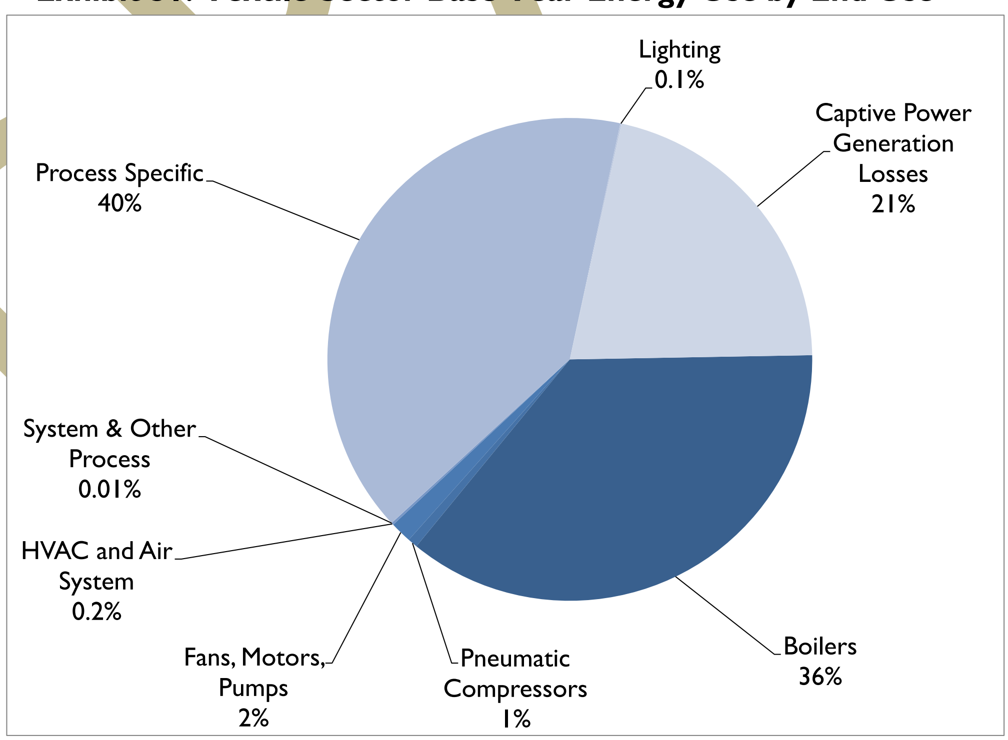
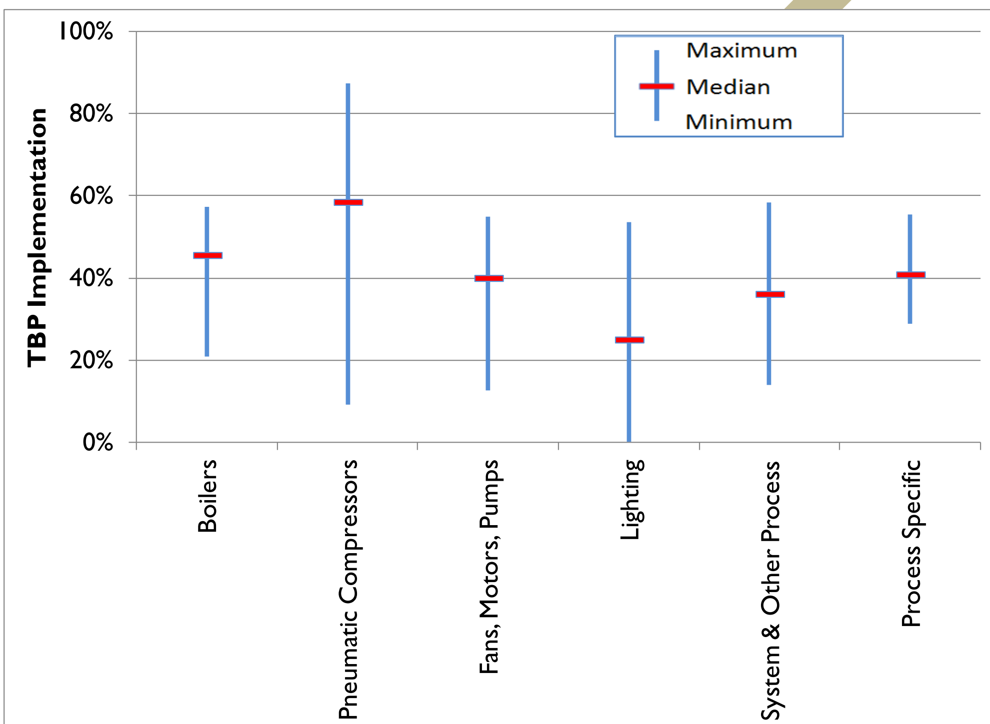



**Exhibit 51: Textile Sector Base Year Energy Use by End Use**



Most of the energy used by the textile sector is used in the process specific (40 %) and boiler (36%) end use. Due to the fact that the sector uses a large amount of natural gas to generate electricity, a relatively large portion of the natural gas energy (21% of the sector total energy use) is lost in the captive power generation process.

**Exhibit 52: Textile Sector Implementation of TBPs**




In the textile manufacturing sector for all end-uses, except pneumatic compressors, all the plants have implemented less than 60% of the EE opportunities and all plants can still implement the remaining 40% of EE opportunities. For lighting half of the plants have implemented less than 30% of applicable EE opportunities and a large potential exist to increase implementation of opportunities.

Most energy is used in the textile manufacturing sectors in the process specific (40% of total energy use) and boiler (36% of total energy use) end uses. In both these end uses half the plants can implement respectively about 60% and 55% of the applicable EE opportunities.

Since natural gas supplies almost all the energy in the textile sector, the energy savings are almost exclusively in purchased natural gas. Most of the savings by end use are in the areas where most of the energy is used, namely boilers, textile production and captive power generation losses.

**Exhibit 53: Textile Sector Technical Potential Scenario Energy Savings by Fuel Type in 2020**

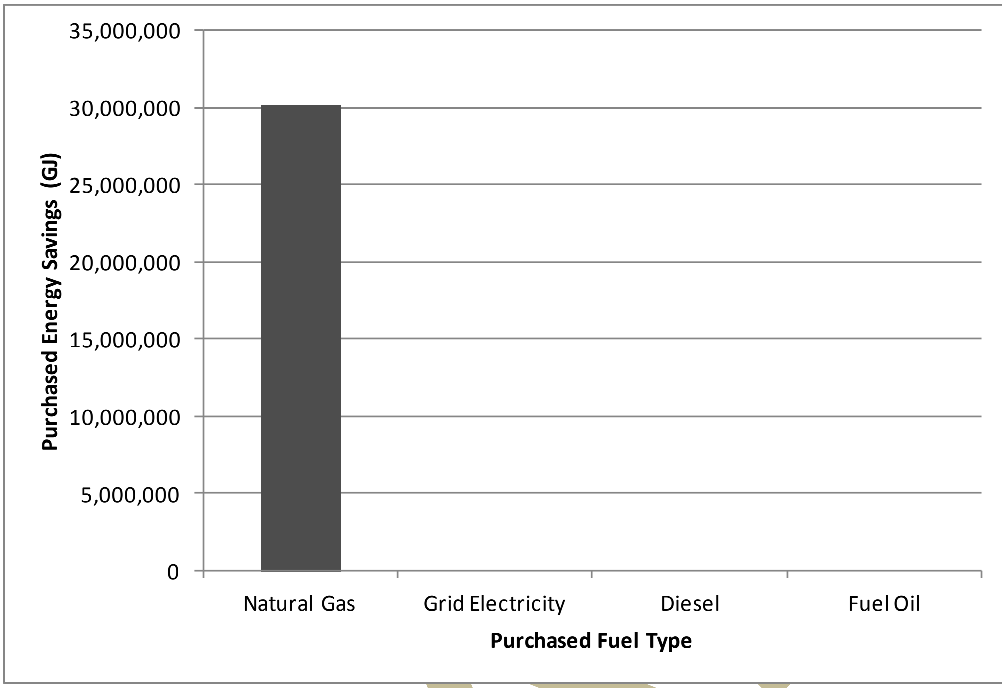
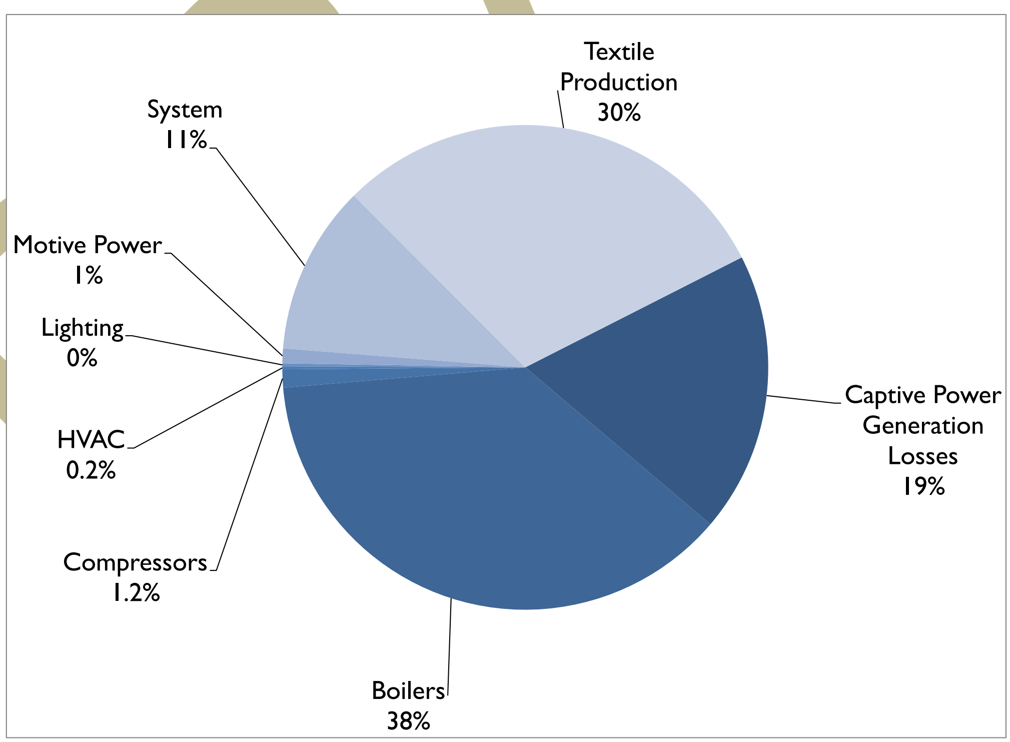



**Exhibit 54: Textile Sector Technical Potential Scenario Energy Savings by End Use in 2020**



# Appendix C: Steel Re-Rolling Sector Detailed Results

The largest portion of energy used in the steel re-rolling sector is used by small and medium sized plants. Natural gas accounts for close to 80% of the total purchased energy. A relatively large portion of electricity used on-site is generated on site.

Almost all the energy used in the sector is used by three end-uses: furnaces (65%), motive driven equipment (17%) and captive power generation losses (18%).

**Exhibit 55: Steel Re-Rolling Sector Base Year Energy Use**

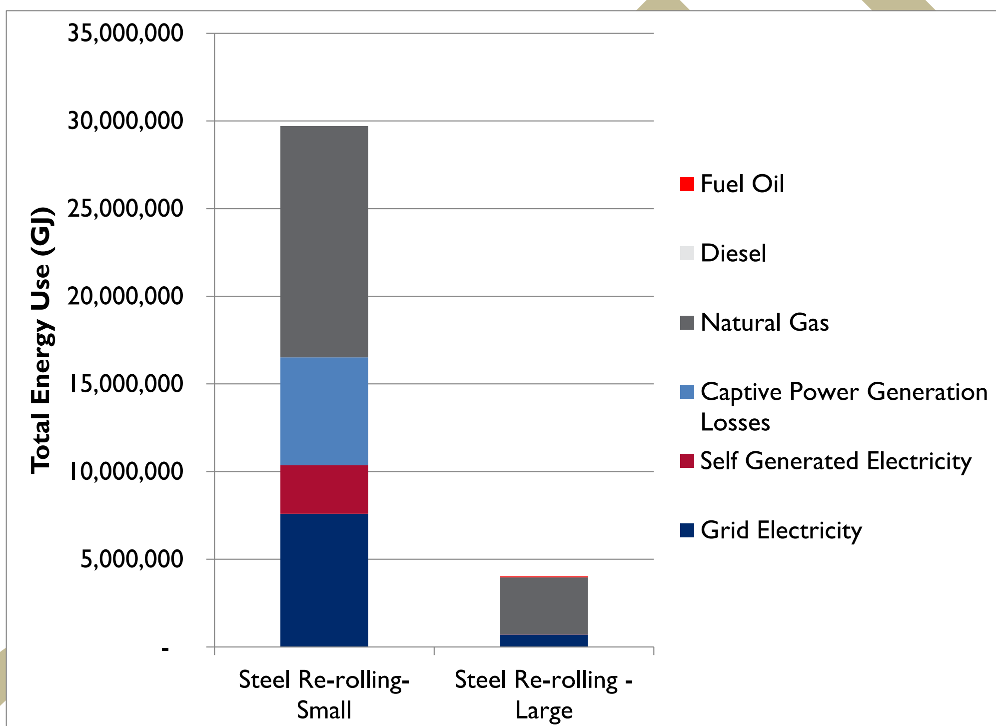


**Exhibit 56: Steel Re-Rolling Sector Base Year Energy Use by End Use**

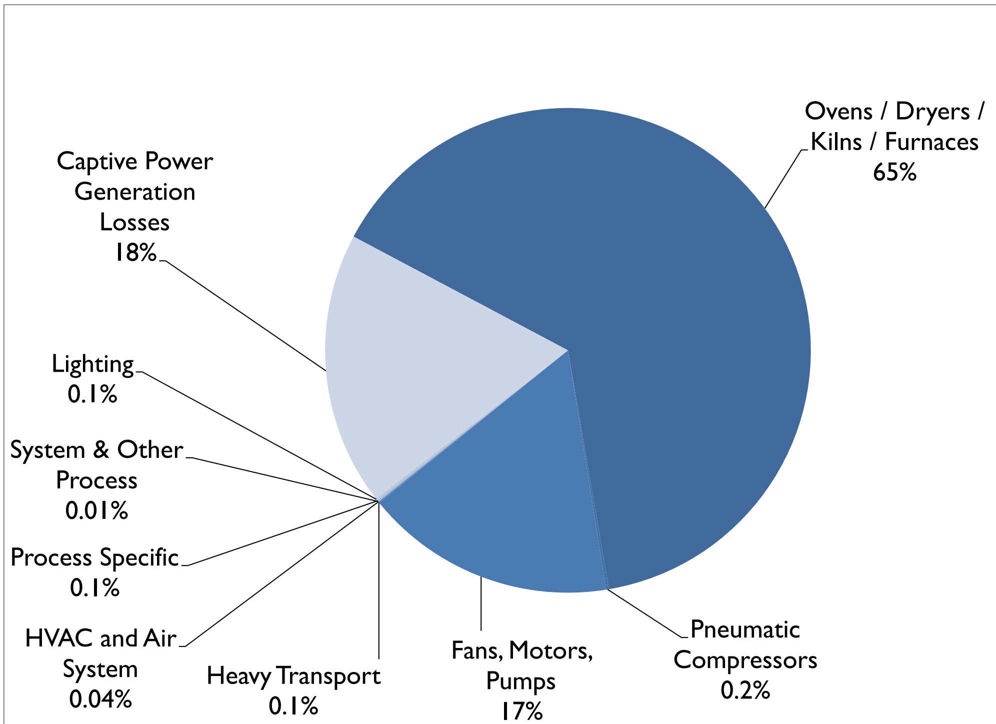
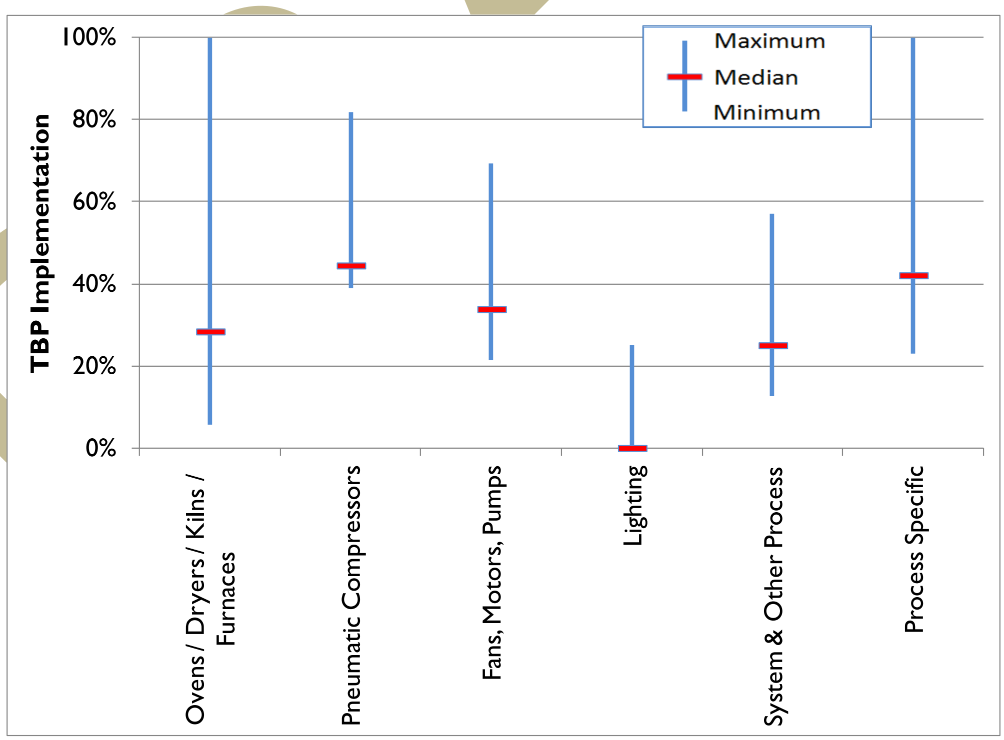



**Exhibit 57: Steel Re-Rolling Sector Implementation of TBPs**



In the steel re-rolling sector close to 65% of all energy is used in ovens/furnaces and half the plants have implemented 30% or less EE opportunities applicable to ovens/furnaces. Motive power uses about 17% of the total energy in the sector and half the plants have implemented 35% or less of the applicable EE opportunities. This indicates a very large potential exists to increase the implementation in EE opportunities in end uses accounting for 82% of the energy use in the sector.

The potential savings in the sector is aligned with the energy use, which means that most of the energy is saving in natural gas, and by end use most of the energy is saved in the areas where most of the energy is used: furnaces, motive power and captive power generation losses. In addition, system wide energy EE opportunities accounts for a relatively substantial portion (15%) of the savings.

**Exhibit 58: Steel Re-Rolling Sector Technical Potential Scenario Energy Savings by Fuel Type in 2020**

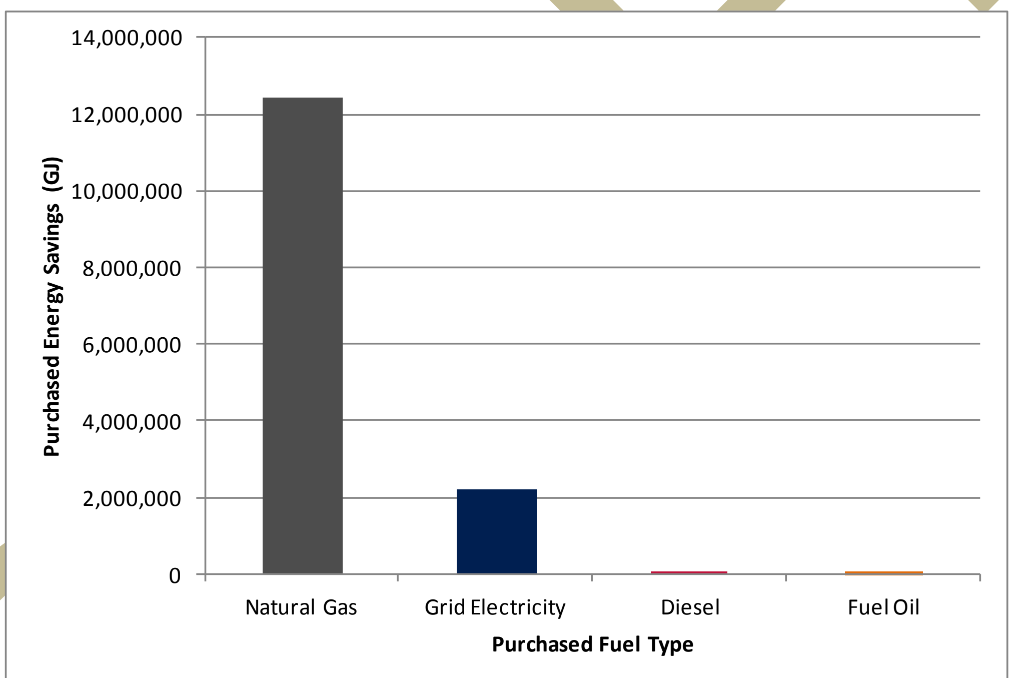
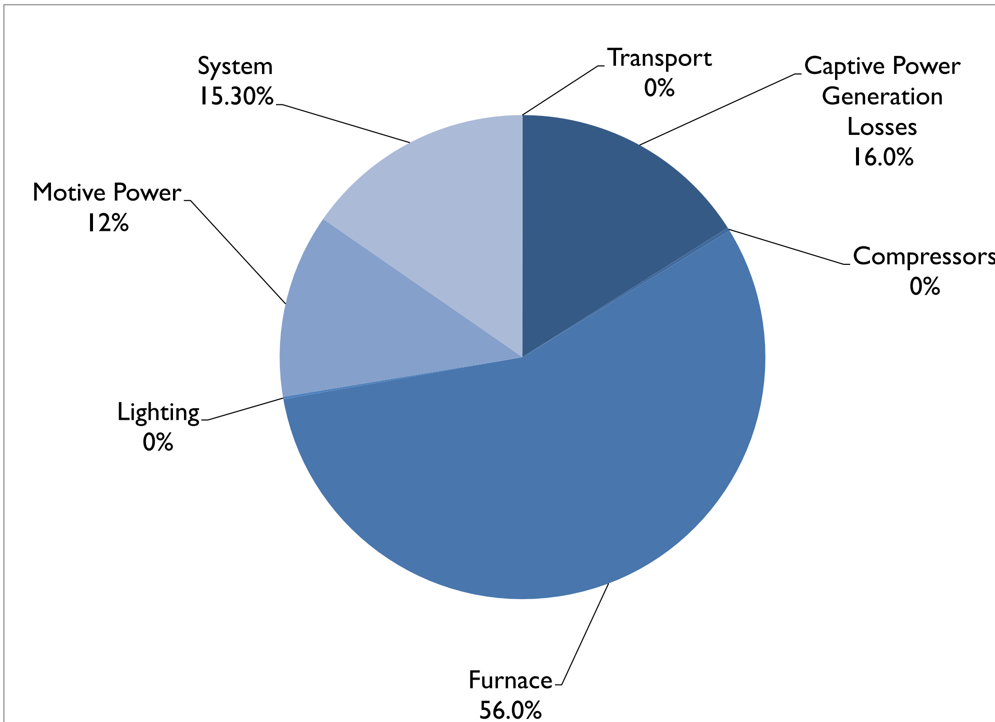


**Exhibit 59: Steel Re-Rolling Sector Technical Potential Scenario Energy Savings in 2020**



# Appendix D: Jute Manufacturing Sector Detailed Results

Close to 80% of all energy used in the jute manufacturing sector is accounted for by natural gas and a relatively large portion of natural gas is used for onsite power generation. This result in a relatively large portion of natural gas energy is lost due to captive power generation losses, i.e. 52% of total energy use. Besides these losses, most energy is used in the process specific end use.

**Exhibit 60: Jute Sector Base Year Energy Use**

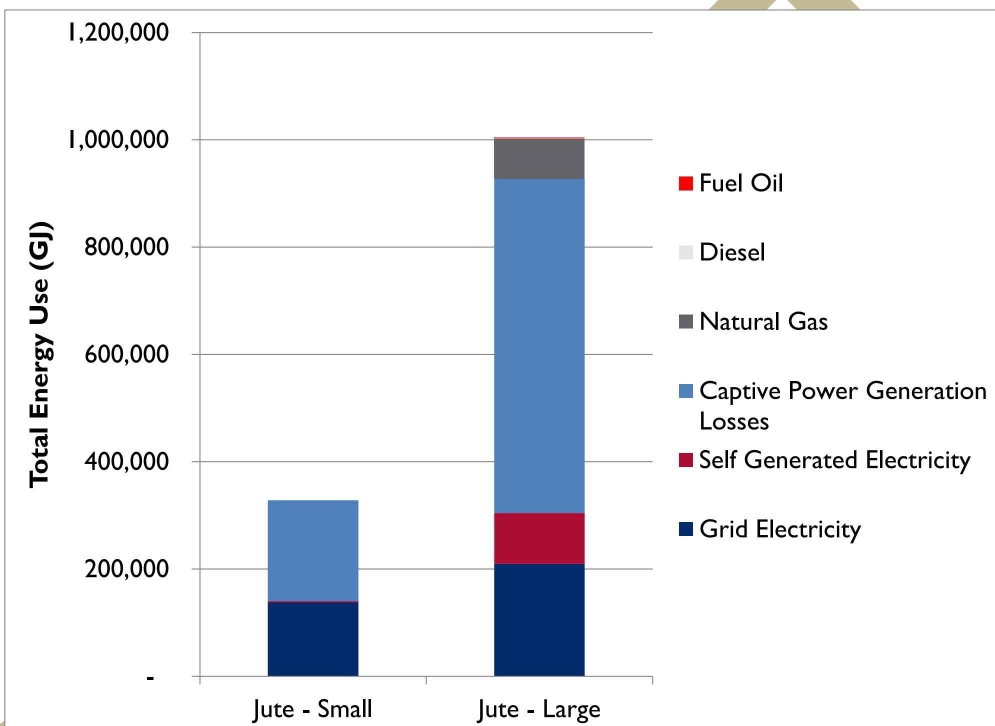


**Exhibit 61: Jute Sector Base Year Energy Use by End Use**

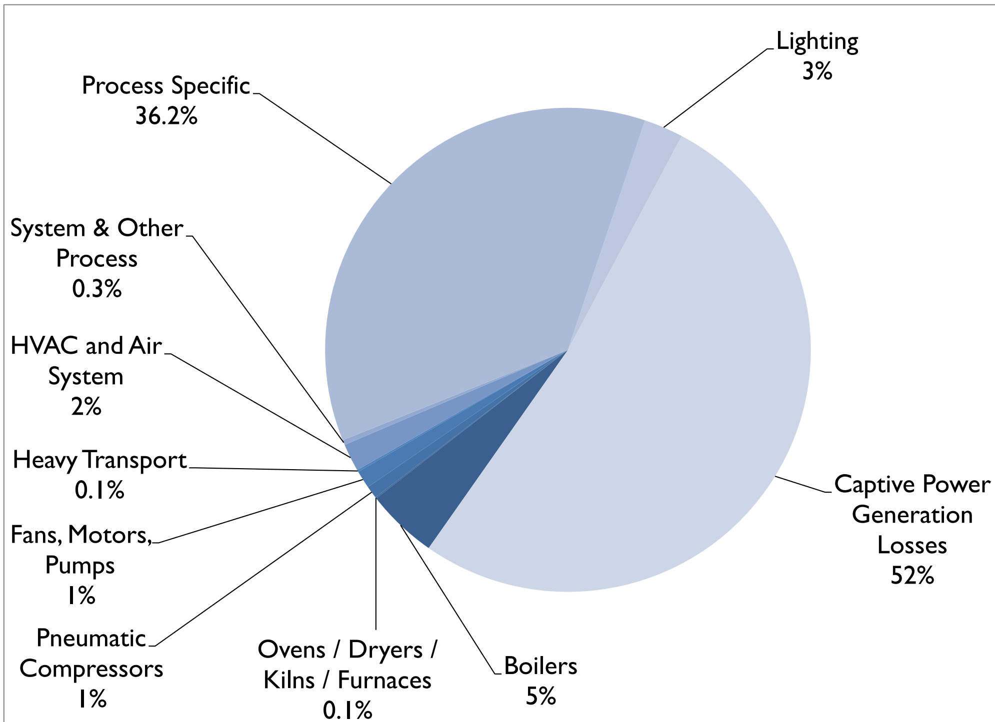
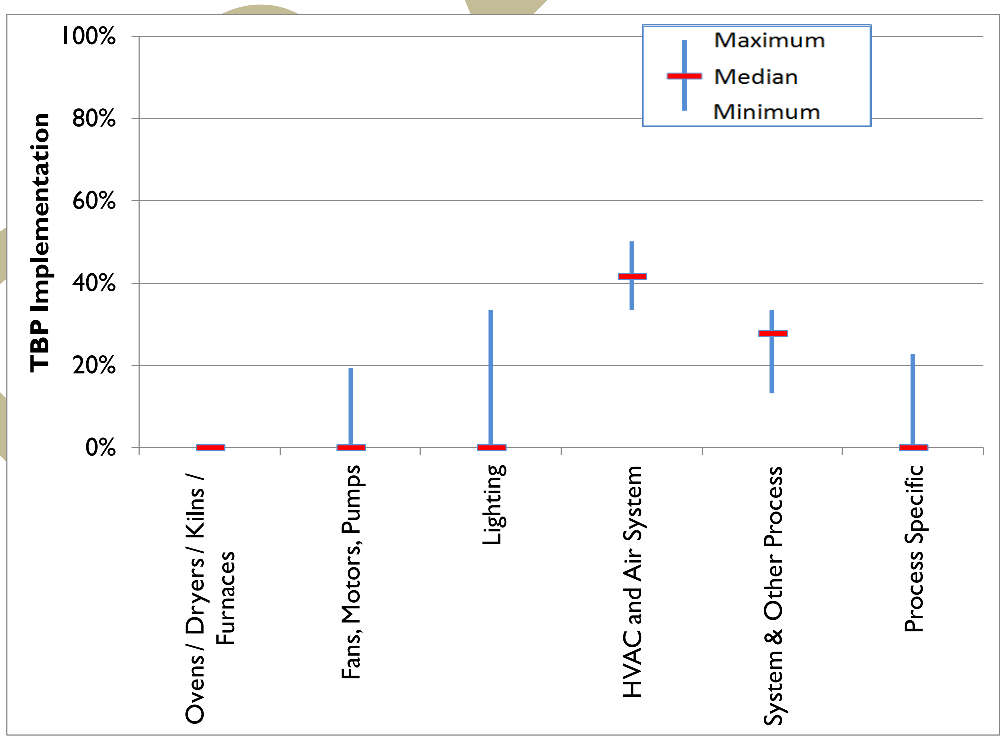



**Exhibit 62: Jute Sector Implementation of TBPs**



In the jute manufacturing sector there is overall very low implementation of EE opportunities and four of the six end uses, where half of the companies have not implemented any EE opportunities. These four end-uses account for about 45% of the energy use by the sector. Besides the 52% of total energy used in the sector but is lost due to captive power generation, the remaining two end uses account for less than 3% of the total energy use.

The potential savings in the sector is aligned with the energy use, which means that most of the energy is saving in natural gas, and by end use most of the energy is saved in the areas where most of the energy is used: captive power generation losses and process specific. In addition, system wide energy EE opportunities accounts for a relatively substantial portion (10%) of the savings.

**Exhibit 63: Jute Sector Technical Potential Scenario Energy Savings by Fuel Type in 2020**

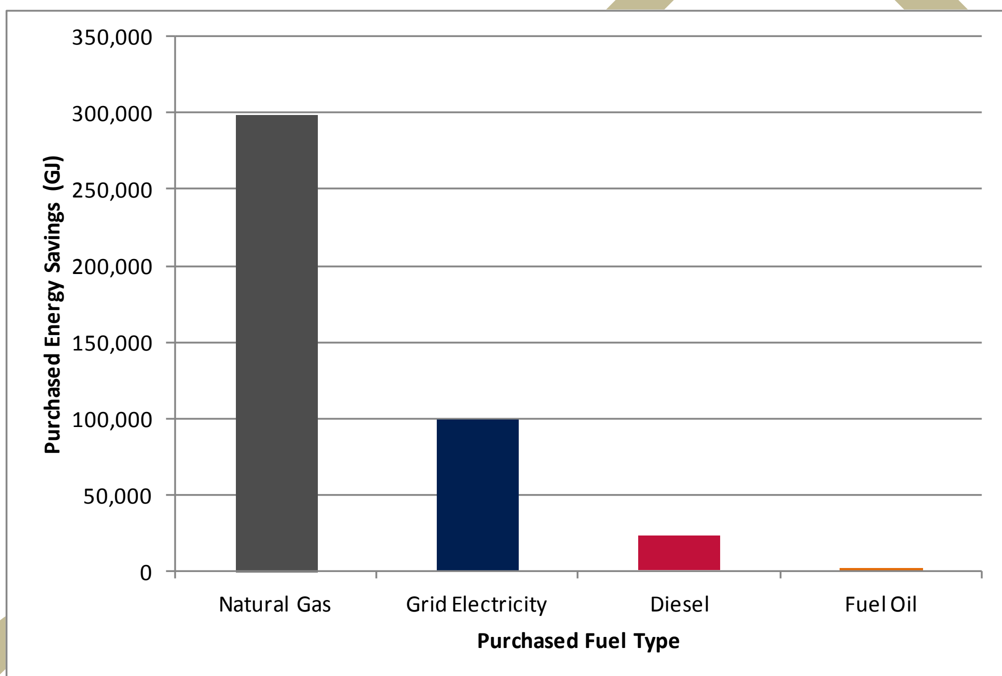
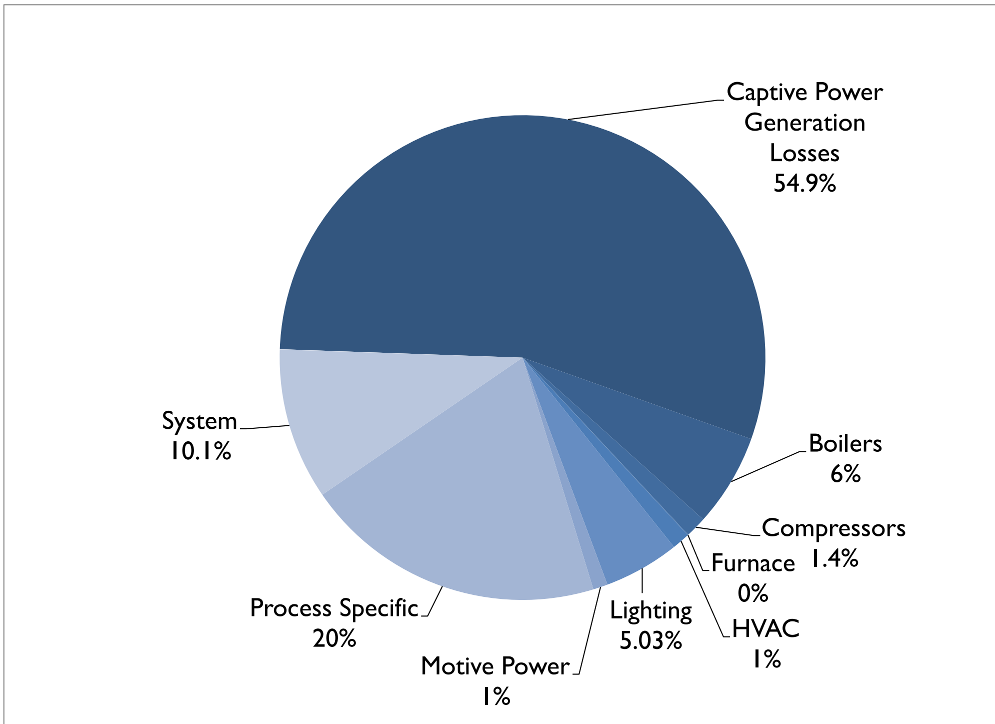


**Exhibit 64: Jute Sector Technical Potential Scenario Energy Savings in 2020**



# Appendix E: Frozen Food Processing Sector Detailed Results

In the frozen food manufacturing sector close to 75% of the energy used is obtained from purchased electricity. The remaining energy is supplied mainly by natural gas, diesel and fuel oil, which is used to generate on-site electricity. Most of the energy is used by refrigeration (28%) and HVAC and air systems (23%). A relative large portion of energy is lost as captive power generation losses (19%).

**Exhibit 65: Frozen Food Sector Base Year Energy Use**

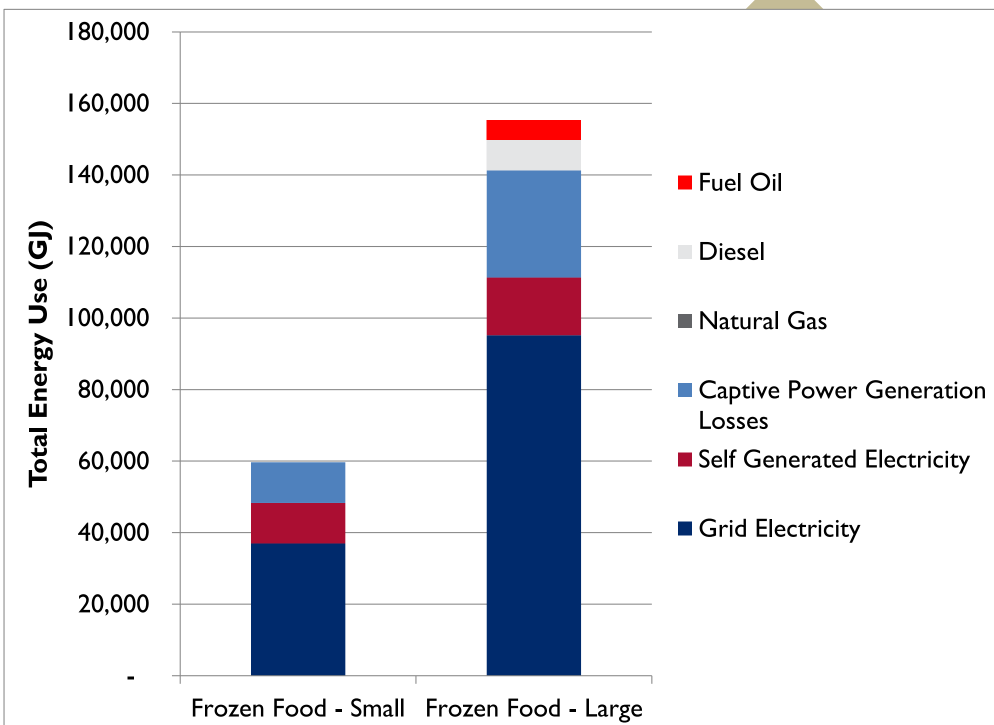


**Exhibit 66: Frozen Food Sector Base Year Energy Use by End Use**

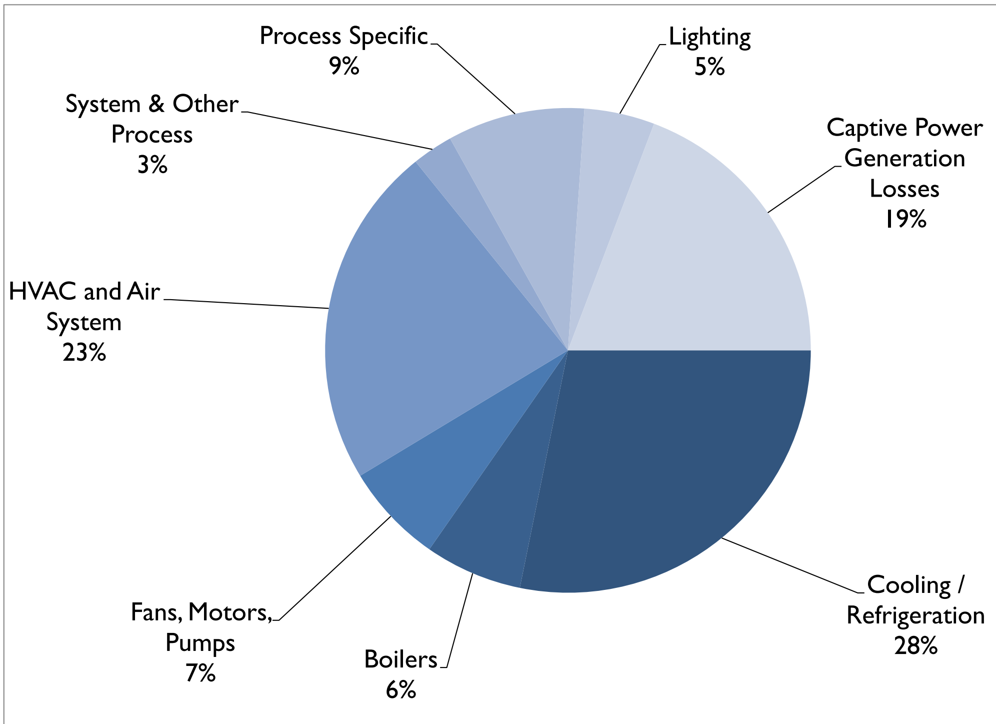
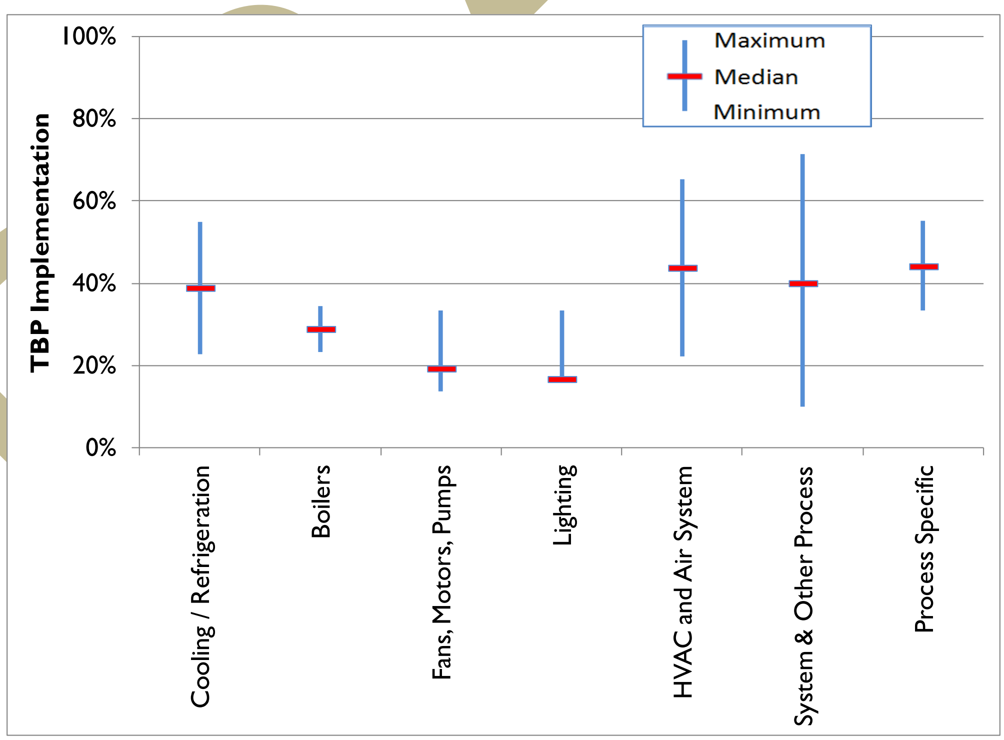



**Exhibit 67: Frozen Food Sector Implementation of TBPs**



Most energy in the frozen food manufacturing sector is used in the cooling/refrigeration (28% of total sector energy use) and HVAC and air systems (23% of total sector energy use). For both these end uses half of the plants have implemented less than 45% of the available EE opportunities and can still implement the remaining 55% of opportunities. Low implementation of EE opportunities are also observed for boilers, motive power (i.e. fans, motors and pumps) and lighting, where all the plants can still implemented 65% of the technically feasible opportunities.

Implementing the EE opportunities will result in most savings in purchased electricity, and a significant portion of diesel. Relatively small amounts of natural gas and fuel oil will be saved. Most of the energy savings are applicable to the cooling/ refrigeration (20%), and HVAC and air system (21%).

**Exhibit 68: Frozen Food Sector Technical Potential Scenario Energy Savings by Fuel Type in 2020**

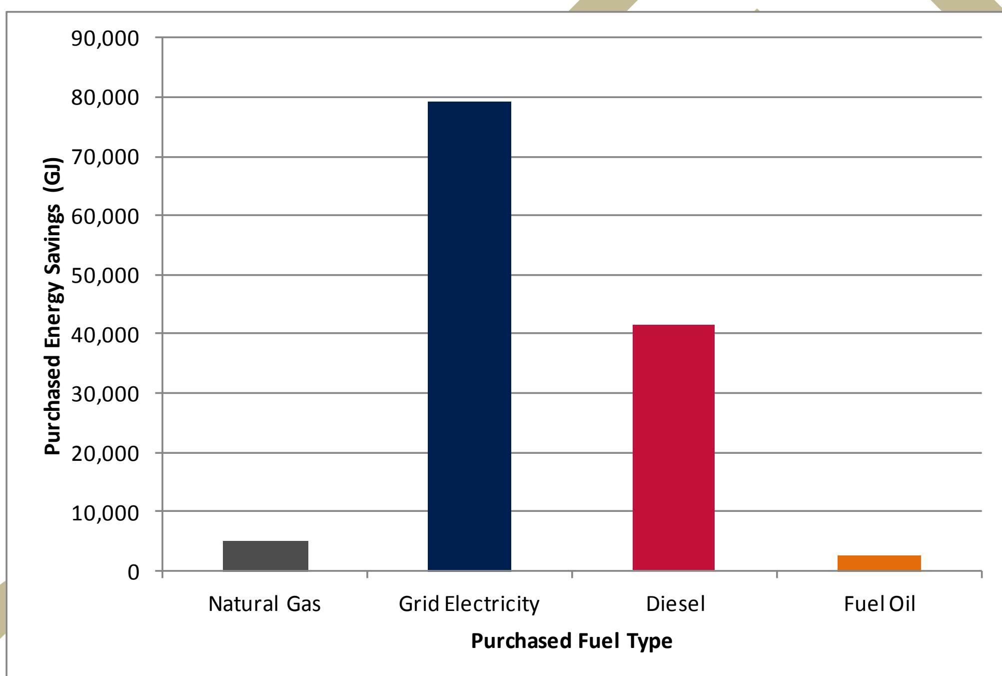


**Exhibit 69: Frozen Food Sector Technical Potential Scenario Energy Savings in 2020**